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BNSF Proposed Scope of Work for Calico Solar Project Glare/Glint Study

The purpose of this study is to prevent adverse impacts, including health impacts, from glint and glare on rail employees, agents or contractors ("Employees") and operations, including a train crews' ability to accurately see and respond to signals, and other modes of transportation ("Adverse Impacts"). This study is divided into two sections. Section One concerns the performance of a site specific study and a Pilot Field Study to analyze the impact of glare and glint from the selected solar technology, including both the specific solar technology selected by Calico and the SunCatchers ("Solar Technology") and the corresponding Adverse Impacts on rail Employees and operations, including a train crews' ability to see and respond to signals, and the identification and implementation of mitigation measures within the boundaries of the Calico Project ("Mitigation Measures"). The scope of work for Section Two will include development of a protocol to address any incidents, which occur related to glare or glint arising from the solar technology. Staff members will visit the site to document the conditions at the time of the incident, to review any relevant data, and to apply the model to understand how the solar technology might have contributed to the incident. As a result of this analysis, mitigation measures will be suggested.

This Glare/Glint Study shall be coordinated with the performance of all studies, reports and plans required under the Soil & Water Conditions of Certification and Civil-1. The potential appropriate locations for solar module grids and corresponding Solar Technology, as identified by the studies, reports and proposed plans of the Soil & Water Conditions, shall be provided to the Glare/Glint experts prior to the commencement of Phase 2 of the Glare/Glint study, and the appropriate locations of the solar module grids and corresponding Solar Technology, as finally determined by Phases 2 and 3 of the Glare/Glint Study, shall be incorporated into the final studies, reports and plans required under the Soil & Water Conditions.

Section 1

The tasks below constitute the steps required to build an accurate 3D model of the site, which will convey scientifically reliable conclusions.

The goals of the model are to evaluate the following:

1. Changes in the train crews' vantage points with respect to the solar collectors as the train travels along the ROW;

2. The effect(s) of the geometry of the track, the changes in elevation, and the direction of travel on the magnitude and pattern of glare;
3. The effect(s) of the time of day on the magnitude and pattern of glare;
4. The effect(s) of the time of year on the magnitude and pattern of glare;
5. The extent to which a level of glare exists that train crews may experience as a result of the solar collectors, which does not rise to a level that would induce temporary flash blindness, but nonetheless causes discomfort or distraction that makes it difficult to attend in the direction of the solar collectors;
6. The effect(s) of perceived glint (high-contrast flicker) in the train crews' peripheral visual field, which may prompt individuals to orient their eyes and attention away from where they should be attending;
7. Visual obstructions, independent of glare, resulting from the size of the solar collectors (up to 40 feet tall), which may prevent train crews from perceiving all job-critical information;
8. Light reflecting off the solar collectors, which may result in a phenomenon known as a "phantom signal" whereby signals, which are not actually illuminated, appear to be because of intense light striking them at low angles;
9. Since the trains are moving through the ROW, the distance traveled during expected look-away times as a result of distraction from the solar collectors' presence should be calculated and the consequences of such travel should be assessed;
10. The effects of viewing multiple solar collectors simultaneously, rather than just one, which must be analyzed to understand any cumulative glare effects that may arise;
11. The effects of viewing multiple solar collectors simultaneously, for the entire period of time that the train crew is passing through the ROW, which must be analyzed to understand any cumulative glare effects that may arise over time;
12. Identification of appropriate location and orientation of Solar Technology grids;
13. Identification of safe orientation for non-operational solar collectors, including their stowage;
14. Identification of any further Adverse Impacts to BNSF Employees or motorists, including retinal burn, flash blindness, veiling reflections, and distracting glare, which could interfere with the train crews' and motorists' ability to safely operate trains and vehicles, respectively;
15. The presence of the issues in 1-14, above, for all solar technologies that may be deployed at the Calico site.

Tasks

Phase 1

Task 1: Initial staff meeting

This task will involve discussions between staff members so that all of the consultants working on the project have a thorough understanding of the overall project and their respective parts of the project. The meeting will serve to institute the outlining and scheduling for tasks and regular meetings as well as introductory phone calls with Dr. Ho of Sandia Laboratories regarding modeling of SunCatchers.

Task 2: Scene surveys

In order to complete this task, staff members will travel to the Calico site as well as the already-established Maricopa site and a pre-agreed-upon representative PV site. They will photograph, measure, and otherwise document the relevant features and equipment at the two sites. This task will provide necessary input to later build a realistic computer model of the site at completion.

Task 3: Inspect exemplar train

In order to understand any potential effects of the solar collectors on a train operator, it is necessary to understand the placement of the eyes for members of the train crew, relative to the solar collectors, as well as the interaction of the engineers with the physical train layout (e.g., sight lines). For this task staff members will photograph, measure, and otherwise document the relevant features of an exemplar train. This will enable the computer model to accurately portray the vantage point of the train crew members.

Task 4: Literature search/review

This task will involve locating publications that are relevant. Specifically, the search will include materials related to understanding and modeling sun reflections of different types and from different surfaces, and understanding how humans might be adversely affected by any light that may be reflected from the Solar Technology. The search will involve locating and acquiring any relevant scientific articles or books. The data from this task will be used to help build the computer model, and to draw conclusions from the results of the model. All collected materials will be made available, via an FTP site, to CEC Staff, Calico, BNSF and other interested parties.

Task 5: Review case materials

Staff members will review any new and relevant case documentation that has been and will continue to be provided as the project progresses. The materials will be evaluated as they are provided. Staff will review material and incorporate any relevant findings, plan changes or technical details into the 3D model in order to ensure its accuracy.

Task 6: Communications with CEC, Calico, BNSF and other interested parties

This task includes regular in-person meetings and teleconferences throughout the course of the project. It also includes verbal progress reports of the staff’s findings as well reports of the anticipated next steps, including model development, implementation and interpretation. This task will be continuous throughout the subsequent phases of the project as well.

Task 7: Model of Solar Technology

This task will start with any available existing data that can be provided with respect to modeling the optical properties of the Solar Technology that is to be employed. To the extent that no data are available, a study of the specific design will be conducted to assess the relevant geometric and reflective properties of the Solar Technology. Based on this information a computer model of the Solar Technology will be built, which can be subsequently incorporated into a 3D model of the site. This model will enough realism to capture the primary reflective properties of the Solar Technology. All equations, assumptions and inputs to the model will be provided in the final written report.

Task 8: 3D model creation – Phase 1

The modeling will occur in two phases—one prior to receiving the initial proposal for the placement of the Solar Technology grid layout, and the second phase will incorporate the information contained in the final grid layout, once that is received.

The creation of the 3D model is dependent upon the integration of the site survey and topographical data, train and right-of-way (ROW) geometry, the initial proposal for placement of the Solar Technology and the individual quantitative model of the Solar Technology. The final model will enable an analysis of the effects of multiple solar collectors, at different attitudes and sun positions, on a train operator.

Phase 1 of the 3D model will provide a scale model of the Calico site. (This will subsequently be integrated with an operational model of the solar collectors in Phase 2 of the 3D model.) In order to complete this task, staff members will utilize the data gathered in Tasks 2 and 3. In order to commence work on this step, it is expected that BNSF and/or Calico will provide detailed topographical maps of the project area. This data should take the form of a Digital Elevation Map (DEM) or other raster format, and represent the ground height at project completion. The visibility of the train crew members and motorists will be accurately represented in the model as the appropriate eye heights and positions will be thoroughly documented in earlier tasks.

This task can begin upon receipt of the DEM or similar information that will serve to create the 3D layout of the project site. This work can commence prior to the final resolution of the layout of all of the Solar Technology, which may be altered due to other factors such as the ongoing hydrological assessment.

Phase 2

Task 9: 3D model creation and implementation – Phase 2

Initiation of Phase 2 will be contingent upon receiving the following information:

1. Detailed design specifications, physical plans, and engineering diagrams for the Solar Technology and stormwater control measures;

2. Detailed tracking operation information for the Solar Technology, including tracking direction, speed, and algorithms; repositioning procedures; and a set of sample tracking data;

3. Stowage procedures for the solar collectors (if applicable), including position, speed, and time course for stowage;

4. Comprehensive sample data sets reflecting one year of actual field operations of a representative existing solar grid, e.g., the Maricopa solar facility for SunCatchers and an agreed-upon representative PV site;

5. Descriptions, algorithms, and operation procedures describing Solar Technology behavior in the event of a failure.

- **3D model implementation and output**

The model is dynamic. That is, it will examine the effects of glare across the entire area of the Calico site as well as across the entire time that a train or motorist is present within the affected area.

Solar Technology tracking operation will be modeled using tracking data from an existing solar grid (e.g., Maricopa solar facility and agreed-upon representative PV site), as well as algorithms provided by Calico, which will detail the tracking direction, speed, and repositioning procedures of the Solar Technology at the Calico site. In addition to modeling normal activity of the solar grid, it will be necessary to model the stowage procedures for the Solar Technology, including position, speed, and time course for stowage. To provide a thorough evaluation of this solar grid's potential impact on visibility, descriptions, algorithms, and operation procedures describing Solar Technology behavior in the event of a failure will also be implemented into the model.

Once the model is operational it will be used to guide sampling times (both time of day and day of year) and locations to understand where it might be possible for Adverse Impacts may occur. As there are complex interactions between the train or motorist location, the collector orientation, and the movement of the sun by hour and by day, it will be necessary to systematically derive a method by which days and times are sampled, such that meaningful conclusions can be reached. A statistical analysis will be conducted to determine whether a subset of model runs can conclusively determine whether Adverse Impacts can occur at any times or locations along the affected ROW.

Once potential times and locations of interest are identified, animations will be generated that represent that view. Each animation will be analyzed in order to determine if there are any glare or glint issues. These results may be used to select additional points of interest for testing.

The final output will take two forms: first, the animations will be provided to show the particular views that were tested. Second, the data will be provided in a tabular form, indicating the time, location, view and whether there are any potential issues for that selection.

Task 10: Probability analysis

Data relating different (brightness/duration) metrics pertaining to photo-intensity will be obtained from peer-reviewed studies published in relevant scientific/safety journals, as identified in Task 4. These data will be combined, where justified, using appropriate statistical methods, and the combined data will be used to characterize exposure-response probabilistically. This characterization will enable and facilitate a corresponding probabilistic characterization of the risk of serious visual incapacitation by train crews or motorists under expected, and reasonable worst-case exposure scenarios involving sunlight glare reflected from planned Solar Technology. The analysis will be summarized, in the final report (Task 11), together with a description of quantitative methods used, results obtained, and listing of references cited.

Task 11: Report

Upon completion of the above-mentioned studies, a report will comprehensively summarize the findings. The report will provide detailed descriptions of the methods used to perform the analysis as well as any conclusions drawn from the work.

Phase 3 – Pilot field study

Task 12: Follow-up Site Visit

This task will involve returning to the site, after the initial phase of solar-collector installation, and taking photographs and other measurements in order to verify the model that has been created. The output of the model will be compared to actual locations around the site.

Task 13: Modeling

If necessary, the model will be updated to match the actual "as built" site. This task will involve reviewing the results from the prior task and attempting to minimize any discrepancies that are found.

Task 14: Supplemental report

If any changes are made to the model, then this task will involve writing a supplemental report to describe those changes. This report will also document the final condition of the model, and the actual match between the model and the "as built" site.

Task 15: Communications with CEC, Calico, BNSF and other interested parties

This task includes regular in-person meetings and teleconferences throughout the course of the project. It also includes verbal progress reports of the staff's findings as well reports of the anticipated next steps, including model development, implementation and interpretation. This task will be continuous throughout the subsequent phases of the project as well.

Section 2

Incident reports

The scope of work will include development of a protocol to address any incidents, which occur related to glare or glint arising from the Solar Technology. Staff members will visit the site to document the conditions at the time of the incident, to review any relevant data, and to apply the model to understand how the solar technology might have contributed to the incident. As a result of this analysis, mitigation measures will be suggested.

As always, feel free to contact me with additional questions or comments.

Sincerely,

David Krauss, Ph.D.
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Exponent, Inc.