Glare Impacts from Solar Power Plants near Airports

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Overview

- Introduction
- Solar Glare
- Ocular Hazard Metrics
- Examples of Glare Assessments
• **Glint and glare may cause unwanted visual impacts**
  – Pilots, air-traffic controllers, workers, motorists

• **Potential visual impacts**
  – Distraction
  – After-image (flash blindness)
  – Retinal burn

**Definitions**

Glint: Momentary flash of light

Glare: Continuous source of excessive brightness

**Objective**

Develop quantified analysis of glare to reduce uncertainties associated with visual impacts of solar power installations
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Examples of Glare from Solar Technologies

**Photovoltaics**

- Solar panels with glare

**Concentrating Solar Power**

- Heliostats and Central Receiver at Sandia Labs, Albuquerque, NM
- Dish Collectors at Sandia
- Parabolic Trough Collectors at Kramer Junction, CA
Types of Reflection

Specular Reflection

(polished surfaces; e.g., mirrors, glass)

Diffuse Reflection

(rough surfaces; e.g., receivers, pavement, snow)
Adapted from ACRP Synthesis 28 “Investigating Safety Impacts of Energy Technologies on Airports and Aviation”
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• Examples of Glare Assessments
• Need to calculate
  – Power entering eye
    • Function of irradiance at the cornea (front of eye)
  – Subtended angle of glint/glare source
Potential Ocular Impacts

Equations and analysis methods detailed in Ho et al. (2010, 2011)
Potential Ocular Impacts as a Function of Distance

- Dish (D=12 m, f=7 m)
- Parabolic Trough (D=5 m, f=1.5 m)
- Heliostat (D=12 m, f=500 m)
- Flat Mirror (D=12 m)

\[ \rho = 0.94, \text{ RMS slope error} = 1 \text{ mrad (5 mrad for trough)}, \text{ DNI} = 0.1 \text{ W/cm}^2 \]

Distance (m)

- Range for Temporary After-Image
- Range for Retinal Burn

- Dish: 10 m, 3.6 m, 1.4 m
- Parabolic Trough: 110 m, 1.6 m
- Heliostat: 3,500 m, 503 m, 492 m
- Flat Mirror: 8,600 m

D = aperture, f = focal length
Web-Based Glare Tool

www.sandia.gov/glare

Solar Glare and Flux Mapping Tools

Measurement of reflected solar irradiance is receiving significant attention by industry, military, and government agencies to assess potential impacts of glint and glare from growing numbers of solar power installations around the world. In addition, characterization of the incident solar flux distribution on central receivers for concentrating solar power applications is important to monitor and maintain system performance.

This website provides tools to analytically and empirically quantify glare from reflected light and determine the potential impact (e.g., temporary flash blindness, retinal burn). In addition, tools are being developed that will evaluate the irradiance distribution on a central receiver. Empirical results are based on digital photographs uploaded by the user. Instructions are included in each of the links below.

- **Empirical Glare Analysis**
  - Upload Glare Photos

- **Analytical Glare Analysis**
  - Analytical Glare Analysis

- **Flux Mapping Analysis**
  - Upload Receiver Photos
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Glare Example: Heliostat Flyover

National Solar Thermal Test Facility
Albuquerque, NM
November 10, 2010

Heliostats aimed in “standby” position 30 m to the east of top of tower
Heliostat Glare Analysis

From Ho (2011)

~1.7 km distance
Glare Assessment Example:

BLYTHE SOLAR POWER PROJECT

CALIFORNIA ENERGY COMMISSION SUPPLEMENTAL STAFF ASSESSMENT PART 2
Blythe Airport Glare Analysis

Source: Federal Aviation Administration, Airport/Facility Directory, SW, 01 APR 2010 to 01 JUN 2010, p. 236; Riverside County Airport Land Use Commission, Riverside County Airport Land Use Compatibility Plan, October 14, 2004 (Exhibit B-7); California Energy Commission, 2010 (facility footprint, air-cooled condenser, power block, transmission line); Goffman Associates, 2001 (airport property line); Kiewit, AECOM, 2010 (mirror arrays, evaporation ponds). Prepared by: Rios Consulting, Inc., June 2010.

Generalized Traffic Pattern
Runway 35

Aviation Assessment for the Blythe Solar Power Project

June 2010
Glare Assessment Process:

1. Identify conditions when glare may be visible by pilots
   - Flight patterns, time/date, solar plant operations

2. If glare conditions exists, identify potential ocular impact

3. If glare is likely to cause ocular impact, identify mitigation measures
Blythe Airport Glare Analysis

- Staff Assessment identified several scenarios where glare may impact pilots
- Mitigations were proposed
  - Barriers and screens
  - Pilot notification
  - Stow procedures
- Based on assessment and hearings, the Commission decided that the project could be licensed
CONCLUSIONS
• Glint and glare can cause unwanted visual impacts
  – Analytical models and safety metrics have been developed to quantify glint and glare from different solar technologies
  – These methods can be used to assess impact of glare near airports

• Identification and quantification of potential impacts will help agencies to develop appropriate mitigations, measures, and/or requirements
  – California Energy Commission
  – Air Force
  – FAA
  – Transportation Research Board/ACRP
BACKUP SLIDES
Examples of Airports with Solar PV

- Denver International Airport (8 MW)
- San Francisco International Airport (500 kW)
- Oakland International Airport (1.7 MW)
- Fresno Yosemite International Airport (2 MW)
- San Antonio Airport (235 kW)
- Charlotte Douglas Int. Airport (306 kW)
Airports near Concentrating Solar Power Plants

- Barstow Daggett County Airport
  - Parabolic trough plant (~1 mile away)
  - Power tower (1980’s – 1990’s)

- Las Vegas International Airport
  - Parabolic trough plant (~15 miles away)