UTILITY-SCALE SOLAR ENERGY FACILITY VISUAL IMPACT CHARACTERIZATION AND MITIGATION

PROJECT REPORT

This document is the project report on the utility-scale solar energy facility visual impact characterization and mitigation study conducted under DOE FY12 AOP SIT 7, “Glare, Visual Impacts and Mitigations,” and is the deliverable for Subtask 7.1. Prepared by Robert Sullivan and Jennifer Abplanalp, Environmental Science Division, Argonne National Laboratory.

12/20/2013

DOE SOLAR SIT 7 GLARE, VISUAL IMPACTS AND MITIGATIONS

UTILITY-SCALE SOLAR ENERGY FACILITY

VISUAL IMPACT CHARACTERIZATION AND MITIGATION STUDY

PROJECT REPORT

Robert Sullivan, Jennifer Abplanalp

Environmental Science Division

Argonne National Laboratory

Sullivan@anl.gov

(630) 252-6182

Executive Summary

This report summarizes the results of a study conducted by Argonne National Laboratory's (Argonne's) Environmental Science Division in support of the U.S. Department of Energy's *Soft Cost Balance of Systems Subprogram* under the SunShot Initiative, and funded through the *Office of Energy Efficiency and Renewable Energy Fiscal Year 2012 Annual Operating Plan*. The study, entitled *Utility-Scale Solar Energy Facility Visual Impact Characterization and Mitigation Study*, documented the visual characteristics of various utility-scale solar energy facilities on the basis of field observations, and developed and described visual impact mitigation strategies for these types of facilities.

An examination of recent environmental assessments for proposed utility-scale solar facilities suggests that stakeholders are increasingly raising the potential negative scenic impacts of solar facilities as a concern, and some local governments are restricting commercial solar energy development specifically to protect scenic resources. However, relatively little is known about the visibility, visual characteristics, and visual contrast sources associated with solar facilities that give rise to visual impacts. This study was undertaken primarily to further establish baseline descriptions of the visual contrasts from utility-scale solar facilities. Of particular concern is the occurrence of glinting (momentary flashes of light) and glare (excessively bright light or high visual contrast that causes visual discomfort to viewers or interferes with the ability to see objects clearly [CIE 2012]). A secondary goal of the study was to identify practical visual impact mitigation methods to avoid or reduce visual impacts from the facilities. Because of the relative newness of utility-scale solar facilities, there is little existing scientific literature available that accurately describes the facilities' visual characteristics, and also little information about the effectiveness of visual impact mitigation methods for these types of facilities.

Study activities consisted primarily of field observations of parabolic trough, thin-film photovoltaic (PV), power tower, and concentrating PV facilities in the southwestern U.S. The field observations included photography and descriptive narratives of sources of visual contrast from the facilities. Other study activities included the development of visual impact mitigation measures based on the field observations. The photographs and descriptive data were incorporated into an existing publicly available Web-based database of solar facility photos and associated visual data that was developed by Argonne for use in various studies funded by the U.S. Department of Interior Bureau of Land Management (BLM) and National Park Service.

Results of the field observations included assessments and photographic documentation of the effects of distance, viewpoint elevation, and lighting on the visual contrasts of various types of solar facilities, and the interaction of these variables with specific visual impact mitigation measures. Photo documentation of the cumulative visual impacts of multiple solar facilities within a single viewshed was developed. A systematic assessment of the effects of distance on the visibility and visual contrasts of a utility-scale power tower (not operating) was conducted, and sources of visual contrast from the facility were documented. A baseline contrast assessment was conducted for a utility-scale concentrating PV facility.

Significant findings of the field observations include the following:

- Color selection for materials surface treatment as directed by BLM resulted in better mitigation than alternative colors;
- Glare from a parabolic-trough facility may be a relatively common occurrence;
- Effective lighting mitigation can result in near-zero night-sky impacts for PV facilities;
- Strong glare from a single power tower heliostat was visible at distances exceeding 10 mi (16 km);
- Unilluminated power towers were easily visible for distances beyond 20 mi (32 km), and one was faintly visible for as far as 35 mi (56 km);
- Daytime aerial hazard lighting on power towers was visible for long distances and added substantially to visual contrast in certain conditions; and
- Reflected light from a concentrating PV facility was plainly visible beyond 25 mi (40 km).

The study also examined solar mitigation opportunities based on the field observations, including developing mitigation for specific contrasts observed at a thin-film PV facility on BLM-administered land in Nevada. Field observations revealed several contrast sources that present mitigation opportunities. These contrast sources include reflections from metal clips used to affix the solar panels to the support structures directly below the panels; reflections from panel support structures without mounted panels; the use of regular geometric forms in panel arrays, cleared areas, and other linear features; and reflected light from light-colored gravel where vegetation has been cleared around the collector array. In collaboration with the facility siting and compliance manager, and with input from BLM and a materials contractor, potential mitigation measures were identified for each of these contrast sources. At the time of this writing, BLM has directed that the proposed mitigation measures be implemented in the next currently planned phase of development at this facility.

Table of Contents

1 Introduction

This introductory section presents the need for and purpose of the study, its scope, the intended use and users of the study results, and the report organization.

1.1 Need for and Purpose of Study

The construction and operation of utility-scale solar energy facilities create visual contrasts with the surrounding landscape, primarily because of the introduction of complex and visually distinctive man-made structures on a large scale into the existing landscape. In the southwestern states where most U.S. utility-scale solar facilities are in operation or planned, solar facility sites are relatively flat, open spaces, typically located in visually simple and uncluttered valley landscapes that often lack screening vegetation or structures. Because of the lack of screening elements, the open sightlines, and relatively clean air typical of the western U.S., solar facilities may be visible for long distances, and their large size and distinctive visual qualities can give rise to strong visual contrasts in some circumstances (BLM and DOE 2010).

The visual contrasts caused by the addition of solar facilities to the landscape give rise to visual impacts from the facilities. Visual impacts include both the changes to the visual qualities and character of the landscape resulting from the visual contrasts created by the facilities, and the emotional responses of persons who view the facilities. While some persons may find the appearance of solar facilities visually pleasing, others may feel that the visual contrasts caused by the facilities detract from the visual qualities of the landscape view. When stakeholders respond negatively to the visual contrasts of solar facilities, their negative perceptions can result in opposition to individual proposed solar projects or to utility-scale solar energy generally. If the negative perceptions are sufficiently strong, such opposition could potentially result in costly delays or even cancellations of projects.

Visual impacts were recognized as an obstacle to solar facility and associated transmission siting in the Sunshot Vision Study (DOE 2012a). While stakeholder opposition resulting from perceived negative visual impacts is not documented to have led to the cancellation of any utility-scale solar projects in the U.S. to date, local governments, such as San Bernardino and Sonoma Counties in California, have recently passed ordinances restricting commercial solar facilities specifically to protect scenic resources, among other values (San Bernardino County Sentinel 2013; Sonoma County 2013). Visual impacts have increasingly become an important concern not just for individuals but for organizations such as tribes, local governments, environmental groups, and the National Park Service (NPS). Concerns over potential negative visual impacts of solar facilities are routinely expressed by stakeholders during the environmental impact assessment processes that are typically required for these types of facilities (Basin and Range Watch 2010; DOE 2012b; NPCA 2012; Colorado River Indian Tribes 2013; Kessler 2013; NPS 2013).

The visual contrasts of solar facilities are not well documented or understood, in part because there are relatively few utility-scale solar facilities in operation worldwide. This is especially true for certain solar technology types such as power towers, concentrating photovoltaic (CPV), and compact linear Fresnel reflector (CLFR) facilities, which have only recently been developed at utility scale. And unlike utility-scale wind turbines, there are several distinctly different solar technologies that work by substantially different underlying principles and mechanisms, such that their visual characteristics differ in important ways, making the task of comprehensive visual characterization more complex than for wind energy facilities. Recent work conducted by Argonne for BLM and NPS has begun to document the visibility, visual characteristics, and visual contrasts associated with utility-scale solar facilities (Sullivan 2011; Sullivan et al. 2012a). The current U.S. Department of Energy (DOE)-sponsored study builds on this previous work to better characterize visual contrasts associated with utility-scale solar energy development, and addresses the need for better and more extensive documentation of visual contrasts from utility-scale solar facilities.

Historically, for many large-scale solar facilities, visual impacts have been determined to be large, but until recently, little substantial/effective mitigation has been identified. Failure to apply effective mitigation may result in large visual impacts on sensitive visual resources and on sensitive viewing locations (e.g., residential areas or roadways) that may engender stakeholder opposition to projects. Because of the very large scale and unique visual characteristics of utility-scale solar facilities, many of the largest contrasts and resulting impacts cannot be mitigated effectively, except by siting facilities in different locations, choosing different solar technologies, reducing the size of the project, or using off-site mitigation to compensate for the impacts. These options are often impractical or difficult to implement. BLM and DOE (2012) and BLM (2013a) have provided a range of mitigation strategies for some visual impacts from solar facilities; but there is a need for further exploration of mitigation opportunities. The current study addresses the need for additional potential mitigation strategies that are both effective and technically feasible.

The work for BLM (discussed by Sullivan [2011] and Sullivan et al. [2012a]) was directly connected to the BLM and DOE's Programmatic Environmental Impact Statement (PEIS) for Solar Energy Development in Six Southwestern States (Solar PEIS) (BLM and DOE 2010, 2012). The work conducted for NPS was initiated in response to NPS concerns regarding the potential visual impacts from utility-scale solar development on BLM-administered and other lands within the viewsheds of NPS units. The current study more fully characterizes the visual contrasts from utility-scale solar facilities than these initial studies did, and suggests additional possible mitigation strategies to avoid or reduce the contrasts. The results of the current study help to inform visual impact analyses for solar energy facilities and to reduce the visual impacts through improved mitigation. More complete and accurate impact assessment and better mitigation will ultimately result in increased public acceptance of solar facilities, thereby easing and speeding permitting. Implementation of the mitigation strategies would also reduce visual impacts to sensitive visual resource areas, such as NPS units, national scenic and historic trails, and other scenic resources.

1.2 Scope

The field observations recorded visual contrasts associated with utility-scale thin-film PV facilities, CPV facilities, parabolic trough facilities, and power tower facilities. The study was limited to discussion of visual contrasts (changes in the visual environment, i.e., changes to what is seen) rather than impacts (changes in landscape character and human reaction to visual contrasts).

All of the facilities observed in the study were located in the southwestern U.S., specifically in southern California, southern Colorado, and southern Nevada.

1.3 Intended Use and Users

This study identifies visual contrasts associated with utility-scale solar energy facilities and identifies potential visual mitigation strategies to avoid or reduce the visual impacts. The study results can be used to

1) Better understand the nature of visual contrasts associated with utility-scale solar facilities, and the mechanisms by which solar facilities cause visual contrasts that generate visual impacts;
2) Better assess potential visual impacts of solar facilities; and
3) Select and apply effective mitigation measures.

The intended users of the document and the study results it contains include

- Professionals conducting visual impact assessments (VIAs) for solar energy facilities and specifying visual impact mitigation measures;
- Agency staff who regulate or approve VIAs and associated mitigation measures;
- Solar industry professionals who must implement mitigation measures; and
- Other stakeholders who may be affected by the visual impacts of solar facilities.

1.4 Document Organization

This report is organized into four main sections:

1) Introduction
2) Literature Review—A discussion of previous efforts to characterize and identify mitigation for solar energy facilities.
3) Methodology and Facilities Visited—A description of the methods and descriptions of facilities visited for contrast characterization.
4) Overview of Visual Contrasts and Contrast Assessment—background information about visual contrast assessment and terminology.
5) Results of Field Observations—Descriptions of the field observations of solar facilities and the visual contrasts and contrast sources associated with solar facilities.
6) Potential Solar Facility Mitigation Strategies—Discussion of visual impact mitigation measures based on the field study observations. The discussion of mitigation measures includes a case study of specialized mitigation measures for a thin-film PV facility.
7) Conclusions and Recommendations—Discussion of study results and recommendations for further studies.
8) References—References cited in this report.
9) Appendices—Data collection forms and methodology notes for the study.

2 Literature Review

As noted above, visual impacts caused by utility-scale solar facilities have been identified as a concern by the public and other stakeholders such as the NPS for numerous proposed projects, and certain solar projects, especially solar power tower projects, have been identified as causing significant visual impacts and significant impacts to cultural resources through impacts to the visual settings of the cultural resources (BLM 2010a; CEC 2010; DOE 2012b; CEC 2013). Although research studies have identified visual impacts of solar facilities as a concern (NRC 1996; Torres-Sibille et al. 2009; Tsoutsos et al. 2005; Turney and Fthenakis 2011), with the exception of the previously mentioned studies conducted by Sullivan et al. for BLM, DOE, and NPS (Sullivan 2011; Sullivan et al. 2012a), and glint and glare analysis by Ho and colleagues (Barrett 2013; Ho et al. 2009, 2010; Ho and Khalsa 2010; Ho 2011, 2012; Ho and Sims 2013), limited research is available that formally addresses this topic. This is especially true for research limited to aesthetic impacts; much of the glint and glare research to date has focused on health and safety hazards.

2.1 Discussion of Visual Impacts in Environmental Assessments

Until relatively recently, VIAs contained in environmental assessments for utility-scale solar facilities proposed on public lands in the United States have varied greatly in terms of level of detail and accuracy, with few visual impact mitigation requirements. An examination of various VIAs conducted over the last five years suggests that stakeholders are increasingly raising potential negative visual impacts of solar projects as a significant concern, and simultaneously, the level of detail in solar VIAs has generally increased, with more extensive visual mitigation requirements and better discussion of potential glare impacts (for example, see BLM 2010b and BLM 2013b). There are several possible direct and indirect causes for the increased level of concern about visual impacts expressed by stakeholders and improved treatment of visual impacts in VIAs:

- Increasing visual impacts as more and larger solar facilities are built, especially power towers, which have substantially larger potential impacts than other solar technologies;
- Increased awareness of potential visual impacts of solar projects among potentially affected stakeholders, such as NPS;
- Increased awareness of potential visual impacts and better oversight of VIA preparation on the part of land management and regulatory agencies with oversight responsibilities for environmental assessments, such as BLM and the California Energy Commission (CEC);
- Greater awareness of the potential impacts of solar facilities on the part of VIA preparers and more experience preparing VIAs; and
- The increasing availability of both visual impact-related research and tools, such as the studies by Sullivan et al. and Ho's glare research and analytical tool development (discussed in Section 2.2).

Obviously, some of these factors are closely related; e.g., increased visual impacts from larger projects may have driven increasing levels of awareness of visual impacts on the part of both stakeholders and regulatory agencies. It is likely that the Solar PEIS increased awareness of potential visual impacts (and impacts of solar facilities in general) because its large scope and regional focus led to wide distribution and more widespread attention to the environmental impacts of solar development on the part of both stakeholders and oversight agencies.

2.2 Dedicated Solar Visual Impact Research

The two largest bodies of research dedicated to visual impacts of solar facilities are the field studies investigating the visibility, visual characteristics, and visual contrasts associated with utility-scale solar facilities in the southwestern United States conducted by Sullivan and colleagues at Argonne for BLM and NPS, and extensive studies of glinting and glare from solar facilities conducted by Ho and colleagues at Sandia National Laboratories (Sandia). Additional studies have been conducted at universities in Europe and the U.S.

2.2.1 Argonne Field Studies for BLM/NPS

Sullivan began field observations of utility-scale solar facilities in Nevada and California in 2010 to support the VIA that Argonne was preparing for the Solar PEIS. At the time, other than short descriptions of selected technologies in EISs, there was no information available regarding the visibility, visual characteristics, and visual contrasts associated with utility-scale solar facilities.

Accompanied by the Chief Landscape Architect for BLM, Sullivan observed Nevada Solar One (NSO), a parabolic trough facility in southern Nevada; the nearby Copper Mountain thin-film PV facility, then under construction; the Solar Energy Generation System (SEGS) parabolic trough complexes at Kramer Junction and Harper Dry Lake in southern California; and the Sierra Suntower power tower facility in Lancaster, California. The observations were conducted in April 2010.

The results of the observations for NSO, SEGS, and Sierra Suntower have been summarized by Sullivan (2011). In the course of these field observations, the occurrence of strong glare visible for several miles was confirmed at the NSO facility, and was also observed at the SEGS III-VII complex. Visibility of the NSO and Copper Mountain facilities at long distances (14+ mi, using Global Positioning System [GPS] measurements) was established for both daytime and nighttime observations. The reflected light from the two Sierra Suntower 2.5-MW power towers was determined to be visible beyond 20 mi. The observations also revealed the extreme variability of the appearance of the various facilities depending on the viewing geometry, lighting angle, weather conditions, and the individual characteristics of the facilities observed. This variability was generally not captured in EISs prepared at the time. The study results and selected photographs were incorporated into the Solar PEIS.

As a result of the Solar PEIS and specific potential impacts posed by solar energy development on BLM-administered lands visible from NPS units, NPS became more actively engaged in identifying potential impacts of solar energy facilities, and sponsored a follow-on study by Argonne to further characterize visual contrast sources associated with solar facilities. This study involved field observations conducted in April-May 2011, September 2011, and January 2012. Objectives of this study included identifying the source of glare at NSO, further characterizing the spatial and temporal extent of glare at the trough facilities, and expanding the types and sizes of facilities observed beyond those identified in the BLM study. Study observations were made at the same facilities visited during the BLM study, but additional observations were made at the following facilities:

- Silver State Solar Energy Project (North), a thin-film PV facility on BLM lands near Primm, Nevada;
- Ivanpah Solar Electric Generating System (Ivanpah) , a power tower facility on BLM lands near Primm, Nevada, under construction at the time of the observations;
- Antelope Valley Solar Ranch One (Antelope Valley), a thin-film PV facility near Lancaster, California, under construction at the time of the observations;
- Desert Sunlight Solar Farm, a thin-film PV facility within the Riverside East Solar Energy Zone near Desert Center, California;
- CPV modules at the Edward W. Clark Generating Station in Las Vegas, Nevada;
- Nellis Solar Power Plant, a crystalline silicon PV facility at Nellis Air Force Base near Las Vegas, Nevada;
- Kimberlina Solar Thermal Energy Plant (Kimberlina), a CLFR facility near Bakersfield, California; and
- Gemasolar Thermosolar (Gemasolar) power tower facility near Seville, Spain.

The results of the observations have been summarized by Sullivan et al. (2012a). In the course of these field observations, the primary source of glare at NSO was identified as the receiver tubes; glare was observed to be visible from some location during the course of several sunny days, and was found to be highly sensitive to viewing geometry, lighting angle, and viewer and mirror movement. Other important study findings included confirmation that views of solar facilities from elevated viewpoints showed much greater contrast than ground-level views, an issue of particular concern to NPS, because solar facilities are often visible from mountain ranges within NPS units; visibility of the Gemasolar receiver tower light at distances exceeding 20 mi, and the visibility of reflected light from dust near the receiver unit at a distance of approximately 5 mi; the documentation of significant visual contrasts during the construction phase of both the Ivanpah and Antelope Valley facilities; and the observation of glare at the Kimberlina facility.

Another important outcome of the NPS study was the design and development of the *Solar Energy Facility Visual Characteristics Study Database,* a publicly available online database of georeferenced photographs of the facilities. The online database is searchable on a number of parameters, such as facility name, distance between the observer and the facility, date and time of day, lighting direction, weather, and view direction. Querying the database returns the study observation data and associated high-resolution photographs of the solar facilities in the study, a useful tool for solar visual impact research. Photos from the current study have been added to the database, which is available at http://web.evs.anl.gov/solarvis/. Accompanying the database is a Google Earth .KMZ file, which provides access to the study observation data and photos via the Google Earth “map” interface. The KMZ file is available at http://web.evs.anl.gov/solarvis/kmz/solarvis.kmz.

2.2.2 Sandia Studies on Glinting and Glare

Ho and colleagues (primarily at Sandia) have conducted numerous studies concerning glinting and glare from solar facilities and developed analytical tools for the prediction of glare occurrence at a variety of solar facilities, including PV, parabolic trough, and power tower facilities. The primary focus of these studies has not been on aesthetic impacts, but rather on the following:

- Ocular health hazards (Ho et al. 2009; Ho and Khalsa 2010; Ho 2011);
- Disability glare that could affect pilots or air traffic controllers near airports (Barrett 2013; Ho 2012); or
- Development of analytical tools for predicting occurrence of glare at PV, power tower, or parabolic trough systems (Ho and Khalsa 2010, 2012; Ho et al. 2011; Ho and Sims 2013).

Ho (2013) provides a basic summary of the causes of glare from solar facilities, circumstances that lead to glare occurrence, factors that determine the magnitude of glare, and general strategies for glare mitigation. Ho et al. (2009, 2011) summarize approaches to glint and glare analysis from concentrating solar power plants; discuss the physiology, optics, and damage mechanisms associated with ocular injury from glare; discuss safety metrics; and introduce a new metric for temporary flash blindness, the loss of clear vision due to a bright afterimage after exposure to strong glare. The paper includes a description of the potential sources of glinting and glare from power towers (the receiver and heliostats), parabolic troughs (the mirrors and receiver tubes), and dish engines (the mirrors and the receiver aperture).

Ho and Khalsa's 2010 study further developed the metrics associated with retinal burn (permanent eye damage) and flash blindness to determine the distance from concentrating solar power facility glare sources at which retinal burn and flash blindness from specular reflections would occur, as well as presenting a Web-based tool for evaluating glinting and glare hazards and comparing the irradiance to safety metrics. Ho (2012) presented a case study applying the Web-based tool for calculating the potential for glare from a planned thin-film PV facility to be observed by pilots approaching a nearby airport (Ho and Khalsa 2010).

The Web-based tool is further described, including testing results, by Ho et al. (2010), and Ho and Sims (2013) subsequently developed a user manual for the Web-based tool, the Solar Glare Hazard Analysis Tool (SGHAT). SGHAT is used to predict potential ocular hazards ranging from temporary after-image to retinal burn resulting from glare from PV panels, on the basis of input provided by users through a Web interface. SGHAT specifies when glare will occur throughout the year, and can also predict relative energy production while evaluating alternative designs, layouts, and locations to identify configurations that maximize energy production while mitigating the impacts of glare.

2.2.3 Other Studies

Chiabrando et al. (2009) present a general approach to assessing the environmental impacts of solar PV facilities, in which they point out (a) the particular importance of assessing and mitigating visual impacts from the facilities and (b) the lack of research and other information for assessments. They then propose a method for calculating glare from PV panels as a quantitative approach to VIA.

Riley and Olson (2011) used Ho's calculations (Ho et al. 2009) to model the effects of glare from PV panels that would be experienced by pilots in aircraft flying over a proposed solar facility. They then compared the predicted effects to the glare effects caused by smooth water, and suggested that the potential for hazardous glare from flat-plate PV systems is similar to that of smooth water, and would therefore not be expected to be a hazard to air navigation.

3 Methodology and Facilities Visited

This section presents the methodology used to conduct visual contrast characterization work for the study, and mitigation measure testing. It also lists and briefly describes the facilities visited during the assessments.

3.1 Visual Contrast Characterization Methodology

The fieldwork conducted for the study involved three separate trips to observe solar facilities in Nevada, California, and Colorado. Two Argonne staff members conducted a week-long photographic documentation survey of five solar facilities in California and Nevada between January 28 and February 1, 2013. A second trip to observe two facilities, one in Nevada (Crescent Dunes Solar Energy Project) and one in California (Ivanpah Solar Electric Generating System), was conducted on May 13–15, 2013. A third trip was conducted between May 29 and June 1, primarily to observe one facility (Alamosa Solar Generating Plant), but with brief observations of other nearby facilities. A total of 73 facility observations were conducted during the course of the study.

These facilities were selected for a variety of reasons. First, they used the same solar technologies and were large enough in size that they are representative of the solar facilities that are currently in operation or under construction in the southwestern United States. They are located in landscape settings that are commonly found in the Southwest. They provided a good range of solar technologies and mitigation approaches for study purposes, and several of the facilities are in conveniently close proximity to each other near Las Vegas.

Each facility was viewed from multiple observation points at various locations and distances around the facility. Observation points were chosen for a combination of factors including their clear, unobstructed view of the facility; distance from the facility; and angle-of-view towards the facility. Facilities were observed at different times of day, from different angles, and under various lighting conditions.

One facility, Silver State North (SSN), was the subject of an escorted walking tour in an effort to address two sources of visual contrast that had been identified on previous visits. During the tour, the plant operators pointed out and described the facility components and structures, discussed some of their maintenance activities, and described the facility and substation lighting.

3.1.1 Written Documentation

Observed data were recorded on the Solar Facility Visual Characteristic Study: Site Description Form created specifically for this study (see Appendix A). Data collection included weather conditions; general locational information; exact location, as determined by hand-held GPS units; the general components of the facility that were visible; facility backdrop color and contrast; viewing angle between the observation point and facility; lighting quality and angle; and collector orientation and color. Any visible contrasts such as glare, light patterns, plumes, or transitory effects were also recorded. A space was also provided to record additional observations not called out on the form.

3.1.2 Photographic Documentation

Photographs were taken at each observation point with a Nikon D7000 DSLR with an 18–300mm lens in an effort to record visual contrasts between the facilities and their surroundings. A series of single-frame photographs were taken at focal lengths ranging from 18 mm to 300 mm. The majority of photos were taken with the camera mounted on a tripod. At some observation points, a series of side-by-side photographs were taken to capture the broader landscape context. After completion of the fieldwork trip, the photos were "stitched" into panoramic photographs using Pano2VR Software. The panoramas were then converted into interactive Flash files using PT Gui Software. The subject of the photograph, focal lengths, bearing to the subject, and file numbers were recorded in a photo log. One facility (NSO) was photographed at night, using timed exposures. The form data and photos (including the panoramas) were subsequently entered into the *Solar Energy Facility Visual Characteristics Study Database* for use in data analysis and for public use.

Additional photographs were taken of various facility components at shorter distances, where applicable. During the site tour of the SSN facility, photographs were taken of the facility components and structures, including the substation. Additional photographs were taken from outside the facility.

3.2 Facilities Descriptions (Visual Contrast Characterization)

The major facilities observed during the study fieldwork trips, their locations, size, technology and operational status are listed in Table 3–1. All dates are for the year 2013.

Table3–1. Observed Facilities

Facility Name	Location (nearest city)	Technology Type	Power Output (MW)	Acreage (approx.)	Operational Status	Observation Dates
Nevada Solar One (NSO)	Boulder City, NV	Parabolic Trough	64	400	Fully Operational	1/28, 1/29, 1/30, 1/31 (day/night)
Silver State Solar Energy Project-North (SSN)	Primm, NV	Thin-film PV	50	600	Fully Operational	1/31, 2/1
Ivanpah Solar Electric Generating System (Ivanpah)	Ivanpah Dry Lake, CA, near Primm, NV	Power Tower	377	3,500	Under Construction	1/29, 1/30, 1/31, 2/1, 5/14, 5/15
Copper Mountain Solar Facility 1 (CM 1)	Boulder City, NV	Thin-film PV	58	450	Fully Operational	1/28, 1/30
Copper Mountain Solar Facility 2 (CM 2)	Boulder City, NV	Thin-film PV	150	1,500	Partially Operational	1/28, 1/30
Crescent Dunes Solar Energy Project (Crescent Dunes)	Tonopah, NV	Power Tower	110	1,600	Under Construction	5/13
Alamosa Solar Generating Plant (Alamosa)	Alamosa, CO	Concentrating PV	30	225	Fully Operational	5/29, 5/30, 5/31

3.3 Mitigation Assessment Methodology

Development of mitigation measures was based primarily on observations and follow-on activities at the SSN thin-film PV facility. Some contrast sources targeted for mitigation had first been noted during a previous study (Sullivan et al. 2012a). The contrast sources were observed and photographed from both outside and within the facility. The plant operators were interviewed in order to gain a better understanding of the facility components and operations; for example, how lighting was managed at night and which lighting was under the control of the facility operators. Subsequent to the site visit, discussions took place with the facility siting and compliance manager for SSN, the Chief Landscape Architect at BLM, and a contractor who supplied materials that could be used for certain mitigation practices. From these discussions, potential mitigation measures were developed, and these mitigations will be required during the next phase of development at the project, a major expansion of the facility, scheduled for implementation in 2014–2016.

4 Overview of Visual Contrasts and Contrast Assessment

This study is focused on *visual contrast. Visual contrast* differs from *visual impact*, though the two terms are often confused. The difference between visual contrast and visual impact is discussed in Section 4.1. The perception of visual contrast from solar facilities and the visibility of objects in the landscape in general are highly dependent on a complex interaction of variables referred to as *visibility factors*. Visual contrast and visibility factors are discussed in Section 4.2.

4.1 Contrasts vs. Impacts

Visual contrast is change to what is seen by the viewer. For example, if a solar power tower facility is built in a natural-appearing desert valley landscape, the introduction of the tall shape of the receiver tower, surmounted by the intensely bright light of the receiver atop the tower, the vast expanse and regular geometry of the heliostat array reflecting the sun and sky, buildings, roads, and transmission facilities at or near the facility, and the facility lighting at night are all visual contrasts that can be seen by people.

Visual impact is both the change to the visual qualities of the landscape resulting from the introduction of visual contrasts—in this case from the building of a renewable-energy facility—and the human response to that change. Continuing with the example above, the introduction of the solar facility to the landscape may affect the perception of the landscape as a natural-appearing setting; instead, it may be perceived as a landscape strongly influenced by human activities and industrial in character. These are changes to the visual qualities of the landscape. Some viewers may think that the addition of the solar facility improves the view, perhaps because it adds visual interest and a strong focal point to an otherwise bland scene, or because they strongly support renewable energy, and regard the sight of the solar facility as a symbol of progress. For these people, the visual impact of the solar facility is positive. Other viewers may feel that the solar facility adds visual clutter, interferes with the view of mountains they enjoy, or introduces an industrial-appearing element into a natural-appearing landscape where they feel it does not belong. For these viewers, the visual impact of the facility is negative. These viewer reactions are human responses to the changes in the visual quality of the landscape caused by the introduction of the facility.

A VIA assesses both the visual contrasts created by a proposed project and the impacts caused by the visual contrast, that is, the likely effect of the project on the character of the landscape and the likely response of viewers to the project. This study describes visual contrasts of solar facilities only, and not the associated visual impacts. It describes the visibility of solar facilities in southwestern desert landscapes, which is determined by the visual contrasts they create with their surroundings, and it describes the sources and the nature of the contrasts themselves, without addressing how individual viewers may respond to the contrasts. While ultimately stakeholder opposition is based on perceived negative visual impacts of the facilities, the visual impacts of a facility arise from the visual contrasts it creates, and without a clear understanding of visual contrasts of solar facilities, it is impossible to assess their visual impacts accurately.

4.2 Visual Contrast in the Natural Environment

An object only becomes visible to an observer as a separate entity when it has sufficient contrast with its background to cross the *visual contrast threshold*, defined as the smallest contrast, produced at the eye of an observer by a given object, that renders the object perceptible against a given background. In the landscape, a variety of *visibility factors* affect the apparent visual contrast of an object with its background.

4.2.1 Visibility Factors

The visibility of an object in a landscape setting, and its apparent visual characteristics for any given view, are the result of a complex interplay between the observer, the observed object, and various factors that affect visual perception, referred to as *visibility factors*. Visibility factors also play a key role in determining the degree of visual contrast from a solar facility, and whether glare events are possible from a facility.

There are eight major types of visibility factors that affect perception of large objects in the landscape:

- *Viewshed limiting factors*. Viewshed limiting factors are variables associated with accurate viewshed analysis, i.e. the determination of whether there is a clear line of sight from the observer to the observed object. Viewshed limiting factors include screening by landforms, vegetation, and structures, as well as the Earth's curvature and atmospheric refraction. Screening can be important to the perception of glare from solar facilities, as it can sometimes be used to block visibility of glare spots.
- *Viewer characteristics*. Viewer characteristics are properties of the persons observing the object (the viewers) that affect their ability to distinguish the object from its background, and include *visual acuity* (how sharp their vision is), *viewer engagement and experience* (how actively or intently they are looking at the landscape and how familiar they are with the object, i.e., if they have seen it or similar objects before), and *viewer motion* (whether the viewer is stationary or moving when viewing the object). Viewer motion is an important factor that determines the occurrence and affects the perception of glare from solar facilities.
- *Lighting factors.* Lighting factors include the angle, intensity, and distribution of sunlight on the project, all of which change in the course of each day and also throughout the year as the sun's apparent path through the sky changes. The angle of sunlight is an important factor that determines the occurrence of glare from solar facilities.
- *Atmospheric conditions*. Atmospheric conditions refer to the presence of gases, dust, and other particles in the air between the viewer and the viewed object that affect its visibility. High humidity levels and high particulate matter concentration affect visibility by diminishing contrast and subduing colors. Cloudiness and poor atmospheric clarity will preclude occurrence of glare or diminish its intensity
- *Distance*. The distance between the viewer and the viewed object affects the apparent size of the object. Distance is an important visibility factor that affects the perceived intensity of glare from solar facilities.

- *Viewing geometry.* Viewing geometry refers to the spatial relationship between the viewer and the viewed object, i.e., looking up or down at an object (observer position) and the horizontal direction of the view (bearing). An elevated observer position makes solar facilities much more visible because the large expanse of the collector/reflector array becomes visible, as well as the (generally) contrasting form of the array; these aspects of the facility are much less visible from ground level views because of the generally low profile of solar facilities. Viewing geometry is an important factor that determines the occurrence of glare from solar facilities.
- *Backdrop*. The backdrop is the visual background against which the viewed object is seen. The color, lightness or darkness, and texture of the backdrop affect the visibility of the objects seen against the backdrop.
- *Object visual characteristics.* Object visual characteristics refer to the inherent visual characteristics of the project, such as its size; its scale relative to other objects in view; its form, line, surface colors and textures; its luminance (both from reflected light and from lighting sources) and any visible motion of its components. The size, shape, orientation, and surface properties of solar facility components determine whether or not glare occurs, and its intensity.

In real landscapes, interactions between these visibility factors are extremely important in determining the actual visibility of an object such as a solar facility (Benson 2005; BLM 2013a). For example, distance interacts strongly with atmospheric conditions as a determinant of visibility; a distant facility that is visible on clear days may be completely invisible on hazy days, or appear grayer and less distinct. Lighting, viewing geometry, and object visual characteristics interact to determine the presence and length of both shadows and glare, which strongly affect the dynamic range of visual contrast the facility creates. Furthermore, some of the factors are highly variable, and the effects are sensitive to even slight changes in one of the contributing factors; for example, the occurrence and intensity of glare spots on a facility may change rapidly and dramatically as the viewer moves over very short distances, or as the sun angle changes over a few minutes.

4.2.2 Types and Descriptors of Visual Contrast

Visual impact mitigation approaches usually seek to reduce the visible contrasts from the project or to avoid the contrasts altogether; this may be accomplished, for example, by painting facility components to blend with the landscape backdrop. For this reason, a good understanding of the sources of visual contrast and the factors that affect the perception of visual contrast in the landscape is important to the identification of appropriate mitigation techniques.

Visual contrast is usually described as the differences in the four basic design elements of *form, line, color*, and *texture* between the proposed project and the surrounding landscape.

Form: The mass or shape of an object or of objects that appear unified. Two types are recognized:

- Two-Dimensional Shape—the presence of an area or areas that contrast in color and/or texture with adjacent areas, creating a two-dimensional shape in the landscape.

- Three-Dimensional Mass—the volume of a landform, natural object, or man-made structure in the landscape.

Examples of forms commonly encountered in natural-appearing landscapes are masses of mountains, valley floors or plains, or large masses of similar-appearing vegetation, such as an expanse of shrubs in a landscape dominated by grasslands. Forms can also be man-made; they can include buildings or the large rectangular block of a solar collector array at a solar energy facility.

Geometry is an aspect of form. Forms in the natural landscape are generally irregular; however, they can approach a standard geometrical figure of two or three dimensions (e.g., square, circle, triangle, cube, sphere, cone). Manmade forms often have regular geometry that contrasts with the irregular geometry of the natural landscape. Solar collector arrays often appear as rectangles, parallelograms, or ellipses as viewed from elevated viewpoints.

Line: The path, real or imagined, that the eye follows when perceiving abrupt differences in form, color, or texture. Line is usually evident as the edge of shapes or masses in the landscape.

Examples of lines commonly encountered in natural-appearing landscapes are the horizon line; lines of stratified layers of topography (e.g., successive ridges); the lines of mountains or ridges against the sky; strata in rock formations; streams; and the edges of vegetation masses. Like forms, lines in the landscape can be man-made; for solar facilities, they include the edges of solar arrays; the edges of buildings, fences, transmission towers and conductors; and the pipelines of solar thermal plants.

Because solar facilities typically have many straight or curved components (e.g., turbine towers, steam pipes, solar panels, mirrors, heliostats, or electricity conductors), line contrast from these facilities can be very strong if the lines are bold, especially when the orientation of the lines introduced by the facility is perpendicular to the predominant natural line. For example, power towers often introduce strong vertical lines into strongly horizontal landscapes, such as the plains and valley floors where solar facilities are commonly sited.

Color: The property of emitted or reflected light of a particular intensity and wavelength (or mixture of wavelengths) to which the eye is sensitive. Color is the major visual property of surfaces.

Colors common to many BLM landscapes, particularly in the desert southwest and intermountain west, are the colors of vegetation, rock, and soil, which tend toward muted greens, browns, and grays.

Depending on the technology, solar facilities use thousands, or even hundreds of thousands, of mirrored surfaces that in some instances are sources of glinting or glare. Glare typically appears as intense, bright white light, while glinting often appears as glittering silver or white flashes of light. When glinting and glare are absent, the mirrors or heliostats may reflect the sky, clouds, or, at certain angles, even the ground or surrounding vegetation. Other colors at solar facilities vary, but are often the silver or gray of galvanized metal or the black of solar panels (for PV facilities), while buildings may be almost any color, but are often white, gray, or tan. Lighting at solar facilities typically includes steady lighting ranging from amber to bluish white, and white flashing strobes (in the day) and slowly flashing red lights (at night) that providing aerial hazard navigation lighting at power tower facilities.

Texture: The aggregation of small forms or color mixtures into a continuous surface pattern; the aggregated parts are small enough that they do not appear as discrete objects in the visible landscape.

Naturally occurring textures include those of vegetation, soils, and rocks. Vegetation and soil textures are often predominantly color mixtures, but light and shade textures are often important components of the coarser textures of rocky areas and mountains. The individual structures of solar facilities often have monotone, smooth surfaces that lack texture even at very close viewing distances; however, light and shade textures (particularly in the collector/reflector array) may be important contrast sources at longer distances. They may be seen as the interplay of shadows and lit surfaces from complex piping and other elements of a power block at a solar thermal plant, or from thousands of visually overlapping sunlit solar collectors/reflectors and the shadows they cast on the ground.

5 Results of Field Observations

This section summarizes results of the field observations of the seven solar facilities observed in the course of the study (see Table 3–1 for a listing of the facilities). Results are reported for each facility in the chronological order of visitation. Because the SSN facility is the subject of the mitigation case study, observations for that facility are discussed in Section 6.2, *Mitigation Case Study: Silver State North*.

5.1 Nevada Solar One

The NSO Facility is a fully operational, 400-acre (161-ha), 64-MW parabolic trough facility located on private lands approximately 12.5 mi (20 km) south-southwest of Boulder City, Nevada, and 1.5 mi (2.4 km) west of US 95, immediately north of El Dorado Valley Road. The facility ranges in elevation from approximately 1,770 ft to 1,820 ft (540 m to 555 m) above mean sea level.

The facility is situated in the El Dorado Valley and is surrounded by other industrial development, including the CM 1 and 2 facilities, a gas plant, a substation, numerous transmission lines, and US 95.

A total of 12 formal observations were made of the NSO facility during the January 2013 and the first May 2013 field trips, at distances ranging from 0.5 mi to11.5 mi (805 m to 19 km). The majority of NSO observations were conducted to the east or northeast of the facility in the early morning. Two observations were conducted in the afternoon and one observation was conducted at night. One of the afternoon observations was made from the summit of Black Mountain, approximately 9 miles north-northwest of the NSO facility. Observation elevations ranged from 1,765 ft to 5,098 ft (538 m to 1,554 m) above mean sea level. Observations were mostly made under clear weather conditions, with occasional partly cloudy skies or cirrus cloud cover. Visibility ranged from good to fair.

Objectives

The primary purposes of the observations at NSO for this study were as follows:

1) Determine if glare was observed at a different time of year (winter) from previous visits, which were made in mid-spring.
2) Obtain high-elevation photos of NSO and the neighboring CM thin-film PV solar facilities to provide documentation of the increased contrast visible from superior (elevated) viewing positions, and to provide photo documentation of potential cumulative visual impacts of solar facilities. These issues are of particular concern to NPS, tribal organizations, the tourism industry, and other stakeholders with respect to potential views of solar facilities within the BLM solar energy zones (SEZs) and other lands where multiple solar facilities could be visible from nearby mountains; for example, views of the Riverside East SEZ from the wilderness area within the Coxcomb Mountains within Joshua Tree National Park. In this case, because multiple solar facilities, substations, and large transmission lines are in close proximity, the visit to NSO also afforded an excellent opportunity to document cumulative visual impacts of solar energy

developments, which are likely to be similar to those that will eventually occur in the larger SEZs.

3) Observe the facility at night to assess lighting-related contrasts.

Results

Glare was observed at NSO during several observations over the course of several days. Glare was observed in the northeastern and southeastern corners of the parabolic trough field, when viewed in the morning from the northeast within 3 mi (5 km) of the facility. Glare appeared both as a band (see Figure 5.1–1) and as “beads” – discrete points of exceptionally bright white light (see Figure 5.1–2). It should be noted that consistent with previous observations, the glare was much brighter than shown in these and other figures in this report, and was sufficiently bright to be difficult to look at for more than a few seconds. Glare was often accompanied by glittering and flashes of light on the eastern or northern edges of the trough array adjacent to the glare spots, sometimes forming an L-shape, and outlining the rectangular shape of the parabolic trough field. During one observation, glare and glittering were observed in the northeast corner, disappeared during the observation, and then returned within a five minute period. No unusual cloud cover was noted at this time, and the observers did not change viewing positions.

Figure 5.1–1. Banded Glare from Front Row of Trough Array at NSO.

Figure 5.1–2. Beaded Glare from Front Row of Trough Array at NSO.

The glare observed during these observations was consistently weaker than that observed at approximately the same time of day (early morning to around noon) on previous visits that took place later in the spring (April-May). This observation is likely related to the lower sun angle and/or lower intensity of sunlight during this wintertime visit.

Photographs of NSO and the adjacent CM thin-film PV facilities were taken from the slope and summit of a nearby mountain. Figure 5.1–3 shows the NSO and CM facilities from the lower slope of a mountain north of the facilities and at a distance of 7.5 mi to the nearest portion of the NSO facility and 9.5 mi to the farthest visible portion of the CM facilities. NSO is the blue-gray rectangle in the center, and the CM facilities are the black bands on either side and just beyond NSO. By far the most prominent element of the photo is the water vapor plume from the cooling tower at NSO. This is consistent with many other observations made of NSO and other wet-cooled solar thermal facilities in which the color and motion contrast of water vapor plume is conspicuous, especially considering its movement, which cannot be seen in a photo.

Figure 5.1–3. NSO and CM Facilities as Seen from a Slightly Elevated Viewpoint 7.5–9.5 mi North of the Facilities.

Figure 5.1–4 shows the NSO and CM facilities from the summit of a mountain north of the facilities and at a distance of 9 mi (15 km) to the nearest portion of the NSO facility and 11 mi (18 km) to the farthest visible portion of the CM facilities. The viewpoint is approximately 3,300 ft (1,000 m) above the facility. NSO is the light gray rectangle in the center, and the CM facilities are the black rectangles on either side of NSO. The regular geometric forms and colors of the facilities contrast noticeably with the dull green of the creosote bush vegetation of the valley floor. Despite the relatively long distance, the facilities attract visual attention and are prominent features within the view. The overall contrast is increased by the proximity of the black color of the PV facilities to the light gray of the trough facility, yielding a cumulative visual impact that is exacerbated by the mixing of solar technologies within the field of view.

It should be noted that these facilities are relatively small, and that facilities several times larger are currently operating and under construction.

Figure 5.1–4. NSO and CM Facilities as Seen from a Mountaintop Viewpoint 9–11 mi (14–18 km) North of the Facilities.

In the course of the observations of NSO, bright reflections were frequently observed to come from pipes conveying heat transfer fluid through the trough array, at the sides of the array, underneath the array, and between the various elements of the power block. Other reflections appeared to come from the bellows shields between sections of the receiver tubes and from disc-like “collars” attached to the receiver tubes at various places. Bright reflections were also observed from galvanized chain-link fence posts and rails.

The buildings and other support structures at NSO do not blend well with the natural colors of the surrounding landscape, and the colors are not uniform throughout the facility. Both of these traits increase the color contrast of the facility.

NSO was also observed and photographed at night (see Figure 5.1–5.). Most of the lighting is unshielded or poorly shielded, and motion detectors are not used to reduce lighting use. For safety reasons, good illumination is required around the steam turbine generator; however, the lighting may be excessive in some areas. The multiple bright lights combined with complex reflective surfaces make the facility visible at night beyond 14 mi (23 km) (Sullivan 2011). A mix of bluish-white and yellowish-white lighting is used, creating additional contrast (bluish-white lighting causes excessive light pollution).

Figure 5.1–5. Nighttime Photo of the Power Block and Part of the Cooling Tower at NSO Parabolic Trough Facility. (Credit: Marc Sanchez, BLM.)

5.2 Copper Mountain Solar Facilities One and Two

The CM 1 and 2 Facilities are fully (CM 1) and partially (CM 2) operational fixed-tilt thin-film PV facilities located on private lands approximately 13 miles (21 km) south-southwest of Boulder City, Nevada, and between 0.4 and 3.2 mi (0.6 and 5.1 km) west of US 95, immediately south of El Dorado Valley Road. CM 1 occupies 450 acres (182 ha), with 64 MW nominal power output, while CM 2 occupies 1500 acres (610 ha), with 150 MW nominal power output. The facilities range in elevation from approximately 1,805 ft to 2,062 ft (550 to 628 m) above mean sea level.

The facilities are situated in the El Dorado Valley and are surrounded by other industrial development, including the NSO parabolic trough facility, a gas plant, a substation, numerous transmission lines, and US 95.

Four direct observations were made of the CM 1 and CM 2 facilities at distances ranging from 0.8-mi to 10.5 mi (1.3 km to 7 km); however, these facilities are visible in many of the NSO observations because of their close proximity to NSO. Observations were conducted from the north, east, southeast, and south-southwest of the facility, with two observations in the morning and two in the afternoon. The CM facilities were visible in the observation of NSO made from the summit of Black Mountain (see above under NSO observations discussion), approximately 10.5 miles (17 km) north-northwest of the NSO facility. Observation elevations ranged between 1,765 ft and 5,105 ft (538 m and 1,556 m) above mean sea level. Three observations were mostly made under clear weather conditions, and one under partly cloudy skies. Visibility ranged from good to fair.

Objectives

The primary purposes of the observations at CM 1 and 2 for this study were as follows:

1) Observe and obtain photographs of the CM 2 facility, which was not built at the time of previous field observations. CM 2, at 1,500 acres (610 ha), is more representative of the large-scale facilities under construction at several locations in the U.S.

2) Compare power conversion unit (PCU) color differences between the CM 1 and SSN facilities. The PCUs at CM 1 are white, and under many lighting conditions contrast strongly with the surrounding black PV panels. The CM 2 panels are brown with gray trim. The SSN PCUs were painted Shadow Gray (a BLM Standard Environmental Color Chart color [BLM 2008]) at BLM's direction (SSN is on BLM land). Observations of all three facilities were needed to assess the effectiveness of using various colors to reduce visual contrast.
3) Obtain photos of the facilities from high-elevation viewpoints, as done for NSO.
4) Observe the facility at night to assess lighting-related contrasts, as done for NSO.
4) Check for possible glare occurrences.

Results

Previous observations of CM 1 established that the white PCUs contrasted very strongly with the black PV panels under normal lighting conditions, i.e., when the panels appear black. However, at certain angles, the black panels appear light-colored or even white because of sunlight reflected off the glass front surfaces of the panels (see Figure 5.2–1). Under these conditions, the white PCUs blend well with the panels. Assessment of the brown and white PCUs at CM 2 and comparison with those at CM 1 show that while overall the contrast at CM 2 is somewhat lower than CM 1 under most lighting conditions, the color is insufficiently dark to blend with either the creosote vegetation surrounding the facility or the black PV panels that form the backdrop for views from high-elevation viewpoints under normal lighting conditions (see Figure 5.2–2). In addition, when the viewing angle is such that the panels appear white, the brown PCUs contrast strongly with the background. Figure 5.2–3 shows how the apparent color of the PV panels varies across a single view, and the effect that has on the contrast of the PCUs with the collector array. Using both dark and light colors on the PCUs creates its own color contrast and makes it more difficult for the PCUs to blend with either dark or light backgrounds, and would appear to be a poor choice with respect to visual mitigation. See the SSN mitigation case study (Section 6.2) for further discussion of color contrast mitigation.

Figure 5.2–1. Black PV Panels at CM 1 and 2 Facilities Appear White When Low-Angle Sunlight Is Reflected from the Panels (Background).

Figure 5.2–2. Brown and White PCUs at CM 2 facility (Foreground) and White PCUs at CM 1 (Background).

Figure 5.2–3. Brown and White PCUs at CM 2 Facility (Foreground) Contrast with Both Dark (at Left) and Light (at Right) PV Panels. White PCUs of CM 1 Facility Are Visible (Background Left). (Credit: Marc Sanchez, BLM.)

Observation of the CM 1 and CM 2 facilities at night showed much lower levels of illumination than for NSO. Because there is no power block or steam turbine generator (a major source of lighting at solar thermal facilities) and very few employees onsite, lighting requirements are minimal. There were no lights visible within the collector array, and very limited lighting around the administration building (see Figure 5.2–4). The lights on the administration building were well-shielded and directed, so that the light was directed downward and light spillage into areas where it was not needed was minimal. Potential improvements include reducing the number of lights and using motion sensors, as the building appeared to be unoccupied, so there was little need for lighting.

Figure 5.2–4. Nighttime Photo of the Administration Building at the CM 1 PV facility. (Credit: Marc Sanchez, BLM.)

As on previous visits, glare was not observed at either CM 1 or CM 2, although glare does occur at some PV facilities (Ho 2012).

5.3 Ivanpah Solar Electric Generating Station

The Ivanpah facility is a 3,500-acre (1,416-ha), 392-MW solar power tower facility currently under construction approximately 4.5 miles (7.2 km) southwest of Primm, Nevada, near Ivanpah Dry Lake, California. The facility is located within the Ivanpah Valley. Primm Golf Course is located approximately 0.5 mile (805 m) northeast of the facility at its closest point and the community of Primm, NV, is located approximately 4.5 mi (7 km) northeast of the facility at its closest point. When operational (the facility is in a testing phase as of this writing), the facility will generate 377 MW using 173,500 heliostats to focus sunlight on receivers atop three towers.

The facility site ranges in elevation from approximately 890 to 988 m (2,920 to 3,240 ft) above sea level. A total of 20 observations were made of the Ivanpah facility during the January 2013 and first May 2013 field trips, at distances ranging from 0.5 mi to 35 mi (805 m to 56.3 km). Observation elevations ranged from 2,650 ft to 5,100 ft (890 m to 1,555 m) above mean sea level.

Observations were conducted mostly in clear weather conditions, sometimes under cirrus cloud cover. Visibility ranged from good to poor.

The three towers run in a line southeast to northwest up a bajada of the Clark Mountains. The distance between the southeasternmost tower and the middle tower is 1.8 mi (2.9 km), and the distance between the middle tower and the northwesternmost tower is 1.5 mi (2.4 km). Each heliostat consists of two mirrors that are 7.2 ft (2.1 m) high by 10.5 ft (3.2 m) wide, mounted on pylons inserted directly into the ground. The pylons are arranged in concentric circles around the tower in order for the heliostats to track the sun. The receiver towers are 137 m (450 ft) tall. Owing to the height of the towers, lighting and lightning poles that are required by the Federal Aviation Administration will extend approximately 3 m (10 ft) above the top of the towers. Each tower will be accompanied by a steam turbine generator set, air-cooled condensers, and other auxiliary systems. The facility will be dry-cooled and will utilize a natural gas backup. Other facilities at Ivanpah will include an administration building, an operation and maintenance building, a substation, and access roads.

Objectives

The primary purposes of the observations at Ivanpah for this study were as follows:

1) Observe and obtain photographs of the completed facility, in operation if possible. Ivanpah is far larger in size than any other power tower facility in the world, but is representative (in terms of size) of projects under construction or planned in the United States.
2) Observe the facility from the farthest distance possible, in order to assess the limits of visibility and to establish a potential future facility observation point.
3) Obtain photos of the facilities from high-elevation viewpoints, as done for the other facilities. This was particularly important for Ivanpah, as there is concern about the appearance of the heliostats from elevated viewpoints.
4) Check for possible glare occurrences, either from the receiver or from heliostats.

Results

The Ivanpah facility was not in operation during the study; however, photos from the January 2013 field trip show the facility nearly completed in terms of physical infrastructure, as shown in Figure 5.3–1. Heliostat calibration testing is underway at the left-hand and central towers, with heliostats raised to focus sunlight on the receiver. Where heliostats are tilted, bright reflections (not bright enough to constitute glare) are visible.

Figure 5.3–1. Ivanpah Power Tower Facility Under Construction from a Distance of 11 mi (18 km) from the Closest Tower, May 2013.

During the January 2013 field trip, the facility was also photographed from a low hill at the base of the Clark Mountains, 3 mi (5 km) southwest of the southeasternmost tower (see Figure 5.3–2). At that distance, the three towers could only be encompassed by the widest-angle zoom setting on the camera lens, and even this photo does not capture the full width of the heliostat fields surrounding the towers, which in total, span a distance of 4.8 mi (7.8 km) across. Figure 5.3–3 shows a view along the long axis of the facility from the southeast, from a distance of 4.3 mi (6.8 km) from the closest tower and 7.3 mi (11.7 km) from the most distant tower. These photos show that the facility is a major source of visual contrast even without the towers operating. When the facility is in operation, the receivers will shine a brilliant white with reflected light from the heliostats, and will become a much greater source of visual contrast.

Figure 5.3–2. Ivanpah Power Tower Facility Viewed from a Hill 3.0 mi (5.0 km) Southwest of the Closest Tower, January 2013.

Figure 5.3–3. Ivanpah Power Tower Facility Under Construction from a Distance of 4.3 mi (6.8 km) from the Closest Tower, May 2013.

At the time the photo shown in Figure 5.3–2 was taken, the heliostats were not tracking the sun and were “pointing” straight up, that is, the heliostat surfaces were roughly parallel to the ground plane, a standby position use to avoid wind loading. In this configuration, an assessment of potential glare as seen from an elevated viewpoint could not be made (however, for further discussion of glare from heliostats, see below). In Figure 5.3–2, the heliostats are reflecting the blue sky, and appear somewhat similar to the surface of a large body of water, a visual effect that is common at solar facilities, and which is sometimes referred to as the “lake effect.”

A single observation of Ivanpah was conducted from the summit of Black Mountain (elev. 5098 ft [1554 m]) at the same time the observations were made of NSO and CM 1 and 2. The mountain summit is approximately 35 mi (56 km) northeast of the Ivanpah facility. From this viewpoint, 2,072 ft (631 m) above the center of the facility, one full tower and its associated steam plant and one partial tower could be seen after visually scanning in the direction of the facility (see Figure 5.3–4). What appeared to be a few rows of heliostats emitting low-level reflections of sunlight were also visible. While the tower and adjacent facilities appeared very small and only weakly contrasting, and would be missed by most casual observers, the fact that the *unlit* towers were visible to the unaided eye at 35.7 mi (57.5 km) suggests that when operating, the towers would almost certainly be visible at much greater distances where there were unobstructed views, likely appearing as small but bright points of light. At very long distances, the facilities are not likely to cause large visual contrasts, but they might be bright enough to attract visual attention.

Figure 5.3–4. Unilluminated Ivanpah Power Towers from a Distance of 35 mi (56 km) from the Closest Tower, May 2013. Arrows Indicate Tower Structures.

While the Ivanpah receivers were not operating during the study field visits, and thus could not be sources of glare, strong glare from heliostats was observed from two observation points during the first May 2013 field trip. The glare appeared to originate from individual heliostats during a heliostat collimation test (see Figures 5.3–5 and 5.3–6, showing glare viewed from different locations several miles apart). Though the glare sources were very small as seen from the viewing distances of approximately 10 mi (16 km) and 11.5 mi (18.5 km), they were far brighter than they appear in the figures, and both observers found them unpleasantly bright at times. They faded in and out of glare-level intensity very rapidly, perhaps as the heliostat positions were adjusted. It is unclear whether this type of glare would be encountered during operations because the heliostats will be tracking the sun and the heliostat positioning might be very different from that observed during this test; however, it is noteworthy that these observations established that unpleasantly strong glare can be produced by an individual heliostat at distances exceeding 10 mi (16 km).

Figure 5.3–5. Close-up View of Glare from Ivanpah Heliostat, as Seen from a Distance of Approximately 10 mi (16 km), May 2013.

Figure 5.3–6. Glare from Ivanpah Heliostat, as Seen from a Distance of Approximately 11.5 mi (18.5 km), May 2013.

5.4 Crescent Dunes Solar Energy Project

The Crescent Dunes facility is a 1,600-acre (650-ha), 110-MW solar power tower facility currently under construction approximately 14 miles (23 km) north-northwest of Tonopah, Nevada. The facility is located east of Pole Line Road, about 1 mi west of the Crescent Dunes dune formation, and about 4 mi (6 km) west of the San Antonio Mountains. When operational, the facility will generate 110 MW using 17, 170 heliostats in a circular array to focus sunlight on a receiver atop a single tower 540 ft. (165 m) tall.

The facility site ranges in elevation from approximately 4,880 to 5020 ft (1490 to 1530 m) above sea level. A total of 11 observations were made of the Crescent Dunes facility on May 13, 2013, between 12:30 PM and 6:40 PM. Observation distances ranged from 1 mi to 29.5 mi (1.6 km to 47.5 km). Observation elevations ranged from 4,800 to 5,200 feet (1,460 to 1,580 m) above mean sea level.

Observations were conducted in clear, partly cloudy, and cloudy weather conditions. Visibility was judged to be good.

Objectives

The primary purposes of the observations at Crescent Dunes for this study were as follows:

1. Observe and obtain photo documentation of a poured concrete power tower facility. The Crescent Dunes tower is made of poured concrete, and is more typical of current designs; the Ivanpah towers are metal and are an atypical design, with very different visual characteristics.
2. Assess maximum visibility and contrast threshold distances for a concrete power tower facility. The Crescent Dunes facility provides much longer sightlines than Ivanpah, and thus is better suited for visibility and threshold distance analysis.
3. Document any occurrences of glare.

Visibility and contrast threshold distance assessments for the facility were conducted using a methodology developed for the Visual Impact Threshold Distance Study (VITD)— an approach developed for BLM (Sullivan et al. 2012b) to assess the effects of distance and atmospheric variables on the visibility and visual contrast levels of wind facilities. In this case, the forms were adapted for use with solar facilities. The visibility assessments consist of numeric ratings on a scale of 1 to 6, scored according to the visibility of a solar facility within its landscape/seascape setting and the weather and lighting conditions at the time of the observation. The visibility rating is a judgment of the observers, made by comparing the solar facility in view with language described on a Visibility Rating Form that accounts for the visual characteristics of the solar facility appropriate to each rating level. Photographs were not used for visibility ratings; the ratings were conducted through naked-eye observations of the facility in the field. More information about the methodology used is available in Appendix B. A Solar Facility Visibility Rating Form is available in Appendix C.

Visibility and contrast threshold distance assessments are useful for two primary purposes:

1) They are useful for determining the appropriate area of analysis for VIAs. Visibility and contrast threshold distance assessments identify the maximum distance at which a facility is likely to be

seen, the approximate distances at which it is easily seen, and the distance at which it is likely to become a major focus of visual attention, and this information can be used to identify the distance from the facility for which impacts should be analyzed. For example, the minimum distance for which impacts should be analyzed in a VIA likely corresponds to the distance at which viewers are likely to see the facility at a casual glance.

2) The visibility and contrast threshold distance assessment methodology requires that the observers record the contrast sources associated with the facility that they see, and identify the facility components or contrasts that contribute most to the project's overall visibility. This approach is quite useful for identifying important contrast sources, which is key to identifying mitigation opportunities.

Results

The Crescent Dunes facility was not in operation during the study; however, photos from the May 2013 field trip show the facility mostly completed in terms of physical infrastructure, and therefore an approximation of how the facility would look when it was in standby mode, as shown in Figure 5.4–1.

Figure 5.4–1. Crescent Dunes Solar Energy Project under Construction, as Seen from a Distance of Approximately 1.3 mi (2.1 km), May 2013.

The results of the contrast threshold distance analysis indicated the following:

1) The unilluminated tower was at the limit of visibility, i.e., just barely visible to the unaided eye, at a distance of 29.5 mi (47.5 km). This corresponds to an average visibility rating of "1" on the VITD visibility scale. At this distance, the unlit tower is tiny and very faint, and would not be noticed by a casual viewer. While the tower would likely cause a negligible visual impact at best, this result suggests that it is highly likely that the reflected light from a receiver on an operating power tower would be visible well beyond this distance, while the tower itself would not be,

and thus the facility would be visible as a bright point of light very low to the horizon (or multiple points of light if there were multiple towers in view).

2) The unilluminated tower became easily visible to both observers after a brief glance at a distance of 18 mi (29 km) (see Figure 5.4–2). This corresponds to an average visibility rating of “3” on the VITD visibility scale. At this distance, the observers stated that the contrast between the black (unilluminated) receiver and the white reflective surfaces immediately above and below the receiver was obvious, and the tower stood out against the darker mountain backdrop. The width of the tower was reported to be discernible, i.e., it appeared as a narrow vertical band rather than a line. The flashing of the white strobe lights that serve as aerial hazard warning lights was reported as being visible, but only a weak source of contrast at this distance. This observation suggests that if it can be assumed that the operating tower would be substantially more noticeable at this distance, then it would be reasonable to assume that the distance for the impact analysis to include in a VIA for an operating tower of similar appearance in similar circumstances should be at least 18 mi (29 km), and likely substantially farther. It must be kept in mind that an observation of one facility cannot be assumed to be valid for other facilities; however, the Crescent Dunes facility is generally similar in appearance to other power tower facilities that are planned or in operation, and the landscape setting is common to many solar projects in the southwestern deserts of the United States.
3) At 10.6 mi (17 km), the tower was judged to compete with other landscape elements for visual attention. This corresponds to an average visibility rating of “4” on the VITD visibility scale. It was judged to be a moderate source of visual contrast at this distance, dropping to a “3” (weak source of contrast) under cloudy conditions, which occurred during the course of the observation. In this case, the lack of sunlight on the tower made it harder to distinguish against the darker mountain backdrop. This observation suggests that lowering the contrast of the tower—for example, by coloring (tinting) the concrete before pouring it—might reduce the contrast of the tower, making it harder to see at long distances when it is cloudy, at sunrise or sunset when the sun’s illumination is too low to operate the tower, and when it is in standby mode.
4) At 7.1 mi (11.4 km), the unilluminated tower was judged to be a major focus of visual attention, that is, it attracted and held viewer attention. At this distance, the other onsite infrastructure was plainly visible, and the white strobe lights were judged to be a major component of the facility’s overall visual contrast.
5) At 1.3 mi (2.1 km), the facility dominated the view, that is, it filled the field of view and was the single major focus of visual attention (see Figure 5.4–1).

No glare was observed from any facility components in the course of the observations.

Figure 5.4–2. Crescent Dunes Solar Energy Project under Construction, as Seen from a Distance of Approximately 18 mi (29 km), May 2013.

Figure 5.4–3. Crescent Dunes Solar Energy Project under Construction, as Seen from a Distance of Approximately 7.1 mi (11.4 km), May 2013.

While clearly there is a need to revisit the visibility and contrast threshold distance analysis when the Crescent Dunes and Ivanpah facilities are operating, these results for the unilluminated tower and heliostats at the Crescent Dunes facility suggest that operating power towers will be visible for very long distances, and are likely to create larger contrasts at long distances because of the height of the towers and the potential for glare from the receivers and the heliostats. In addition, these observations identified the aerial hazard navigation lighting as an important cause of visual contrast at shorter distances, a new finding.

5.5 Alamosa Solar Generating Plant

The Alamosa facility is a 245-acre (99-ha), currently operating 30-MW CPV facility located approximately 10 miles (16 km) north-northwest of Alamosa, Colorado, in the San Luis Valley, which is bounded on the east by the Sangre de Christo Mountains and on the west by the San Juan Mountains. The facility is located in a relatively flat agricultural area, about 5 mi (8 km) west of Highway 17, and west of County

Road 104 N. The facility consists of 504 dual-axis tracking Amonix 7700 panels. each of which contains 7,560 fresnel lenses that concentrate sunlight onto multijunction PV cells, as well as an operations support building and a substation. Each panel is 72 ft (22 m) wide and 49 ft (15 m) tall, and is mounted on a 3-ft (1-m)-wide pedestal approximately 20 ft (6 m) high, so that the maximum height of a tilted panel is more than 50 ft (15 m).

The facility elevation is approximately 7,590 ft (2,313 m) above sea level, and the entire site varies in elevation by only a few feet. A total of 20 observations were made of the Alamosa facility on the second May 2013 field trip. Observations were made from before sunrise until evening over the course of three days (May 29–31). Observation distances ranged from 1 mi to 25.6 mi (1.6 km to 41.2 km). Observation elevations ranged from 7,565 to 9,072 ft (2,306 to 2,765 m) above mean sea level.

Observations were conducted in clear weather conditions. Visibility was judged to vary from poor (because of wind-blown dust) to good.

Objectives

The primary purposes of the observations at the Alamosa facility for this study were as follows:

1. Observe and obtain photo documentation of a CPV facility. This study marks the first known assessment of visual contrasts associated with a CPV facility. While CPV facilities vary widely in design and visual characteristics, these observations and photos provide baseline information regarding a viable utility-scale CPV design.
2. Document any occurrences of glare.

Results

The Alamosa facility shares some visual characteristics with conventional PV facilities in that the infrastructure is largely devoted to the collector array, with fewer ancillary structures; no power block, cooling towers, or water vapor plumes; and fewer workers and associated activity. Like conventional PV facilities, the solar collectors are flat rectangles, and similarly to some PV facilities, the collectors track the sun throughout the course of the day, such that at a given viewpoint, a viewer may be looking at the face, the backs, or the sides of the collectors, and with widely varying degrees of tilt. However, the collectors are vastly larger in size and much taller than conventional PV collectors (see Figure 5.5–1). While conventional PV arrays are easily screened by relatively low vegetation, structures, or even small changes in topography, the Amonix panels are taller than trees, and wider than most houses, so they are much more difficult to screen and present a relatively large surface to the viewer when the viewer faces the panels' fronts or backs. The large size of the panels also means that they subtend a relatively large angle of view at a given distance; combined with their height, this feature makes them much easier to see at long distances.

Figure 5.5-1. Close-Up View of Amonix 7700 CPV Panels at Alamosa Solar Generating Plant.

Observations of the facility were made from two viewpoints on the slopes of the Sangre de Cristo Mountains, and the facility was faintly visible under normal lighting conditions from these viewpoints, located 21.3 (34.3 m) and 25.6 mi (41.2 km) from the facility, and elevated approximately 600 and 1500 ft (180 and 460 m) higher than the facility, respectively. However, at one of the two viewpoints, on two occasions, just after sunrise on successive days, the facility was much brighter, appearing as a small but very bright band of light across the distant valley floor. Although far too small to dominate the view, the bright band of light attracted and held visual attention, and was judged to be a major source of visual contrast (see Figure 5.5–2, but note that the reflections were substantially brighter than shown in this photo). The light was insufficiently bright to cause discomfort, and could be viewed for extended periods, but it was by far the brightest light source visible at the time. The effect lasted less than 30 minutes on both days; however, during that time, the reflections varied noticeably in intensity, with individual spots "flaring up" or fading rapidly over the space of a few minutes or seconds. During one of the observations, the observers moved several miles by vehicle and noted that the reflections were visible across the entire area traveled, indicating that unlike glare observed at NSO and at the Kramer Junction SEGS trough facility, the reflections were not sensitive to short-distance viewer movement. Inspection with binoculars revealed that the band was caused by very bright reflected sunlight from the front row of panels in the array, with the "flare-ups" seemingly confined to individual panels or groups of panels (see Figure 5.5–3). These effects were not observed at any other locations or times, although during a few other observations, an individual panel was noticeably brighter than the others, and low-level glare was observed from a distance of 1 mi (1.6 km) during one early-morning observation, when the panels were at a high angle relative to the ground plane, i.e., substantially tilted to face the low-angle sun.

Figure 5.5-2. Bright Reflections from CPV Panels at Alamosa Solar Generating Plant, as Seen from a Distance of 25.6 mi (41.2 km). San Juan Mountains in Background.

Figure 5.5-3. Close-Up View of Reflections from CPV Panels at Alamosa Solar Generating Plant, as Seen from a Distance of 25.6 mi (41.2 km).

The observation of very bright reflections from a relatively small facility at distances beyond 25 mi (40 km) was an unexpected finding. While the exact cause could not be determined with certainty, it may have to do with the combined effects of lighting, viewing geometry, and the facility's visual characteristics. At the time of year of the observations, the sun rose directly behind the viewer facing the panels, so sunlight reflected off the flat panels directly back toward the sun might have been visible at the viewpoint and nearby locations, assuming a small amount of “spread” in the reflections from the panel surfaces. This hypothesis could be tested easily by further field observations.

In this case, the viewpoint was the visitor center at the Great Sand Dunes National Park, an example of a highly sensitive viewpoint. There are likely to be very few visitors at the Visitor Center immediately after sunrise, and if this effect is confined to this time of day for a short number of days in the year, there will likely be little impact on the National Park; however, if the effect is more widespread, both temporally and spatially, it has the potential to negatively affect the Park visitors’ experiences.

Aside from these bright reflections viewed from a single viewpoint, the facility was generally not found to be a source of strong visual contrast except for views facing the panels from relatively short distances of 1–3 mi (2–5 km). It generally appeared as a dull gray “wall” low on the horizon, and viewed against distant mountain backdrops which were generally gray, it was often difficult to detect even at shorter distances, and did not strongly attract visual attention (see Figure 5.5–4). Because the facility is small relative to many other utility-scale facilities, it does not occupy a large portion of the field of view until viewers are relatively close to the panels. When it is not reflecting light, its relatively dull gray color and horizontal orientation within a landscape dominated by a strong horizon line make it blend in with the background. However, if the viewer is sufficiently close (less than 1 mi [1.6 km]), the size of the facility and the individual panels becomes dominant, and when the viewer is very close to the facility, the panels “loom” overhead and present a striking appearance (see Figure 5.5–1).

Figure 5.5–4. View of Alamosa Solar Generating Plant, as Seen from a Distance of 2.4 mi (3.8 km).

6 Potential Solar Facility Visual Impact Mitigation Strategies

Section 6.1 suggests both general and technology-specific potential mitigation strategies, based on lessons learned during the field observations of solar facilities described in Chapter 5, and on previous field observations of solar facilities (discussed in Sullivan [2011] and Sullivan et al. [2012a]).

6.1 General and Technology-Specific Mitigation

BLM (2013a) has recently published a comprehensive guide to best management practices (BMPs) for visual impact mitigation for renewable energy projects, including wind, solar, geothermal, and electric transmission projects. The reader is referred to the BLM BMP publication and to the draft Solar PEIS (BLM and DOE 2010) for a comprehensive listing of contrast sources associated with the major solar technologies, and mitigation measures generic to all large energy projects but also specific to solar energy projects. Both publications point out that because of the large size and unique characteristics of solar facilities, the visual impacts from the facilities are often large, and mitigation for the major contrast is very difficult. A particular challenge is the use of vast arrays of reflective surfaces and, especially for non-PV technologies, operating principles that rely on using highly reflective surfaces to focus sunlight to generate heat to drive steam turbines. Intense reflected light, highly reflective surfaces, more and larger support structures, complex networks of pipes, cooling towers, water vapor plumes, substantial lighting needs, and more human activity are fundamental to these technologies and make their visual impacts substantially larger than for PV facilities and the mitigation much more challenging. This is especially true for power tower facilities, because they lack the low vertical profile of PV and trough facilities. The height and luminosity of the receivers and the need for both daytime and nighttime hazard navigation lighting make them especially visible in open desert landscapes, both day and night. Even PV facilities can cause large visual impacts, despite their inherent advantages, especially when viewed from elevated viewpoints, where their size, regular geometry, and generally contrasting but highly variable apparent colors are visible.

As noted in the introduction to this report, many of the largest contrasts and resulting impacts from solar facilities cannot be mitigated effectively, except through siting facilities in different locations, choosing different solar technologies, reducing the size of the project, or using offsite mitigation to compensate for the impacts. In many circumstances, offsite mitigation is the only feasible strategy, yet it fails to reduce the actual visual impacts of the project. However, impacts not directly associated with the collector/reflector arrays and associated reflected light sources can sometimes be effectively mitigated, thereby reducing the overall impacts of the facilities, especially when the facilities are distant from the viewer; these strategies, in general, are directed at making the facility harder to notice or to distinguish from naturally occurring landscape features.

The following suggested mitigation measures are contained within the BLM BMP publication (BLM 2013a), but are further discussed here because observations of a variety of solar facilities for the current and previous studies (discussed in Sullivan [2011] and Sullivan et al. [2012a]) suggest that they may be particularly effective. Several of these mitigation measures are discussed further in the mitigation case study in Section 6.2.

- **Reduction/treatment of all exposed metal or reflective surfaces.** The authors have repeatedly observed that only a few square inches of untreated reflective surfaces may be visible for several miles in the intense sunlight and clear air of the southwestern deserts. Even chain link fences can cause reflections visible at long distances. Many of these surfaces are not directly associated with the sunlight collecting/reflecting surfaces and may be eliminated by more careful design of the components, may be replaced by materials that are less reflective, or may be coated or treated to have non-reflective surfaces, except where safety or functional requirements prevent it. For existing facilities, careful observation from distant vantage points may reveal surprisingly bright reflection sources that potentially may be mitigated. It should also be noted that dark-colored objects may still cause bright reflections, as is evident in the numerous observations of black PV panels appearing to be bright white under certain lighting conditions and viewing geometries; reducing reflectivity of the surfaces is critical to effective mitigation.
- **Use consistent color treatments.** Wherever possible, use uniform (and well-chosen) color treatments on all structures and surfaces. NSO has buildings that use two very different colors, neither of which blends well with the surrounding landscape. CM 2 has two-toned PCUs that do not blend with the panels when they appear to be black, white, or shades in between. In both cases, the inconsistent coloring creates additional color contrast that draws the eye in some viewing situations.
- **Use BLM standard environmental colors.** BLM visual resource experts have conducted studies to determine colors that best match naturally occurring landscapes. In the judgment of the authors, observations of SSN, CM 1, and CM 2 clearly show that the BLM-required color treatment substantially reduced the visibility of the PCUs, potentially a major source of color contrast at PV facilities. Choosing effective color treatments is more challenging than many non-specialists realize, and many treatments intended to blend with the surrounding landscape are ineffective and may actually increase the visibility of the facility.
- **Avoid regular geometry where feasible.** It is a given that solar facilities require the use of large arrays of identical components in the collector/reflector arrays; at short distances, the regular geometry is a dominant visual feature that contrasts strongly with natural landscapes, and is an unavoidable contrast. However, at longer viewing distances, the internal components of the facility become indistinguishable, and the forms of the collector/reflector arrays become dominant. If these shapes are regular polygons, they may be instantly identifiable as man-made elements in a natural landscape; however, if the arrays have curving or irregular edges, they may become difficult for casual observers to distinguish from cloud shadows, rock outcrops, or vegetation masses. PV arrays, in particular, do not need to be in rectilinear arrays, and the Ivanpah heliostat fields also have irregular outlines, so there is no insurmountable obstacle to using non-rectilinear arrays for these technology types. This type of mitigation may be particularly effective for PV facilities, because in most viewing situations, they do not cause glare, do not have large expanses of highly reflective surfaces, and consequently are the easiest

to blend with natural landscapes. This same principle should be applied to vegetation management: the edges of cleared areas should be feathered to make them appear more natural.

- **Minimize vegetation clearing outside of the arrays.** There are a host of non-visual reasons to minimize vegetation clearing at solar facilities; however, vegetation removal also causes strong color and texture contrasts by exposing (typically) light-colored soils that lack the visual texture that vegetation provides. The light-colored soils are particularly visible adjacent to black PV panels, and become even more noticeable if the lines of the cleared areas repeat the edge lines of the array forms; in other words, if there are strips of cleared vegetation that parallel the edges of the array. These repeated lines create a high-contrast striping effect that can be visible for long distances an d is obviously artificial in its appearance.
- **Design and use lighting effectively.** The BLM BMP publication discusses several mitigation measures for lighting, and they can be very effective when properly applied. Again, PV facilities present mitigation advantages because they need little lighting to begin with. They do not have complex high-temperature components and taller structures that require extensive lighting for safety reasons, and they require very few individuals onsite for operation. With proper lighting design and good lighting practices, they can be made nearly invisible at night. And while solar thermal plants do require more extensive lighting, when lighting is minimized and properly shielded and good lighting practices are used, night-sky impacts can be substantially reduced. Observations at the NSO facility showed what appeared to be poorly shielded and excessive lighting, with large expanses of lit but unused areas and high levels of offsite visibility and glare, while the CM 1 and 2 facilities, with only moderate lighting mitigation in place, were difficult to see from a relatively short distance.

6.2 Visual Impact Mitigation Case Study: Silver State (North) Solar Energy Project

While the mitigation recommendations in the previous section were the result of observation of a variety of solar facilities, each of them is currently being implemented or tested at the next phase of development of the Silver State Solar Project. As noted elsewhere in this report, observations in this and a previous study (Sullivan 2012) included observations of the SSN project, currently in operation on BLM lands near Primm, Nevada. The SSN observations revealed contrast sources that offered potential mitigation opportunities. In collaboration with BLM's Chief Landscape Architect and First Solar's (the project developer's) manager for siting and permitting, mitigation measures were proposed and are currently being implemented or tested in the next phase of development, the Silver State South (SSS) project, a 250 MW expansion of the Silver State Solar Project. This case study is presented as an example of successful collaborative design of mitigation measures for a solar energy project.

6.2.1 SSN—Current Visual Mitigation

Good visual impact mitigation measures have already been implemented at SSN. Particularly successful has been the painting of all structures on the site (except for the substation, which is not under the control of the solar developer and operator) with a BLM Standard Environmental Color, Shadow Gray, a deep gray-green that blends well with the vegetation around the facility, predominantly creosote bush. Figure 6.2–1 shows how well the color treatment has blended the PCUs with the surroundings, and how the color treatment also does not contrast strongly with the panels under normal lighting conditions. For comparison, Figures 6.2–2 and 6.2–3 show the white PCUs at CM 1 and the two-toned brown and white PCUs at CM 2, respectively. The white PCUs at CM 1 and the white portions of the PCUs at CM 2 clearly increase contrast with the surroundings. The brown color of the PCUs at CM 2 is a somewhat better match to the surroundings, but the uniform Shadow Gray PCUs at SSN are a superior color match.

Figure 6.2–1. Shadow Gray PCUs at SSN Facility.

Figure 6.2–2. White PCUs at CM 1 Facility.

Figure 6.2–3. Brown/White PCUs at CM 2 Facility (foreground), White PCUs at CM 1 Facility (background).

Lighting mitigation at SSN is also better than at many facilities. A lighting plan is in place, lighting is minimal, and motion detectors are used. While lighting fixtures are not fully shielded full-cutoff luminaires, they are shielded, and according to site operators, they are very rarely on in any event.

6.2.2 SSN – Mitigation Opportunities

Multiple reflections from panel array

Previous field observations by Argonne of the operating SSN facility revealed several visual contrast sources that presented mitigation opportunities. The first and most obvious contrast source involved myriad reflections in a geometric pattern across the entire collector array. The visual effect was quite striking (see Figures 6.2–4 and 6.2–5). This effect was observed on multiple occasions at SSN at relatively short distances (less than 1 mi [1.8 km]), but may be visible at longer distances. A similar effect was observed at the Blythe Solar Project, another First Solar project using similar panels and mounts. This effect has been observed from ground level at relatively short distances (less than one mile), but may be visible at longer distances.

Figure 6.2–4. Reflections from Multiple Regularly-Spaced Components in the SSN PV Panel Array.

Figure 6.2–5. Wide-Angle View of Reflections from SSN Panel Array.

Argonne informed the BLM Chief Landscape Architect, who arranged a consultation with First Solar's manager of siting and compliance. A site visit was arranged as part of the current project, and Argonne was able to visit the site in January 2013 to further investigate the potential causes of the visual contrast. Observations made during the January 2013 visit suggest that the source of the effect is the reflection of sunlight from the metal support structures directly underneath the solar panels. These metal supports are mounted perpendicular to the two rails mounted on the tilt bracket. The panels are attached to the metal supports by clips that wrap around the edges of the panels. The supports project an inch or so beyond the top and bottom edges of the top and bottom panels in each row. The supports are made of galvanized steel.

Argonne suggested that at certain times of day, e.g., midafternoon, the sun angle is such that the sunlight falls directly onto the end of the support structure just above and below the edge of the top panel in the row and also in the small gaps between the panels. For the most part, except for the panels closest to the viewer, the gaps between panels are obstructed from view by other panels and mounting structures (e.g., posts, rails, and tilt brackets). Even though only a few square inches of metal at the end of the support structure are exposed to direct sunlight, the galvanized metal surface strongly reflects the sunlight, and at a distance, appears as a bright spot of light that is easily visible for at least 0.5 mi (0.8 km), and possibly much further. Because there is regular spacing between the panels and rows and there are typically thousands of panels in view from any given point, the reflections from the ends of the support structures appear as a vast geometric grid of closely spaced lights.

Figure 6.2–6 is a photograph taken during the January site visit that shows a more detailed view of the structures involved. This figure shows reflections from sunlight falling on the top few inches of the support structures underneath the solar panels, as well as falling on the tilt brackets through gaps between the panels,.

Figure 6.2–6. Sunlight Reflected from the Top Few Inches of the Support Structures Underneath the Solar Panels, and from the Tilt Brackets.

After consultation with project engineering staff, First Solar determined that the contrast could be mitigated by treating the PV panel mounting clips with a non-specular dull finish or using the BLM-standard environmental color Shadow Gray or Covert Green. This mitigation will be implemented for the SSS expansion if a fixed-tilt design is chosen.

East-west oriented white "stripes" visible in the collector array

Three white "stripes" (shown in Figure 6.2–7) were noted within the facility during observations conducted from Interstate 15 near the SSN facility. Under some lighting conditions, this effect increased the visual contrast of the facility substantially. The stripes were also visible from an elevated viewpoint about 5 mi (8 km) east of the facility (see Figure 6.2–8), though there was less visual contrast in this view because the white "stripes" are similar in appearance to "stripes" caused by the contrast between bare soil and the gaps between sections of the solar collector array.

Observations made during the January 2013 visits suggest that the source of the three white "stripes" is three groups of one or more rows of support structures, or tables (post, tilt bracket, panel support, rail), that lack PV panels. Figure 6.2–9 is a close-up photograph of one of the sections that is missing panels. The tables are galvanized metal, and without panels to shade them, they strongly reflect sunlight and are especially conspicuous next to the black panels in the rest of the array. Note that this photo also shows the panel support structures (discussed above), without panels but with panel clips visible. This source of contrast could be eliminated by installing panels in these rows or otherwise covering or color-treating them, but color-treating the PV panel mounting clips will mitigate this potential source of contrast for the SSS expansion.

Figure 6.2–7. East-West-Oriented White “Stripes” visible in the Collector Array as Seen from Ground-Level Viewpoint Approximately 1.5 miles from Facility.

Figure 6.2–8. East-West Oriented White “Stripes” (Indicated by Red Arrows) Visible in the Collector Array as Seen from Elevated Viewpoint Approximately 5 Miles from Facility.

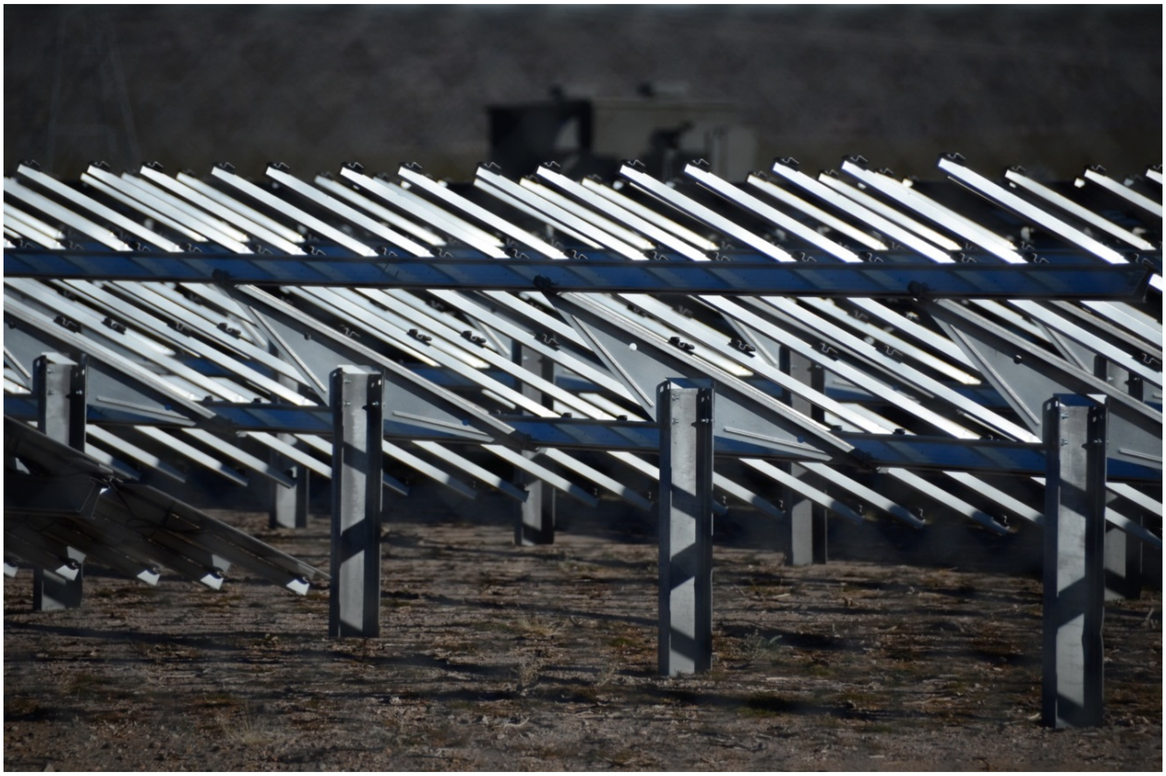

Figure 6.2–9. Table without Mounted Panels. The galvanized metal reflects sunlight strongly.

Unnecessary regular geometry in roads and array access ways

In a previous visit, the author and the BLM Chief Landscape Architect had observed the SSN facility from distances of between 10 and 22 mi (16-35 km). They noted that at these longer distances, the facility might be mistaken for a dark rock outcropping or, in some cases, a cloud shadow, except that the regular geometry of the array was apparent and looked artificial, and that straight roads and access ways through the panel array heightened the contrast between the facility and the surrounding landscape and made it more apparent that it was not a natural feature, as shown in Figure 6.2–10. These observations were discussed by BLM with First Solar and led to the following mitigation measures for SSS:

- Locating the perimeter road at a variable distance from the perimeter fence to allow for feathering of the footprint and selective vegetation removal, with the intent to result in an organic or irregular line.
- Offsetting solar field access ways at appropriate intervals to minimize the appearance of straight lines within the panel array.

Figure 6.2–10. View of SSN Facility from a Distance of 10 mi (16 km).

Contributing to the man-made appearance and overall visibility of the facility at longer distances were the strong contrast provided by the light soils in areas where vegetation was cleared adjacent to the black panels; these contrasts were due in part to a firebreak of cleared vegetation around the array. BLM suggested the possibility of using a non-toxic coloring agent to reduce the soil contrast. Argonne talked to First Solar about potentially eliminating or reducing the size of the firebreak and using a rock stain or similar coloring agent to darken the gravel soil surface of the cleared areas in order to reduce the contrast. Argonne discussed the mitigation objectives with a rock-coloring agent vendor to verify that the coloring agent would work on gravel, as opposed to larger rocks. These discussions led to the following mitigation measures for SSS:

- Portions of the SSS drainage control basins will undergo an experimental treatment with Permeon or a similar type of contrast-reducing product.
- If a firebreak is not required and topographic and vegetation conditions allow, in the perimeter and tortoise fence construction areas, vegetation will be cut to a height of 6 in prior to fence construction.

First Solar is also talking to county fire officials about the possibility of reducing the size of the firebreak.

This mitigation case study demonstrates how careful observation of existing facilities can lead to the identification of mitigation opportunities which are sometimes unique to the particular site or project. It also demonstrates the benefits of collaboration between visual and solar technical experts to design practical and effective mitigation strategies.

7 Conclusions and Recommendations

This study more fully characterized the visual characteristics and visual contrasts associated with several types of utility-scale solar facilities operating or under construction in the southwestern United States, based on field observations conducted in 2013. The field observations were also used to identify particularly effective visual impact mitigation measures for solar facilities, and to identify and collaboratively develop new mitigation strategies for use at a particular facility, but with potential application to other projects.

Results of the field observations included assessments and photographic documentation of the effects of distance, viewpoint elevation, and lighting on the visual contrasts of various types of solar facilities, including three thin-film PV facilities, two power tower facilities, a parabolic trough facility, and a CPV facility. The interaction of these visibility factors with specific visual impact mitigation measures was also observed and documented. Photo-documentation of the cumulative visual impacts of multiple solar facilities within a single viewshed was developed. A systematic assessment of the effects of distance on the visibility and visual contrasts of a utility-scale power tower (not operating) was conducted, and sources of visual contrast from the facility were documented. A baseline contrast assessment was conducted for a utility-scale CPV.

Significant findings of the field observations include the following:

- Color selection for materials surface treatment as directed by BLM resulted in better mitigation than alternative colors;
- Glare from a parabolic trough facility was observed to be a relatively common occurrence;
- Effective lighting mitigation can result in near-zero night-sky impacts for PV facilities;
- Strong glare from a single power tower heliostat was visible at distances exceeding 10 mi (16 km);
- Unlit power towers were easily visible for distances beyond 20 mi (32 km), and one was faintly visible as far as 35 mi (56 km);
- Daytime aerial hazard lighting on power towers was visible at long distances and added substantially to visual contrast in certain conditions; and
- Reflected light from a CPV facility was plainly visible at long distances (beyond 25 mi (40 km).

The study also identified and assessed contrast sources at the SSN thin-film PV facility on BLM land in Nevada. These contrast sources include reflections from metal clips used to affix the solar panels to the support structures directly below the panels; reflections from panel support structures without mounted panels; the use of regular geometric forms in panel arrays, cleared areas, and other linear features; and reflected light from light-colored gravel where vegetation has been cleared around the collector array. In collaboration with the facility siting manager and with input from BLM and a materials contractor, potential mitigation measures were identified for each of these contrast sources. At the time of this writing, BLM has directed that the proposed mitigation measures be implemented in the next currently planned phase of development at this facility.

Further research into the visual characteristics of utility-scale solar facilities is needed in order to develop accurate visual impact assessments for proposed projects. To date, only a few facilities have been examined, and a larger sample of facilities is needed to make valid assumptions about the characteristics of other projects. Of particular importance is the assessment of visual contrasts from large-scale power tower facilities. These facilities are likely to have very large visual impacts, but because facilities of this size have no precedent, little is known about how they may impact scenic resources.

Additional work needs to be done to assess the effectiveness of visual impact mitigation measures for solar facilities. Demonstrating the effectiveness of visual impact mitigation measures is critical to their being more widely applied; also important is eliminating or modifying mitigation measures that cannot be demonstrated to be effective. Also important is the collaborative design of new mitigation measures specific to solar facilities. As shown by this study, careful observation of operating facilities can lead to the identification of previously unknown or unidentified contrast sources, which can in some cases be practically and effectively mitigated through the combined efforts of visual resource and solar technology experts.

A particularly important area of future mitigation research concerns night-sky impacts, which are a significant concern to stakeholders. While this study suggests that good lighting mitigation and lighting practices can result in near-zero night-sky impacts at PV facilities, solar thermal facilities present much greater lighting mitigation challenges. Research and development to assess potential lighting mitigation opportunities at solar thermal facilities and to design mitigation that is both effective and consistent with safety and functional requirements is an important near-term need.

8 References

Barrett, S. 2013. Glare Factor: Solar Installations and Airports. *Solar Industry*, vol. 6(5). June. Available at http://solarindustrymag.com/issues/SI1306/FEAT_02_Glare_Factor.html. Accessed Dec. 7, 2013.

Basin and Range Watch. 2010. Rebuttal Brief, Basin and Range Watch. TN #: 200075. California Energy Commission Docket for Ivanpah Solar Electric Generating System. Docket No. 07-AFC-5. April. Available at http://docketpublic.energy.ca.gov/PublicDocuments/Regulatory/Non%20Active%20AFC's/07-AFC-5%20Ivanpah%20Solar%20Electric/2010/Apr/TN%2056281%2004-15-10%20Rebuttal%20Brief%20from%20Basin%20-%20Range%20Watch.pdf. Accessed Dec. 6, 2013.

Benson, J.F. 2005. "Visualization of Windfarms," in *Visualization in Landscape and Environmental Planning: Technology and Applications*. I. Bishop and E. Lange (editors). New York: Taylor & Francis.

BLM (Bureau of Land Management). 2008. Standard Environmental Color Chart CC-001. June.

BLM. 2010a. *California Desert Conservation Area Plan Amendment/Final Environmental Impact Statement for Ivanpah Solar Electric Generating System FEIS-10-31*. July. Available at http://lpo.energy.gov/wp-content/uploads/2010/10/Final-EIS-Appendix-A-Summary-of-Comments.pdf. Accessed Dec. 5, 2013.

BLM. 2010b. *Final Environmental Impact Statement for the Silver State Solar Energy Project.* DOI No. FES 10-50.September. Available at: http://www.blm.gov/pgdata/etc/medialib/blm/nv/field_offices/las_vegas_field_office/energy/nextlight_-_other/FEIS_FedReg_NOA.Par.21644.File.dat/Silver%20State%20Solar%20FEIS%20Volume%20I.pdf. Accessed Dec. 6, 2013.

BLM. 2013a. *Best Management Practices for Reducing Visual Impacts of Renewable Energy Facilities*. Cheyenne, Wyoming. 342 pp. April. Available at http://www.blm.gov/pgdata/etc/medialib/blm/wo/MINERALS__REALTY__AND_RESOURCE_PROTECTION_/energy/renewable_references.Par.1568.File.dat/RenewableEnergyVisualImpacts_BMPs.pdf. Accessed Dec. 5, 2013.

BLM. 2013b. Final Supplemental Environmental Impact Statement for the Silver State Solar South Project and Proposed Las Vegas Field Office Resource Management Plan Amendment. DOI-BLM-NV-S010-2012-0067-EIS. September. Available at http://www.blm.gov/nv/st/en/fo/lvfo/blm_programs/energy/Silver_State_Solar_South/final_seis.html. Accessed Dec. 6, 2013.

BLM and DOE (U.S. Department of Energy). 2010. *Draft Programmatic Environmental Impact Statement (PEIS) for Solar Energy Development in Six Southwestern States.* DES 10-59; DOE/EIS-0403. December. Available at http://solareis.anl.gov/documents/dpeis/index.cfm. Accessed Dec. 5, 2013.

BLM and DOE. 2012. *Final Programmatic Environmental Impact Statement (PEIS) for Solar Energy Development in Six Southwestern States.* FES 12-24 DOE/EIS-0403. July. Available at http://solareis.anl.gov/documents/fpeis/index.cfm. Accessed Dec. 5, 2013.

CEC (California Energy Commission). 2010. *Staff Assessment and Environmental Impact Statement, Genesis Solar Energy Project.* CEC-700-2010-006. Docket 09-AFC-8. March. Available at http://www.energy.ca.gov/sitingcases/genesis_solar/documents/staff_assessment/01_CEC-700-2010-006_Cover-SectB.pdf. Accessed Dec. 5, 2013.

CEC (California Energy Commission). 2013. *Palen Solar Electric Generating System Final Staff Assessment - Part B.* CEC-700-2013-003-FSA-PTB. Docket 09-AFC-07C. September. Available at http://docketpublic.energy.ca.gov/PublicDocuments/09-AFC-07C/TN200564_20130923T153458_Palen_Solar_Electric_Generating_System_Final_Staff_Assessment.pdf. Accessed Dec. 5, 2013.

Chiabrando, R., et al. 2009. The territorial and landscape impacts of photovoltaic systems: definition of impacts and assessment of the glare risk. Renewable and Sustainable Energy Reviews, vol. 13 (8), pp. 2441–2451. Available at http://www.sciencedirect.com/science/article/pii/S1364032109001026#. Accessed Dec, 5, 2013.

CIE (Commission Internationale de l´Eclairage). 2012. e-ILV Termlist. Available at http://eilv.cie.co.at/. Accessed Dec. 13, 2013.

Colorado River Indian Tribes. 2013. Colorado River Indian Tribes re the PSA for the Palen Solar. TN #: 200075. California Energy Commission Docket for Palen Solar Power Project. Docket 09-AFC-07C. November. Available at http://docketpublic.energy.ca.gov/PublicDocuments/09-AFC-07C/TN201261_20131119T144746_Exhibit_3066_NPS_comments_on_PSEGS_SDEIS.pdf. Accessed Dec. 5, 2013.

DOE (U.S. Department of Energy). 2012a. *Sunshot Vision Study*. Office of Energy Efficiency & Renewable Energy report. May.

DOE. 2012b*. Final Environmental Impact Statement for the Quartzsite Solar Energy Project and Proposed Yuma Field Office Resource Management Plan Amendment.* DOE/EIS-0440. December. Available at http://ww2.wapa.gov/sites/western/transmission/interconn/Documents/quartzsite/FinalQSEIS.pdf. Accessed Dec. 7, 2013.

Ho, C.K. 2011. Observations and Assessments of Glare from Heliostats and Trough Collectors: Helicopter Flyover and Drive-By Sightings. In Proceedings of SolarPACES 2011, Granada, Spain, Sept. 20–23. Available at https://share.sandia.gov/phlux/static/references/glint-glare/Glare_SolarPACES2011_ID23538_Ho_header.pdf. Accessed Dec. 7, 2013.

Ho, C.K. 2012. Glare Impacts from Solar Power Plants near Airports. In Proceedings of ACC/AAAE Airport Planning, Design and Construction Symposium, Denver, CO, Feb. 29–Mar. 2.

Ho, C.K. 2013. Relieving a Glaring Problem. *Solar Today*, April. Available at https://share.sandia.gov/phlux/static/references/glint-glare/Ho-SolarToday-April13_v2.pdf. Accessed Dec. 7, 2013.

Ho, C.K., et al. 2009. Hazard Analyses of Glint and Glare from Concentrating Solar Power Plants. SAND2009-4131C. In Proceedings of SolarPACES 2009, Berlin, Germany, Sept. 15–18. Available at https://share.sandia.gov/phlux/static/references/glint-glare/Glint_Glare_SolarPACES2009.pdf. Accessed Dec. 7, 2013.

Ho, C.K., and S.S. Khalsa. 2010. Hazard Analysis and Web-Based Tool for Evaluating Glint and Glare from Solar Collector Systems. In Proceedings of SolarPACES 2010, Perpignan, France, Sept. 21–24. Available at: https://share.sandia.gov/phlux/static/references/glint-glare/Glint_Webtool_SolarPACES2010_paper_v5_header.pdf. Accessed Dec. 7, 2013.

Ho, C.K., and C.A. Sims. 2013. *Solar Glare Hazard Analysis Tool (SGHAT) User's Manual v. 2.0.* SAND2013-7063P. Sandia National Laboratories, Albuquerque, NM. Available at https://share.sandia.gov/phlux/static/references/glint-glare/SGHAT_Users_Manual_v2-0_final.pdf. Accessed Dec. 7, 2013.

Ho, C. K., et al. 2011. Methodology to Assess Potential Glint and Glare Hazards from Concentrating Solar Power Plants: Analytical Models and Experimental Validation. ASME J. Sol. Energy Eng., 133. Available at. Accessed Dec. 7, 2013.

Kessler, B. 2013. Inyo Supervisors lodge critical comments on DWP solar project. *Sierra Wave Media*. October 16. Available at http://www.sierrawave.net/26916/inyo-supervisors-lodge/. Accessed Dec. 5, 2013.

NPCA (National Parks Conservation Association). 2012. *Solar Energy, National Parks, and Landscape Protection in the Desert Southwest*. Center for Park Research report. May. Available at http://www.npca.org/about-us/center-for-park-research/solar/solar-energy-and-desert-southwest_final-technical-report_050712_reformat.pdf. Accessed Dec. 7, 2013.

NPS (National Park Service). 2013. Exhibit 3066. NPS comments on PSEGS SDEIS. California Energy Commission Docket for Palen Solar Power Project. Docket 09-AFC-07C. November. Available at http://docketpublic.energy.ca.gov/PublicDocuments/09-AFC-07C/TN201261_20131119T144746_Exhibit_3066_NPS_comments_on_PSEGS_SDEIS.pdf. Accessed Dec. 5, 2013.

NRC (U.S. Nuclear Regulatory Commission). 1996. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Volume 1*. NUREG-1437 Vol. 1. Available at http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1437/v1/. Accessed Dec. 5, 2013.

Riley, E., and S. Olson. 2011. A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems. *ISRN Renewable Energy*, vol. 2011, Article ID 651857. Available at http://www.hindawi.com/isrn/renewable.energy/2011/651857/ref/. Accessed Dec. 9, 2013.

San Bernardino County Sentinel. 2013. County Revamps Commercial Solar Power Project Development Code. December 6. Available at: http://sbsentinel.com/2013/12/county-revamps-commercial-solar-power-project-development-code/. Accessed Dec. 9, 2013.

Sonoma County. 2013. Sonoma County Municipal Code Sec.26-88-206. Solar Energy Facilities—Special Use Standards. Available at: http://library.municode.com/index.aspx?clientId=16331. Accessed Dec. 9, 2013

Sullivan, R. 2011. Visual Impacts of Concentrating Solar Power Facilities on Desert Landscapes of the American Southwest. In Proceedings of SolarPaces 2011, Granada, Spain, Sept. 20–23, 2011.

Sullivan, R., et al. 2012a. Visual Impacts of Utility-scale Solar Energy Facilities on Southwestern Desert Landscapes. In Proceedings of the National Association of Environmental Professionals 37th Annual Conference, Portland, OR, May 21–24, 2012. Available at http://visualimpact.anl.gov/solarvis/docs/Solar_Visual_Impacts.pdf. Accessed Dec. 5, 2013.

Sullivan, R., et al. 2012b. Wind Turbine Visibility and Visual Impact Threshold Distances in Western Landscapes. In Proceedings of the National Association of Environmental Professionals 37th Annual Conference, Portland, OR, May 21–24, 2012. Available at http://visualimpact.anl.gov/windvitd/docs/WindVITD.pdf. Accessed Dec. 5, 2013.

Torres-Sibille, A.C., et al. 2009. Aesthetic Impact Assessment of Solar Power Plants: An Objective and a Subjective Approach. *Renewable and Sustainable Energy Reviews,* vol. 13(5), pp. 986–999.

Tsoutsos, T., et al. 2005. Environmental Impacts from the Solar Energy Technologies. *Energy Policy*, vol. 33, pp. 289–296. Available at http://www.circleofblue.org/waternews/wp-content/uploads/2010/08/Tsoutsos_Frantzeskaki_2006_EIA_ST.pdf. Accessed Dec. 5, 2013.

Turney, D., and V. Fthenakis. 2011. Environmental impacts from the installation and operation of large-scale solar power plants. *Renewable and Sustainable Energy Reviews,* vol. 15, pp. 3261–3270. Available at http://www.firstsolar.com/Innovation/~/media/Files/Sustainability%20-%20Sustainability%20Documentation/CdTe%20Docs/Environmental_Impacts_from_installation_operation_large-scale_solar_power_plants.ashx. Accessed Dec. 5, 2013.

Appendix A: Solar Facility Visual Characteristic Study: Site Description Form

Solar Facility Visual Characteristics Study: Data Collection Form

SITE DESCRIPTION

Observation#:	Observers:	Date:	Time:
Facility:	Secondary Facility:		
Location:			
Weather: Clear Mostly Clear Partly Clear Partly Cloudy Mostly Cloudy Cloudy Cirrus Rain Fog Snow			
Visibility: Good Fair Poor			
GPS Coordinates:	Bearing:		
VAV Descriptor: Superior Normal Inferior			
General Description of Viewed Facility:			
Facility Backdrop: Sky Sky/Ground Ground			
Facility Backdrop Lightness: Dark Medium Light			
Facility Backdrop Contrast: High Medium Low			
Facility Backdrop Color:			
Lighting Quality Even Sun Part Sun/Part Shade Even Shade			
Solar Azimuth:	Elevation:		
Lighting Angle: Frontlit Sidelit Left Sidelit Right Backlit Shade Not Apparent			
Collector Field Orientation: Forward Forward Oblique Side Rear Oblique Rear			
Collector Array Color(s):			
Glare Visible? Yes No			
Light Patterns Visible? Yes No	Plumes Visible? Yes No		
Other Transitory Effects? Yes No			
Other Infrastructure Prominent? Yes No			
Other Observations:			

PHOTOGRAPHS

Photographer	
Camera	
Lens	

Photo Number	**FL**	**Bearing**	**Subject**

Appendix B: Visual Contrast Threshold Distance Methodology

Visibility assessments for the Crescent Dunes Solar Energy Project used a methodology developed for the Visual Impact Threshold Distance Study, a U.S. Department of the Interior, Bureau of Land Management study to assess the effects of distance and atmospheric variables on the visibility and visual contrast levels of wind facilities (Sullivan et al. 2012). The visibility assessments consist of numeric ratings on a scale of 1 to 6, scored on the visibility of a facility within its landscape setting and for the weather and lighting conditions at the time of the observation. The visibility rating is a judgment of the observer made by comparing the facility in view with language described on a Visibility Rating Form that accounts for the visual characteristics of the facility appropriate to each rating level. Photographs were not used for visibility ratings; the ratings were conducted through naked-eye observations of the facilities in the field.

The rating scale is based on the Bureau of Land Management's Visual Resource Management system (Bureau of Land Management, 1984), specifically, the Visual Contrast Rating (Bureau of Land Management, 1986), which is used to predict the visual contrast of a proposed project with the surrounding natural landscape. The Visibility Rating Form was customized for use with existing rather than proposed facilities. The form also included several open-ended questions soliciting information from the observer to justify, explain, and/or expand upon the numeric visibility rating. The visibility ratings and instructions used by the observers to rate visibility are reproduced in Table 1.

Visibility ratings of "1" or "2" would generally correspond to low levels of visual contrast in the framework of the Visual Contrast Rating; ratings of "3" or "4" would correspond to moderate levels of visual contrast; and ratings of "5" or "6" would correspond to high levels of visual contrast.

Each observer completed a separate Visibility Rating Form for each observation, rating the visibility and answering the questions for each form independently without consulting the other observers. Observers could discuss their ratings after each observation, but they were not allowed to change the ratings once the form was completed.

REFERENCES

BLM (Bureau of Land Management). 1984. *Visual Resource Management*. BLM Manual Handbook 8400, Release 8-24, U.S. Department of the Interior, Washington, D.C.

BLM (Bureau of Land Management). 1986. *Visual Resource Contrast Rating.* BLM Manual Handbook 8431-1, Release 8-30, U.S. Department of the Interior, Washington, D.C.

Sullivan, R., et al. 2012. "Wind Turbine Visibility and Visual Impact Threshold Distances in Western Landscapes." In *Proceedings, National Association of Environmental Professionals, 37th Annual Conference*, May 21–24, 2012, Portland, Ore. Available at http://visualimpact.anl.gov/windvitd/docs/WindVITD.pdf. Accessed Dec. 5, 2013.

Table 1. Visibility rating form instructions used by observers to rate visibility of wind facilities.

VISIBILITY RATING FORM INSTRUCTIONS	
Visibility Rating	**Description**
VISIBILITY LEVEL 1: *Visible only after extended, close viewing; otherwise invisible.*	An object/phenomenon that is near the extreme limit of visibility. It could not be seen by a person who was unaware of it in advance, and looking for it. Even under those circumstances, the object can only be seen after looking at it closely for an extended period of time.
VISIBILITY LEVEL 2: *Visible when scanning in general direction of study subject; otherwise likely to be missed by casual observer.*	An object/phenomenon that is very small and/or faint, but when the observer is scanning the horizon or looking more closely at an area, can be detected without extended viewing. It could sometimes be noticed by a casual observer; however, most people would not notice it without some active looking.
VISIBILITY LEVEL 3: *Visible after brief glance in general direction of study subject and unlikely to be missed by casual observer.*	An object/phenomenon that can be easily detected after a brief look and would be visible to most casual observers, but without sufficient size or contrast to compete with major landscape/seascape elements.
VISIBILITY LEVEL 4: *Plainly visible, could not be missed by casual observer, but does not strongly attract visual attention, or dominate view because of apparent size, for views in general direction of study subject.*	An object/phenomenon that is obvious and with sufficient size or contrast to compete with other landscape elements, but with insufficient visual contrast to strongly attract visual attention and insufficient size to occupy most of the observer's visual field.
VISIBILITY LEVEL 5: *Strongly attracts visual attention of views in general direction of study subject. Attention may be drawn by strong contrast in form, line, color, texture, luminance, or motion.*	An object/phenomenon that is not of large size, but that contrasts with the surrounding landscape elements so strongly that it is a major focus of visual attention, drawing viewer attention immediately, and tending to hold viewer attention. In addition to strong contrasts in form, line, color, and texture, bright light sources (such as lighting and reflections) and moving objects associated with the study subject may contribute substantially to drawing viewer attention. The visual prominence of the study subject interferes noticeably with views of nearby landscape/seascape elements.
VISIBILITY LEVEL 6: *Dominates view because study subject fills most of visual field for views in its general direction. Strong contrasts in form, line, color, texture, luminance, or motion may contribute to view dominance.*	An object/phenomenon with strong visual contrasts that is of such large size that it occupies most of the visual field, and views of it cannot be avoided except by turning the head more than 45 degrees from a direct view of the object. The object/phenomenon is the major focus of visual attention, and its large apparent size is a major factor in its view dominance. In addition to size, contrasts in form, line, color, and texture, bright light sources and moving objects associated with the study subject may contribute substantially to drawing viewer attention. The visual prominence of the study subject detracts noticeably from views of other landscape/seascape elements.

Appendix C: Solar Facility Visibility Rating Form

SOLAR FACILITY VISIBILITY STUDY: VISIBILITY RATING FORM

Observation #:	Date:	Time:
Facility:	Location:	
Rater:	Other observers:	

VISIBILITY RATING

VISIBILITY RATING	NOTES

QUESTIONS

Would the facility be likely to attract the attention of a casual viewer? Yes   No
Is the facility a major focus of visual attention? Yes   No   Explain.
Which facility elements contribute most to visibility? Facility Size   Component Size   Geometry   Color   Glare/Glinting   Other Explain.
Does the facility repeat basic elements of form/line/color/texture found in predominant natural features?
Does the facility repeat basic elements of form/line/color/texture found in predominant man-made features?
Notes

“View in general direction of study subject” defined as field of view visible when observer is looking toward study subject without turning head more than 45 degrees in either direction.
VISIBILITY LEVEL 1: Visible only after extended, close viewing; otherwise invisible.

An object/phenomenon that is near the extreme limit of visibility. It could not be seen by a person who was unaware of it in advance, and looking for it. Even under those circumstances, the object can only be seen after looking at it closely for an extended period of time.

VISIBILITY LEVEL 2: Visible when scanning in general direction of study subject; otherwise likely to be missed by casual observer.

An object/phenomenon that is very small and/or faint, but when the observer is scanning the horizon or looking more closely at an area, can be detected without extended viewing. It could sometimes be noticed by a casual observer; however, most people would not notice it without some active looking.

VISIBILITY LEVEL 3: Visible after brief glance in general direction of study subject and unlikely to be missed by casual observer.

An object/phenomenon that can be easily detected after a brief look and would be visible to most casual observers, but without sufficient size or contrast to compete with major landscape elements.

VISIBILITY LEVEL 4: Plainly visible, could not be missed by casual observer, but does not strongly attract visual attention, or dominate view because of apparent size, for views in general direction of study subject.

An object/phenomenon that is obvious and with sufficient size or contrast to compete with other landscape elements, but with insufficient visual contrast to strongly attract visual attention and insufficient size to occupy most of the observer’s visual field.

VISIBILITY LEVEL 5: Strongly attracts visual attention of views in general direction of study subject. Attention may be drawn by strong contrast in form, line, color, or texture, luminance, or motion.

An object/phenomenon that is not of large size, but that contrasts with the surrounding landscape elements so strongly that it is a major focus of visual attention, drawing viewer attention immediately, and tending to hold viewer attention. In addition to strong contrasts in form, line, color, and texture, bright light sources (such as lighting and reflections) and moving objects associated with the study subject may contribute substantially to drawing viewer attention. The visual prominence of the study subject interferes noticeably with views of nearby landscape elements.

VISIBILITY LEVEL 6: Dominates view because study subject fills most of visual field for views in its general direction. Strong contrasts in form, line, color, texture, luminance, or motion may contribute to view dominance.

An object/phenomenon with strong visual contrasts that is of such large size that it occupies most of the visual field, and views of it cannot be avoided except by turning the head more than 45 degrees from a direct view of the object. The object/phenomenon is the major focus of visual attention, and its large apparent size is a major factor in its view dominance. In addition to size, contrasts in form, line, color, and texture, bright light sources and moving objects associated with the study subject may contribute substantially to drawing viewer attention. The visual prominence of the study subject detracts noticeably from views of other landscape elements.