LAHMEYER INTERNATIONAL

Master's Thesis

An Analysis of Key Environmental and Social Risks in the Development of Concentrated Solar Power Projects

Student: George Aluru Otieno

Institute of Physics, Postgraduate Programme Renewable Energy

Carl von Ossietzky Universität Oldenburg

Industry Supervisor: MSc. Alexander Loosen

1st examiner: Prof. Dr. Jürgen Parisi

2nd examiner: MSc. Hans-Gerhard Holtorf

Bad Vilbel, 4th March, 2015

Carl von Ossietzky Universität Oldenburg

- The photo on the title page shows a collage composed of photos showing a Peregrine Falcon (mendobrew.com), the Ivanpah power plant [1], monarch butterflies[2], the Shams I power plant (gizmag.com), a dry land river (landscapehdwalls.com) and night dry land scenery.

Abstract

The implementation of large scale projects changes the surrounding natural environment and social conditions. The development of concentrated solar power projects has also raised environmental and social concerns of the traditional nature; such as displacement of economic activities and habitats, and of a new nature; such as concerns over the effects of glint and glare and effects of thermal oil leaks. Such risks are normally governed by regulations, procedures and guidelines developed by financial institutions and governments that attempt to reduce their impacts.

In this work seventeen environmental and social risks posed by concentrated solar power projects are identified after a review of literature from projects. The proposed mitigation measures are also highlighted. Independent engineers are then surveyed to rank the risks from low to high in a 5-tier system; low, low-moderate, moderate, moderate-high and high, for five factors; occurrence, ignorance, unmitigated impact, mitigation ineffectiveness and mitigation cost. The respective rankings are then averaged and used to develop an inter-risk ranking for pre- and post-mitigation.

The risk adjudged to have the highest score was the risk to local water resources, ranked at moderate-high before mitigation and moderate after mitigation. Surveyed experts indicated a high potential impact where mitigation is not done and a moderate-high chance of occurrence and cost of mitigation. This could be due to the sensitivity of water as a resource and the unpredictable nature of weather and possibility of climate change and the effects climate change may have on water availability.

The risks to avian species, worker health and safety, due to noise, to visual resources and due to production of hazardous materials and waste, complete the top six risks.

The environmental and social risks in the development of CSP projects were found to be generally low-moderate with twelve of the seventeen reviewed risks ranked as low-moderate before mitigation and fourteen given the same rank after mitigation. Despite the low-moderate ranking of the risks, it is important to note that issues such as avian fatality and water resource risks need to be better understood and more efforts towards their avoidance or mitigation undertaken.

Barring development of any unforeseen risks, the risk level of CSP development is expected to move closer to a score of low. This is predicated on increased knowledge in, and experience with the technologies and the risks.

Dedication

This thesis is dedicated to the cause of provision of clean and sustainable energy through the use of solar technologies. It is my hope that the findings highlighted in this thesis will be used to better respond to the challenges facing successful implementation of solar power projects.

G.A.O

Acknowledgement

I would like to thank the Deutsche Akademischer AustauschDienst (DAAD) for their financial support that enabled me to undertake this master's programme. My appreciation also goes to Ms. Julia Hillmann and staffs of the section for Development-Related Postgraduate Courses / 431 for the continued guidance during the course of my scholarship.

I also owe my deepest gratitude to the staffs of Lahmeyer International GmbH's Renewable Energy Department for the supportive atmosphere and insight accorded to me. In particular, I would like to thank my industry supervisor Mr. Alexander Loosen for his tireless efforts and guidance at all stages of preparation of this work. I would also like to mention Mr. Javier Herrera, Mr. Thomas Klinge and Mr. Alex Stryk for their valued inputs to this thesis.

My appreciation also goes to the staff and my fellow students in the Postgraduate Program Renewable Energy of the University of Oldenburg, from whom I have gained much knowledge, and shared many memorable experiences. I particularly appreciate the much necessary guidance and support provided to me by my university supervisor Mr. Hans-Gerhard Holtorf in ensuring the successful undertaking of this thesis.

I acknowledge the efforts of the California Energy Commission especially, the availing of project related data for CSP plants in their jurisdiction. The open access to official project fillings enabled me to acquire much necessary information for the successful drafting of this thesis.

Last but not least, I would like to acknowledge the love and efforts of my parents, Alfred and Ruth Otieno who have sacrificed to educate and provide for my needs and have been a great source of support during the preparation of this thesis. May God continually enrich and bless you.

LAHMEYER INTERNATIONAL

Declaration

I state and declare that this thesis was prepared by me and that no means or sources have been used, except those, which I cited and listed in the references section. The thesis is in compliance with the rules of good practice in scientific research of Carl von Ossietzky Universität Oldenburg.

Bad Vilbel, 4th March, 2015 ________________________________

An Analysis of Key Environmental and Social Risks in the Development of Concentrated Solar Power Projects

Student: George Aluru Otieno

Institute of Physics, Postgraduate Programme Renewable Energy

Carl von Ossietzky Universität Oldenburg

Prepared for:

Lahmeyer International GmbH, Friedberger Straße 173, 61118 Bad Vilbel &

Carl von Ossietzky Universität, Ammerländer Heerstraße 114-118, 26129 Oldenburg

Prepared by

George Aluru Otieno

george.aluru@uni-oldenburg.de

+49 177 517 6554 / +254 720 541 975

Table of Contents

List of Figures

List of Tables

List of Annexes

List of Abbreviations

EJ	Exajoules
Mtoe	Million tonnes of oil equivalent
CSP	Concentrated Solar Power
kWh	Kilo Watt Hour
m^2	Square meters
DNI	Direct Normal Irradiation
USA	United States of America
E&S	Environmental and Social
CO_2 eq.	Carbon dioxide equivalent
IFC	International Finance Corporation
GHG	Green House Gases
DRECP	Desert Renewable Energy Conservation Plan
WCC	Water Cooled Condenser
MW / MWH	Megawatt / Megawatt Hour
CEC	California Energy Commission
HTF	Heat Transfer Fluid
dBA	A-Weighted Decibels
OSHA	Occupational Safety and Health Act
SOx & NOx	Oxides of sulphur and oxides of nitrogen
ppmv	Parts per million by volume
sdcf	Grains per standard cubic feet
RE	Renewable Energy
NOAEL	No observable adverse effect level

1 Introduction

1.1 Background

The primary energy demand of the world is currently approximately 500 EJ[1] of which approximately 200 EJ provides the final required service as illustrated in Figure 1-1.

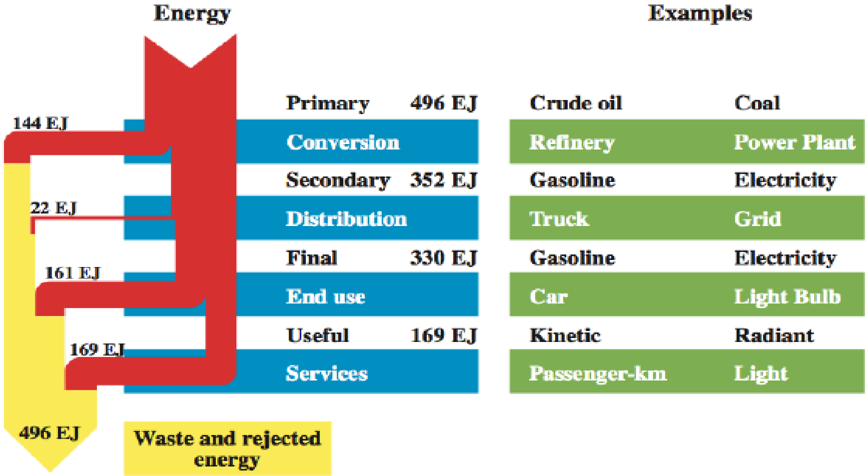


Figure 1-1: Energy flow diagram of current global energy use in Joules with examples of the various stages of energy conversion. The total primary energy demand is approx. 500EJ of which approx. 200EJ performs the actual service required by the consumer (Source: [3]).

The source of this energy as illustrated in Figure 1-2 is predominantly conventional (coal, oil and natural gas). These technologies contribute significantly to the increase of CO_2 in the atmosphere and thus global warming and further climate change.

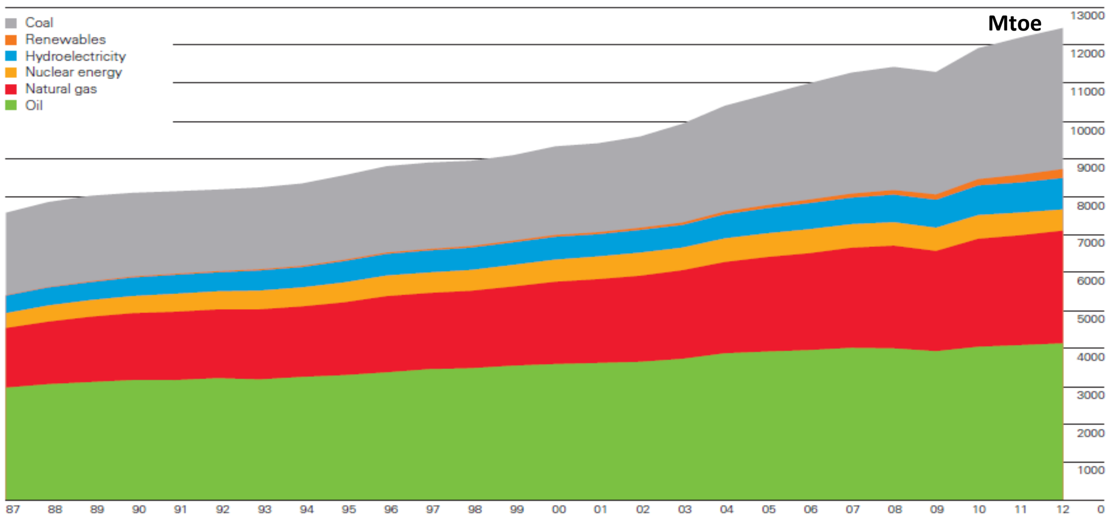


Figure 1-2: World annual primary energy consumption from 1987 to 2012 in million tonnes of oil equivalent, Mtoe (1Mtoe = 0.041863 EJ). In 2012 oil's total share reduced to 33.1% while Hydropower and renewables increased in total share to 8.6% (Source: [4]).

[1] Exajoules – Unit of measuring energy equal to 1 x 10^{18} Joules

Renewable energies are currently being developed as an alternative to conventional energies. Renewables have the advantage of significantly reduced pollution and are also seeing rapid reduction in prices as the technologies mature. Currently wind energy, hydroelectric energy, solar energy and ocean energy amongst others are under development. Solar energy is of interest in this study.

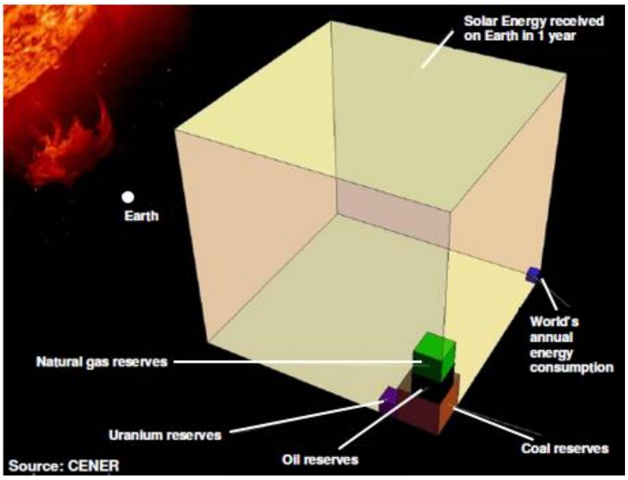


Figure 1-3: Comparison of the world annual energy consumption and conventional energy reserves versus the solar energy received on the Earth in one year (Source: [5])

The potentially useable annual solar energy received on the Earth's surface is 3.618 X 10^6 EJ. This corresponds to about 7,000 times the current annual global consumed energy as illustrated in Figure 1-3 [5].

This solar energy potential is harnessed via various technologies and biological processes including photosynthesis, photovoltaic technologies, solar heaters and cookers and concentrated solar power (CSP) technologies. CSP is of interest in this study.

1.1.1 Introduction to Concentrated Solar Power Technologies

CSP refers to those technologies that concentrate direct irradiation from the Sun to heat up a working fluid that then runs a turbine, generating electricity.

A CSP plant is made up of two main parts, the solar field and the power block. At the solar field, direct solar irradiation is concentrated and reflected onto an absorber or receiver, which circulates a heat transfer fluid. This thermal energy absorbed in this fluid is then passed to the power block where a thermodynamic process converts thermal energy into kinetic energy that then runs a generator as depicted in Figure 1-4.

Additionally, CSP plants may have thermal storage systems and auxiliary heating to cater for periods when the irradiation from the Sun is unavailable, ensuring smooth and prolonged generation.

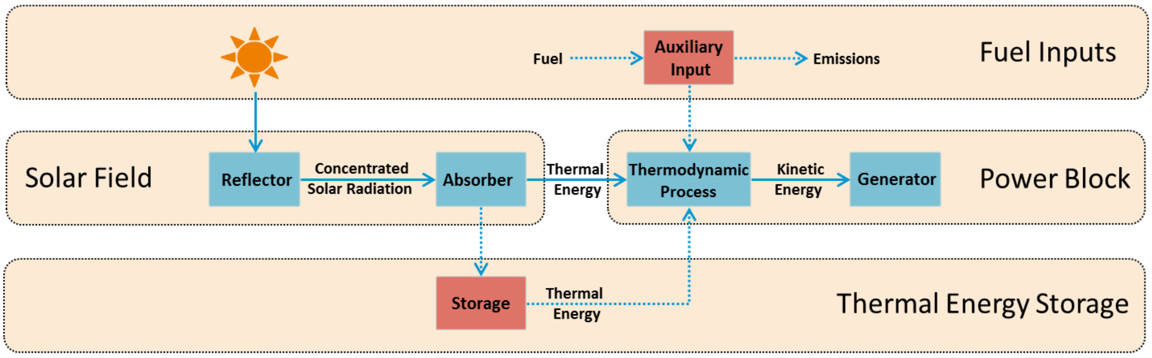


Figure 1-4: The main parts of a CSP plant showing the energy flow from the Sun to the generator and optional storage and auxiliary heating systems[6]

There are four main types of technologies of CSP, classified by how they focus the Sun's rays and the receiver technology. The first grouping has the receiver and concentrator aligned and moving together tracking the Sun. This grouping has the parabolic trough and dish stirling plants as illustrated in Figure 1-5. The receiver is fixed in position at the focal point of the mirror assembly.

Figure 1-5: Left: A parabolic trough plant showing the collector (curved mirror) and absorber tube. Right: A dish stirling system showing the concentrating dish and the fixed Stirling engine at the focal point (Source: [7])

The parabolic trough plant has parallel rows of curved reflectors concentrating irradiation to an absorber tube that may have synthetic oil or steam flowing in it. The heated fluid is then used to run a Rankine cycle and generate electricity.

Dish Stirling plants on the other hand have a singular parabolic dish concentrating the Sun's rays onto a Stirling engine located at the focal point of the dish. The Stirling engine is a heat engine operated by the cyclic compression and expansion of air or other gas. This occurs at different temperature levels such that the heat energy is converted to mechanical energy on a piston which then runs a micro-turbine producing electricity.

The second grouping has the receiver fixed, stationary and mechanically independent of the concentrator. The concentrator tracks the Sun and reflects solar irradiation onto the stationary receiver. In this grouping are the tower and linear fresnel plants illustrated in Figure 1-6.

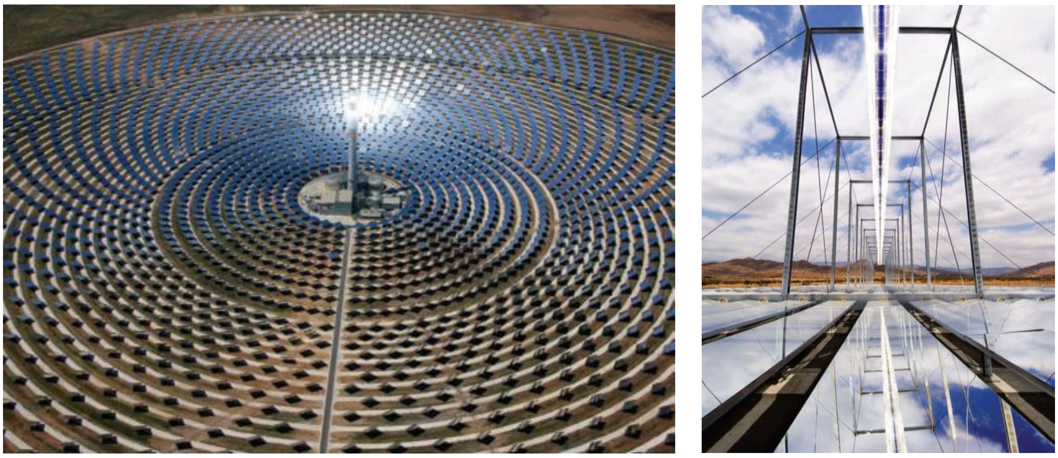


Figure 1-6: Left: A Tower plant with an illuminated tower at the centre of a field of heliostats (mirrors). Right: A linear Fresnel plant with a fixed absorber tube (receiver) above flat mirrors at the centre of a parabolic formation (Source: [7])

The tower plant is composed of a field of mirrors, referred to as heliostats that concentrate the Sun's irradiation onto a central tower atop of which the receiver is located. At the receiver, molten salt can be heated up and sent to a heat exchanger to produce steam. Optionally, direct steam generation may be employed, directly heating the water using the concentrated irradiation. This steam is then used to run a Rankine cycle to produce electricity. The Brayton / gas cycle may also be applied owing to the high temperatures achieved in these plants.

In linear Fresnel plants, flat or slightly curved strips of mirrors are arranged to approximate a parabolic shape reflecting the irradiation from the Sun onto an absorber tube at the focal point of this approximate parabola as can be observed to the right in Figure 1-6. The absorber has steam flowing inside it that is heated up and used to run a Rankine cycle producing electricity.

CSP technologies operate based on the Direct Normal Irradiation (DNI) from the Sun at values typically **above 1,900 kWh/m^2/year**. These values are typically found in areas between latitudes 10° and 40° North and South of the equator as illustrated in Figure 1-7.

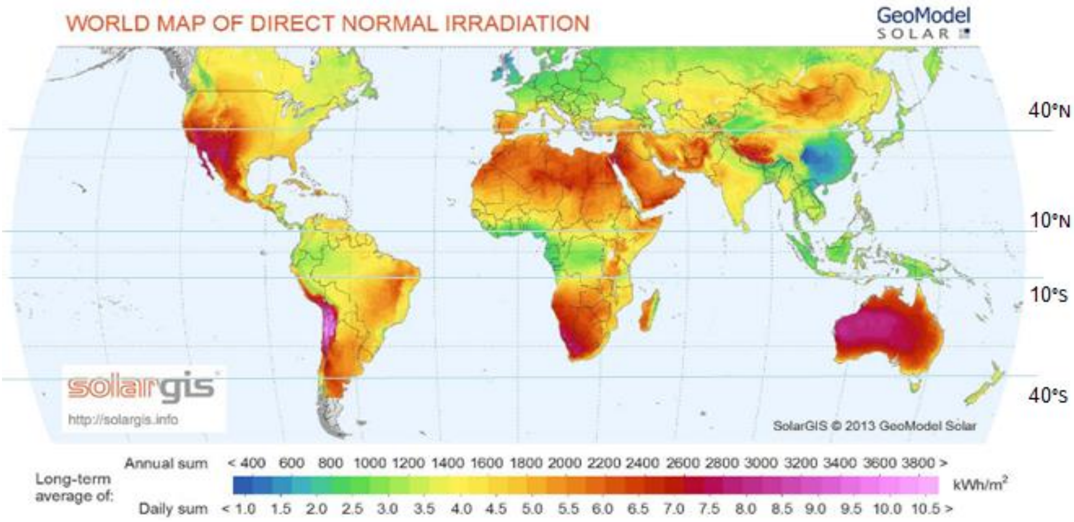


Figure 1-7: The Global map of direct normal solar irradiation. Typically suitable areas for CSP are Western Australia, The Arabian Gulf, The Sahara Desert, Southern Spain, North-western South Africa, Northern Chile and South-western USA[8].

1.1.2 Environmental and Social Risks

The development of large-scale projects of all kinds will alter the natural environment and affect the people and communities that live in the area. The development of CSP projects has also raised environmental and social (E&S) concerns of the traditional nature; such as displacement of economic activities and habitats, and new in nature; such as concerns over the effects of glint and glare (Section 4.1.). Greenhouse gas emissions from CSP plants has however been estimated to be 15 – 20 g of CO_2 eq./kWh compared to conventional plants' 400 – 1000 g of CO_2 eq./kWh[9].

Recent highly publicised media reports drew concern over the death of birds at the Ivanpah tower plant in California. The report claimed that the plant would kill tens of thousands of birds annually[10], [11]. This report was dismissed as highly exaggerated and not sufficiently put into context by the developer of the plant[12], [13]. Data collected from the plant over a period of 18 months agrees with the developer's assertion (refer to Section 4.2.2.1.2).

Concerns have also been raised about the use of water in CSP plants and the threat it would pose to local supplies. CSP suitable regions may also have irrigated agricultural activities that rely heavily on water sources that CSP would also utilise.

Previous studies available on this issue focus either on individual risks or on solar energy in general (including photovoltaic energy). Comprehensive studies on CSP are mainly project specific impact analyses. There is thus not a great deal of scientific study to analyse the E&S risks in development of CSP projects.

It is in the backdrop of these kinds of concerns and state of research that it was seen necessary to investigate the environmental and social risks posed by the development of CSP projects.

1.2 Research Question

The main research question is;

"What are the most important Environmental and Social risks in the development of Concentrated Solar Power projects?"

The sub-questions aiding in answering the research question are;

- ***"What are the environmental and social risks in the development of CSP projects?"***
- ***"How do the risks compare/ rank compared to each other before and after mitigation*?"**

1.3 Research Objectives

The aims of the research are as listed below.

- To Identify the Key Environmental and Social risks in the development of CSP plants
- To identify and describe mitigation measures for the Key Environmental and Social risks
- To carry out risk analysis for the identified risks
- To rank the Key Environmental and Social risks before and after possible mitigation measures are undertaken

1.4 How to Read the Master Thesis

This thesis identifies and analyses the risks in the development of CSP plants. The methodology applied to perform this task is outlined (section 2) and a presentation of some of the existing E&S regulations and standards applicable to CSP projects is then given (section 3). The specific risks as identified are then outlined illustrating their occurrence, the risk they pose and recommended mitigation efforts (Section 4). The results of the ranking process are then given (section 5) followed by a discussion as to why the respective ranks are given and further analysis for the top six risks (section 6). Conclusions are then drawn on the E&S risks posed by CSP (section 7) and an outlook of how these risks are expected to affect CSP developments is given (Section 8).

2 Methodology

This section gives a description of the methods used in the undertaking of this research including the research approach and the limitations of the research.

2.1 Research Approach

The research involved undertaking of a literature review aimed at identifying the E&S risks posed by the development of CSP plants, and of a risk analysis process that gives a score and rank for the risks. The procedures applied are outlined here below.

2.2.1 Literature Review

A broad set of literature sources was used during the Literature Review including scientific papers, project fillings, strategic plans and environmental reports. These dealt with CSP projects that were proposed, under construction or operational. Scientific papers that address environmental and social risks in CSP development as presented in conferences such as SolarPACES were also reviewed.

The bulk of the official project specific documents were retrieved from the California Energy Commission's open access document log for various projects in the state of California. This was accessed at http://www.energy.ca.gov/sitingcases/alphabetical.html. The projects reviewed included Ivanpah Solar Electric Generating System (this included documents on Gemasolar Thermosolar plant, Nevada Solar One Project and Dimona Solar Energy Development Centre), Palen Solar Electric Generating System, San Joaquin Solar, Imperial Valley Power Project, and Rice Solar Energy Project. Lahmeyer International GmbH's confidential project database provided for the remainder of the official project specific documents.

Where official documents were insufficient a review of other publicly available reports and studies was used to augment the available information. These included environmental impact analysis documents on some North African, South African and Middle-Eastern plants that were publicly available.

The reviewing process involved evaluating the occurrence or perceived probability of occurrence of environmental and social risks, their proposed mitigation measures and other additional comments and clarifications. These risks were then analysed to gauge their impact and the effort required to mitigate them. The risk analysis procedure is described in the following section.

2.2.2 Risk Analysis

The risk analysis procedure was used to rank the identified risks on a scale of Low to High as a product of five risk factors. Experts were asked to fill out a form (see Annex A) with risk factors as defined here below, used to score each identified risk detailed in section 4.

2.2.2.1 Risk Factors

The risk factors used in the development of the survey are as described below.

1. **Occurrence Factor (OF)**

This factor accounts for the probability of occurrence of the identified risk with 'Low' as least likely to occur and 'High' as most likely to occur.

2. **Ignorance Factor (IF)**

This factor accounts for the level of knowledge and experience in the industry with the identified risk. It is measured as an ignorance factor with 'Low' indicates the lowest risk due to extensive knowledge and experience and 'High' indicating the highest risk due to minimal knowledge and experience.

3. **Unmitigated risk Impact Factor (UIF)**

This factor accounts for the impact of the risk if it would be left unmitigated. 'Low' represents the lowest impact while 'High' represents the highest impact.

4. **Mitigation Ineffectiveness Factor (MIF)**

This factor accounts for the availability and extent to which mitigation measures reduce the impact of the identified risk. The current state of development of mitigation measures is also considered. A score of 'Low' implies a high effectiveness while 'High' represents a highly ineffective measure. Effectiveness here refers to the extent to which a mitigation effort reduces the impact of a risk.

5. **Mitigation Cost Factor (MCF)**

This accounts for the cost of the mitigation activity in relation to the project cost and cost benefits due to the mitigation efforts, 'Low' being lowest cost and 'High' highest cost.

These factors are scored low to high with factors having values as illustrated in Table 2-1.

Table 2-1: Scale for assignment of score to risk

Overall Risk	Value
Low	0.1
Low-Moderate	0.3
Moderate	0.5
Moderate-High	0.7
High	0.9

2.2.2.2 Overall Risk Scores

After the individual risk scores are determined, a Mitigated Overall Risk score (MORS) and a Non Mitigated Overall Score (NMORS) are calculated as given in equation 1 and equation 2.

Equation 1: $$MORS = OF \cdot IF \cdot UIF \cdot MIF \cdot MCF$$

Where:

MORS – Mitigated Overall Risk Score
OF - Occurrence Factor
IF - Ignorance Factor
UIF - Unmitigated Impact Factor
MIF - Mitigation Ineffectiveness Factor
MCF - Mitigation Cost Factor

Equation 2: $$NMORS = OF \cdot UIF$$

Where: NMORS – Non-Mitigated Overall Risk Score
OF - Occurrence Factor
UIF - Unmitigated Impact Factor

The overall risk scores are then ranked from High to Low using a scale modified from a ranking scale suggested by the United Nations Environment Program (UNEP)[14]. The applied ranking is as illustrated in Table 2-2.

Table 2-2: Left: Scale for the assignment for the non-mitigated overall risk score Right: Scale for the assignment of the mitigated overall risk score

NMORS	Value
Low	x < 0.05
Low-Moderate	0.05 ≥ x <0.17
Moderate	0.17≥ x <0.37
Moderate-High	0.37 ≥ x <0.65
High	x ≥ 0.65

MORS	Value
Low	x< 0.001
Low-Moderate	0.001 ≥ x <0.017
Moderate	0.017 ≥ x <0.1
Moderate-High	0.1 ≥ x <0.379
High	x ≥ 0.379

Where: NMORS – Non-Mitigated Overall Risk Score
MORS – Mitigated Overall Risk Score

The overall scores were then used to rank the surveyed risks from highest scoring to lowest before and after mitigation. The results of this process are then discussed in Section 5 and Section 6.

2.2 Limitations of the Research

The author's aim is to have the research as representative as possible of the environmental and social risk ranking in CSP. Even so, some assumptions and generalisations have had to be made. Some of these and their possible effects are as outlined below.

a. Snowball sampling of independent engineers

The independent engineers were sampled from Lahmeyer International GmbH staff and other independent engineers known in the industry. This may result in sampling biases and raise issues on the representativeness of the research. The use of a bigger pool of independent engineers and specialists may reduce errors related to sampling size. However due to time and resource limitations within a master thesis, the number of respondents was set to six (6), including the author.

b. Data mainly from California

A large amount of the data used in assessing the risks and their mitigation methods was derived from documents filed in California. To the best possible extent California-specific issues have been eliminated, but may have influenced the research. This is however also an advantage as California is one of the strictest and most openly accessible regulatory environments for the development of CSP.

c. Generalising risks for trough and tower plants

The risks were analysed only for trough and tower plants disregarding the Fresnel and dish plants. The first two are the most mature technologies and currently comprise the overwhelming majority of the global CSP project pipeline.

Further, the risks for trough and tower are also combined to finally end up with a general risk for CSP plants. This process may degrade the use value of the research, but was deemed necessary to increase reader comprehension. Detailed explanations are however given as to how the two technologies contribute to the identified risk.

d. Generalising risks over construction to operation

The risks posed over construction, operation and decommissioning were combined to an overall risk. In practice, each stage of development would need to have its risks isolated and analysed. This research intends to give a quick indication of risks that should be addressed when developing CSP plants. Whereas the research is detailed, it is not exhaustive. Attempts to cover every facet would introduce cumbersomeness to the survey of the two CSP technologies and draw attention away from the key points of focus of the study.

e. Focus on risks posed by plants and little on risk to plants

This work puts more emphasis on the risks posed by plants and not the risks posed to successful development of plants. This focus was settled on as the research is intended to ensure CSP plants benefit the environment and people around them. Nevertheless, some environmental and social risks that may hinder the successful development of CSP plants are also highlighted.

3 Environmental and Social Regulations and Standards

In response to E&S risks posed by projects, financial institutions and governments have put in place various regulations, procedures and guidelines that attempt to reduce impacts. Project developers wanting to access finance and acquire development permits and licences are required to fulfil some minimum requirements.

This section highlights some of the most notable guidelines related to E&S risks in CSP development. These guidelines cover a broad range of issues that have been identified after lenders' experience with similar projects.

3.1 Regulations from Financial Institutions and Associations

Financial institutions that provide loans for the development of CSP plants have some minimal environmental and social compliance requirements for developers requiring financing. Typical development banks include the World Bank (WB), International Finance Corporation (IFC), Inter-American Development Bank (IDB) and the African Development Bank (AfDB).

Commercial banks also lend to projects and have voluntary associations that review the environmental performance of projects. The equator principles is one such association. A description of the IFC performance standards and the equator principles follows.

3.1.1 International Finance Corporation (IFC) Performance Standards

The IFC Performance Standards on Environmental and Social Sustainability give an approach to the management of E&S risks. They provide guidance on how to identify risks and impacts and help to avoid, mitigate and manage risks in line with sustainable businesses, engagement of stakeholders and disclosure obligations. The IFC expects the eight standards to be applied throughout the life of an investment funded by it. Compliance with national laws in addition to these standards is also emphasised [2]. The standards are as described in Table 3-1.

Table 3-1: The performance standards of the IFC. These cover the overall environmental and social risks in the development of projects like CSP. Project developers utilising or applying for IFC funding are required to meet the standards[15].

Standard	Description
i. Assessment and management of Environmental and Social Risks and Impacts	Emphasises - integrated assessment in identifying the environmental and social risks, impacts and opportunities - Effective community consultations and engagement on issues directly affecting them and - The management of these issues over the lifetime of the project.
ii. Labour and working conditions	Emphasises - Protection of the fundamental rights of workers - Development of constructive worker-management relationships and - Fair treatment of workers by provision of safe and healthy working conditions.

Standard	Description
iii. Resource efficiency and pollution prevention	Focuses on - Efficient use of finite resources and reduction of pollution - Application of efficient and effective pollution prevention and GHG avoidance and mitigation technologies and practices - Monitoring and continual improvement of these approaches
iv. Community health, safety and security	Focuses on - Reduction of risks and impacts of projects on communities - The project developer's responsibility to avoid or limit risks and impacts to community health, safety and security - Vulnerable groups
v. Land Acquisition and involuntary resettlement	Emphasises - Avoiding or minimising displacement of persons and forced evictions. - Anticipating avoiding or minimising the social and economic impacts caused by project land acquisition and withdrawal of sustenance activities - Compensation for loss of assets - Transparent resettlement processes with informed participation of the affected people. - Improvement of the living standards of the displaced people - Provision of adequate housing and security of tenure at the resettlement sites.
vi. Biodiversity Conservation and Sustainable management of living natural resources	Emphasises - Protection of the biodiversity, maintaining the ecosystem services and managing the living environment at a project site. - Sustainable management by adoption of practises that integrate conservation needs and development priorities.
vii. Indigenous peoples	Focuses on - The protection of indigenous people by ensuring respect for their human rights, dignity, culture, aspirations and natural-resource-dependent livelihoods. - Anticipation of adverse effects to indigenous communities and minimisation or compensation for these effects. - Informed consent of indigenous populations and their full consultations in matters affecting their livelihoods during the lifetime of the project. - The need to respect and preserve the cultures of indigenous peoples.
viii. Cultural Heritage	Focuses on - Protection of cultural heritage - Equitable sharing of gains from any use of cultural heritage.

3.1.2 Equator Principles

The Equator Principles is a voluntary association treaty that applies to willing financial institutions that lend to project developers. It is a risk management framework used to determine, assess and manage E&S risks in projects with the primary role of providing minimum standards for due diligence studies for commercial financial institutions looking to fund projects. The principles allow for more responsible E&S risk decision making. There are currently 80 equator principles signatory banks that cover the majority of project finance debt in emerging countries[16].

This system involves 10 principles as described in Table 3-2. The application of these standards by signatory financial institutions enables protection of the environment and society in jurisdictions where laws and permitting requirements are not robust enough or able to handle sophisticated project related E&S impacts.

Table 3-2: Details of the 10 Equator Principles that are applicable by signatory financial institutions on financing proposals for projects brought to them. The principles shore up environmental and social regulations in project countries and support the due diligence processes of the lending institution[17].

Principle	Description
i. Review and Categorisation	Involves - Categorisation of the project according to its potential environmental and social risks and impacts based on IFC guidelines. - Ranked as A, B and C from the highest impact to that with lowest respectively.
ii. Environmental and Social Assessment	Category A and B projects required to conduct assessment of the environmental and social risks and impacts. This should - Propose measures to minimise, mitigate or offset adverse impacts. - Include an Environmental and Social Impact Assessment (ESIA) - Include a human rights due diligence is also needed for high risk circumstances - Include an alternatives analysis for less greenhouse intensive options where emissions > 100,000 tonnes of CO_2 equivalent emissions annually
iii. Applicable Environmental and Social Standards	- Compliance with the host country's laws, regulations and permits relating to the environment and social issues is stressed. - The IFC Performance Standards on Environmental and Social Sustainability and the World Bank Group EHS guidelines apply where national laws are not robust enough
iv. ESMS & Equator Principles Action Plan (AP)	- An Environmental and Social Management Systems (ESMS) is required to be developed and maintained for category A and B projects. - Where standards are not met then the client and the bank are required to agree on an action plan

Principle	Description
v. Stakeholder Engagement	Client project required to - Demonstrate that the stakeholders are being engaged effectively on an on-going basis in a structured and culturally appropriate manner. - Tailor consultation process to the risks and impacts of the project, language preferences of the affected communities, their decision-making process, and needs of disadvantaged and vulnerable groups and the project's phase of development. - No interference, intimidation, coercion and manipulation. - The assessment documents must be made available to local residents in their local language and in a culturally appropriate manner
vi. Grievance Mechanism	- Mechanism to air grievance and facilitate their resolution at a scale appropriate to the risk and allow easy, free and non-retributive access to affected communities without barring them from seeking further legal redress.
vii. Independent Review	Independent Environmental and Social consultant to - Review the assessment documentation including the ESMP, ESMS and stakeholder engagement documentation. - Assess compliance with equator principles and help the lenders due diligence process.
viii. Covenants	Commitment built into financing contract - To comply with host country regulations, ESMPs and equator principles - provide periodic compliance reports - Decommission the facilities according to a decommissioning plan
ix. Independent Monitoring and Reporting	Independent Environmental and Social consultant - To monitor the project and share with the financial institution the monitoring information.
x. Reporting and Transparency	- Project to make a summary of the ESIA accessible and available online - Publicly report GHG emissions levels when in excess of 100,000 t CO_2 equivalent.

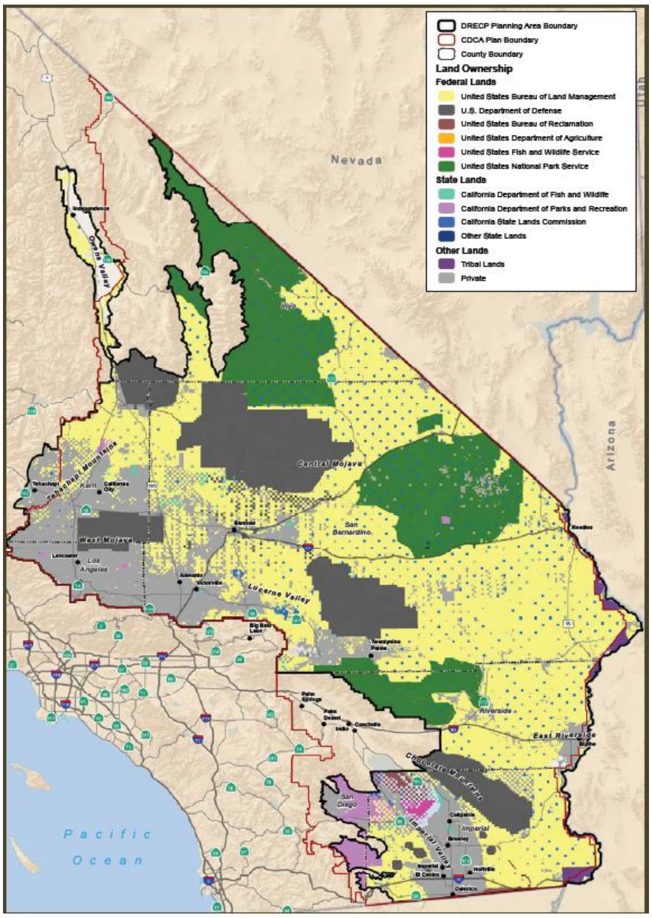
3.2 Regulations from Governing Bodies

Governing bodies are also developing regulations on the management of social and environmental risks in areas suited for CSP. The DRECP is an example of these plans and is described briefly in Section 3.2.1.

3.2.1 Desert Renewable Energy Conservation Plan (DRECP)

The DRECP is a multiagency plan of the state government of California that aims to protect endangered species in the areas suited for the development of Renewable Energy (RE) projects. The plan aims to streamline permitting processes with regards to endangered species while planning for RE project developments in over 89, 030 million m^2 of the California Deserts.

The agencies involved are the California Energy Commission (CEC), California Department of Fish and Wildlife (CDFW), U.S. Bureau of Land Management (BLM) and the U.S. Fish and Wildlife Service (USFWS).



The plan uses a scientific development approach for RE technologies and the conservation of species with an aim to create connectivity improvements and habitat protection in the Mojave and Colorado/ Sonoran desert regions. Its accrued benefits are those that may not be easily realised when focusing on a project-by-project basis. 8, 094 million m^2 in this region have been set aside as development focus areas for RE[18]. These are shown in light grey in Figure 3-1.

The draft plan includes restrictions such as limiting development of plants within 1.6 km of a Golden Eagle's nest and set back of up to 0.4 km from riparian resources.

These regulations may have a double effect of limiting the further development of CSP projects in this area while also streamlining the arduous permitting process in California.

Figure 3-1: A map of the DRECP plan area in California showing various specially designated protection areas and areas set aside for the development of RE projects including CSP (in light grey) (Source: [19]).

4 Key Environmental and Social Risks in CSP Development

In this section, a detailed review of the E&S risks in the development of CSP projects is done. An in-depth review of risks posed by glint and glare; risk to water resources; risk to ecological resources including avian species; risk to land use and visual resources, risk to worker health and safety; risk due to noise on the acoustic environment and other miscellaneous risks is undertaken.

For each risk an introduction is given and the incidence of occurrence, risk impact and applicable mitigation outlined.

4.1 Glint and Glare

The description of glint and glare and how it occurs in CSP plants and the risks based on measurements is given in this section. The section ends with an outline of the proposed mitigation measures.

4.1.1 Introduction

Glint is defined as a momentary flash of reflected light, while glare is a more persistent reflected light, as seen in Figure 4-1. Both are brighter than the ambient lighting[20]. CSP plants have been shown to generate glint and glare with reflections from the heliostats/mirrors and tower. It is important to assess the effects of glint and glare to ensure ocular safety of individuals.

Glint and glare have the potential to cause permanent eye damage such as retinal burn[2] or flash blindness[3]. These may pose a safety risk to workers on site, motorists, pedestrians and pilots.

Figure 4-1: Specular glare as observed from a plane flying close to the Ivanpah CSP power tower plants on the 24th April 2014. The characteristic sharp reflection is from the heliostats at a low Sun angle (Source: [21])

The irradiance that reaches the retina of the human eye as depicted in Figure 4-2 is computed using Equation 3.

[2] Retinal Burn is a permanent destruction of the retina causing blindness

[3] Flash blindness is a temporary blindness caused by bleaching of the retinal visual pigments by light

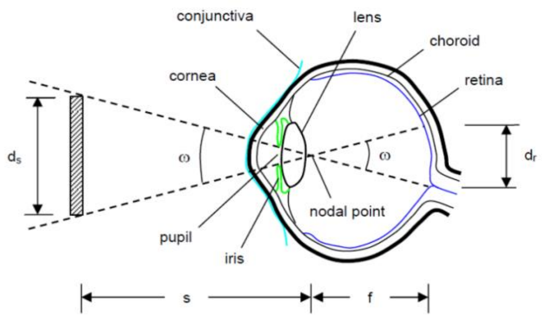


Figure 4-2: cross section of the human eye showing image projected to the retina (Source: [20])

Equation 3: $$E_r = E_c\left(\frac{d_p^2}{d_r^2}\right)\tau$$

Where:

dr – Diameter of the image on the retina : $dr = f \cdot \omega$
ω - Subtended source angle: $\omega = \frac{d_s}{r}$
ds - Source size
r – Radial distance between eye and source
f – Eye focal length (approx. 0.017 m)
Ec - Irradiance at a plane in front of the cornea (W/m^2)
dp – Daylight adjusted pupil diameter
τ - Transmission coefficient of the eye (approx. 0.5)

A high ω implies larger retinal area, greater power to the retina and a lower retinal safe irradiance threshold. Brumleve [22] defines the retinal irradiance causing burn as in Equation 4 and Equation 5.

Equation 4: $$E_{r,burn} = \frac{0.118}{\omega} \quad for\ \ \omega < 0.118\,rad$$

Equation 5: $$E_{r,burn} = 1 \quad for\ \ \omega \geq 0.118\,rad$$

An empirical fit[20] developed by Sandia National Laboratories for the minimum retinal irradiance causing an after image is given by Equation 6.

Equation 6: $$E_{r,flash} = \frac{3.59 \cdot 10^{-5}}{\omega^{1,77}}$$

Glint/glare is either of specular or diffuse in nature. Specular glare results from reflections off polished highly reflective surfaces like mirrors resulting in a sharp reflection. Diffuse glare on the other hand results from reflections off rough surfaces producing a less sharp reflection.

The thresholds for safe flux for humans range from 1.42 kW/m^2 to 5 kW/m^2[23].

4.1.2 Occurrence of Glint and Glare

Glint and glare can occur when there are rogue heliostats, heliostats are in standby, during tests before commissioning or when the Sun angle is low. These situations are described here below.

a. Rogue Heliostats

Heliostats that are moving in a different direction from those focused on the receiver can cause glare. This can be observed to the bottom right of Figure 4-3. From measurements at Ivanpah it was found that a single 15 m^2 heliostat will produce an afterimage up to 4 km away[21].

Figure 4-3: Photograph of specular glare from a rogue heliostat at Ivanpah CSP plant's unit 3 receiver with illuminated receiver (displaying diffuse glare) (Source: [21])

b. Heliostats in standby

When heliostats are in standby mode, the common practice is to point them in a toroid around the tower as seen in the model to the left in Figure 4-4, shown by arrows. The toroid is a donut shaped area around the receiver that represents the most applied standby position for tower plants. Other positions can also be applied as seen in the picture to the right of Figure 4-4. The figure shows a bright spot in the air to the right of the receiver caused by accumulated heated particles at the point where the standby heliostats are pointed.

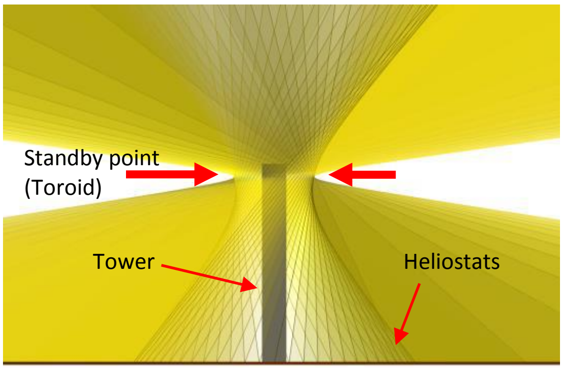


Figure 4-4: a model (left) and photo (right; Ryan Goerl, NRG Energy)) of heliostats aiming at a standby point around the top of the tower (shown by arrows) that results in a toroid glare in the sky (Source: [21])

Additionally, glare will always be observed in operational tower plants when the observer looks at the receiver.

c. Heliostat reflection before commissioning

Specular reflections can result from mirrors during construction before they are oriented to point at the receiver. They may point in random directions, introducing glare in these areas.

d. Position of the Sun relative to plant in the morning and late afternoon

Glare/ Glint can also be caused by the spilling off of rays at the ends of troughs when the Sun is low in the horizon. This is the case in the mornings and evenings and may occur in varied locations at varied times[24].

This effect can be observed in Figure 4-5. The same effect of low Sun position is also visible in tower plants as can be seen in the picture of Ivanpah tower plant, to the right in Figure 4-1.

Figure 4-5: Glare from Nevada Solar One parabolic trough plant, Nevada viewed at a road located 3 km away (Source: [24])

4.1.3 Risks based on measurements from the Ivanpah Plant

From measurements carried out at the Ivanpah tower plant in California it was found that the specular glare from mirrors was much more pronounced than the diffuse reflections from the receiver. The specular reflections were visible 32 km from the site in the air when the heliostats were on standby. Lower elevations (on hills around site) experience glare from heliostats far from the tower while higher elevations (in the air) experience glare from heliostats close to the tower. There was no glare observed directly above the tower and at low elevations far from the plant [21].

The highest retinal irradiance recorded was approx. 60 kW/m^2 at locations close to the site, reduced by atmospheric attenuation at further distances [21]. Retinal irradiance refers to the irradiance at the retina of the eye and is different and approximately 80 times as much as the irradiance entering the eye (corneal irradiance). The retinal irradiance is higher owing to the smaller image area projected onto the retina as compared to the pupil size. As a comparison, direct observation of the Sun results in a retinal irradiance of 80 kW/m^2. The safe retinal irradiance limit is up to 127 kW/m^2 [25].

An annoying after image, disappearing after some seconds, is reported as likely to be experienced by observers inside the plant boundary.

On the roadside outside the site at Ivanpah, the combined effect of the retinal irradiance and subtended angle of the receiver produced a glare that had low potential for after image.

Glare was visible on the ground out to 10 km from the tower causing an after image. Beyond this distance there was low potential for after image due to a reduced retinal irradiance and subtended angle[21].

4.1.4 Mitigation

Some of the mitigation measures suggested in the literature are as listed below.

1. Advance warning given to pilots closely overflying the plants with recommendations such as not looking directly at the plant. To the extent possible, plants should also be sited away from known fight paths.
2. Modifying the control and coordination algorithm for standby positions of the heliostats by [21]
    a. Increasing the number of aim points close to the receiver in the standby mode and having adjacent heliostats point at different directions to disperse and thus minimise the glare visible around the ‘toroid’.
    b. Positioning of the heliostats in a vertical or other orientation that would avoid reflections. Vertical orientation of heliostats would however result in the creation of substantial collision risk for avian species flying in the heliostat area [26].
    c. Sequentially bringing heliostats to standby as necessary, avoiding a large number reflecting into the sky at the same time
    d. Incorporating a glare shield (or light dump) next to the receiver to serve as an aim point and also preheat the heat transfer fluid.
3. Regular monitoring and surveying of the field for rogue heliostats and correcting their positioning
4. Use of anti-glare goggles for workers and visitors within site boundary.

5. Covering of mirrored surface during construction until the heliostats are properly seated, oriented and under computer control. This may however be a cumbersome undertaking that may introduce unnecessary costs.

Interestingly, in a plant in Spain it was reported that the bright glare from CSP plants was observed as a sign of progress by communities and did not cause rejection[7].

4.2 Ecological Resources

CSP plants are located in dry lands where unique flora and fauna exist. The possible effect of CSP plants on flora and fauna in these areas is described in this section.

4.2.1 Vegetation (Flora)

Flora here refers to the plant life found within areas where CSP is developed. The occurrence, risks and mitigation mechanisms for risks to flora are described in this section.

4.2.1.1 Occurrence of Risks

The risks to vegetation occur due to the heightened human activity in the area. This is manifested by the possible introduction of invasive species into the project area and trampling and cutting of vegetation during site preparations and works. These two occurrences are described below.

a. Introduction of Invasive species

Invasive species may be introduced or benefit from activities on the land during the development of CSP plants. The digging up of the ground and construction of access roads may act to propagate foreign plant species. Invasive species are known to be highly drought resistant, adaptive to disturbed soils and quick propagators towards undisturbed habitats.

These species thrive in disturbed soils, outcompeting native species by having minimal water requirements, high germination potentials and higher seed production[23].

One of these species in the southwest USA is the Tamarisk, native to dry areas of Eurasia and Africa. It is fire adapted and has long tap roots that it uses to access deep water tables and exploit natural groundwater. In addition to limiting access to water for the native species, the tamarisk also limits competition by taking up salt from the deep ground, accumulating it in its foliage and depositing it on the ground[27]. These deposits are detrimental to other plants' ability to grow.

Some of the special status plant species under risk in this region include the Barstow Wooly Sunflower (*Eriophyllum mohavense*) that is endemic to the southwest USA and the Desert Cymopterus (*Cymopterus deserticola*) that is dormant and underground during hot periods and summer. These plants are as seen in Figure 4-6.

Figure 4-6: Left: Barstows wooly Sunflower (Eriophyllum mohavense) [Source: [28]] and Right: Desert Cymopterus [Source: [29]]. These are plants of special conservation interest in the dry lands of the South West USA. They face the risk of loss of habitats and or destruction by the invasive species and land preparation and maintenance activities in CSP plants

b. Trampling and Cutting

Clearing of bushes in the actual plant site and in preparation of access roads may lead to loss of certain plants. The maintenance of the heliostat/trough fields including the trimming of vegetation and cleaning of mirrors exposes vegetation to trampling by workers and their equipment.

4.2.1.2 Risk impact

- Invasive plants may alter the surface hydrology and basic geomorphic processes that support native and rare plants and their habitats[30]. These plants may obstruct the transportation of fluvial and Aeolian sand.
- The takeover by invasive species may threaten the existence of native species that may lead to loss of habitat or food for some animal species leading to the reduction of biological diversity and numbers of native species.
- The likelihood and extent of wild fires may also increase if the invasive species form a dense vegetative pattern. This existence of more plants implies more dry matter to feed fires. Activities like welding during construction and smoking could act as a flashpoint, igniting dry vegetation.
- Digging up of land may disturb the structure and ecological functioning of the top soils affecting seed germination. The soil is also exposed to water and wind erosion reducing the nutrition available to plants.

4.2.1.3 Mitigation

- Putting in place measures to minimize or avoid spread of invasive species such as engaging in weed control.
- Minimizing the size of the disturbed area.
- Restoration of the degraded portion of the land at the end of the construction or project
- Specialised attention and management to protect and sustain populations of sensitive species and habitats.
- Purchase of compensatory conservation lands where no developments are undertaken and vegetation is allowed to recover
- Proper site and drainage design.

4.2.2 Wildlife Species (Fauna)

CSP developments may impact the animal life in the area. The impacts are described separately for avian species and land based species.

4.2.2.1 Avian Species

Areas where CSP plants are developed also provide a habitat for bird and bat species. Birds build their nests, breed, forage and migrate through these areas. Bats are also known to live in the crevices of rocks and high up in trees in such areas. An analysis of the effects of insect attraction and fact checking of negative reporting related to avian fatalities at the Ivanpah plants is also done. The proposed mitigation measures are then outlined.

4.2.2.1.1 Occurrence of Risks

The risks to avian species occur due to solar flux effects, collision with structures and power lines, intake of saline water at evaporation ponds and electrocution. These are illustrated as below.

a. Solar Flux effects in tower plants

The operation of CSP tower plants leads to the development of solar fluxes in the airspace between the heliostats and the tower in the direction of the receiver. These fluxes get more intense closer to the receiver and lead to heating up of airborne particles or objects close to the receiver. These fluxes are as illustrated in Figure 4-4.

When birds fly across these areas of high intensity flux concentrations they have been observed to experience singeing of flight feathers in their dorsal aspects and wings, illustrated in Figure 4-7 that leads to loss of flight function. This then leads to birds falling in, or close to the plant area where they may collide with structures and experience bone fractures, death, or become prey. Some birds have been seen to get to the ground safely, but then, due to inability to forage, are faced with starvation leading to death. However, necropsy done on birds found at the Ivanpah CSP plant did not find any indications of ocular or soft tissue damage to the birds[26].

Flux exposure could also cause elevated body temperatures, compromise the molecular structure of feathers, cause thermal stress on the body of the bird, or death immediately or a short time after exposure [23].

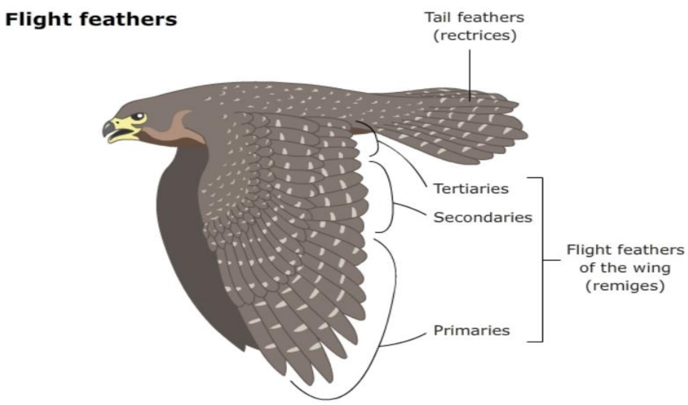


Figure 4-7: Flight feathers of a bird showing the remiges and rectrices. The loss of 1-6 cm of the primary remiges with loss of secondary and tertiary remiges has been shown to eliminate take-off in house sparrows[26] [Source:[31]]

It must be noted that the effect of the heat from the flux does not penetrate the feathers owing to the feather-arrangement's natural insulation properties[32]. Only the outer layers of feathers have been observed to show signs of singeing, and not burns that go deeper into the flesh, as can be observed in Figure 4-8. This could also be related to the relatively short period of exposure to the fluxes.

Figure 4-8: Left: singed dorsal aspect of a Peregrine Falcon found at Ivanpah plant unable to fly and emaciated. Right: singed feathers of a Northern rough-winged Swallow. The singeing occurs on the outer feathers and flux effects do not get to the flesh (Source: [26])

Lab experiments with bird feathers determined that at an air temperature of 450°C bird feathers burn when exposed for 30 seconds[26]. However it was added that in reality the bird is able to regulate or at least reduce temperature by its behavioural motion, convection, evaporation and heat storage. After tests, it was reported that no effects would be expected on live birds at flux concentrations lower than 50 kW/m^2. Above 50 kW/m^2 for 20-30 seconds small birds showed muscle tissue effects while big birds showed no effects on the muscles[33].

b. Collision with plant structures

Collision is more common in trough plants owing to their continuous reflected image that birds mistake for the sky or a water body[26]. As can be seen in Figure 4-9 the reflection appears like a continuous blue body that creates an illusion of the sky. Contrasting this with Figure 4-10, the appearance of a heliostat field is more like patches in a dry background and not as optically uniform as a trough plant.

Figure 4-9: Aerial view of a parabolic trough plant giving the impression of the sky. On a less cloudy day this may appear like a lake or a pool of water in the dry surroundings [Source [34]]

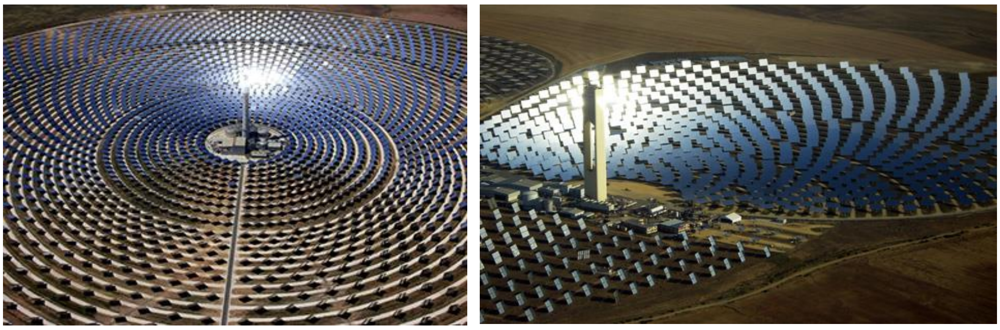


Figure 4-10: Aerial views of Gemasolar (left) and PS10 (Right) solar tower power plants showing a toothed (spaced out) heliostat reflection that gives a less continuous image of the sky [Source [35][36]]

Collisions occur when structures are invisible, deceptive, or confusing to the birds. Vertical positioning of heliostats in tower plants have however also been identified as a common cause of collision as they reflect the surrounding area [26]. This position is however good for the reduction of glint and glare as outlined in section 4.1.4.

Collisions also occur with transmission lines near wetlands, in narrow passes that have power lines passing perpendicularly and in valleys bisected by power lines. Up to 175 million bird fatalities occur in the USA due to collisions with transmission and distribution lines in general [10].

c. Loss of Habitats and Noise disturbance

Birds and bats may lose their nesting or foraging habitat during activities like ground clearing at the commencement of construction of CSP plants. The noise levels from heavy equipment, human presence, mirror washing activities, and exposure to dust may displace birds and interfere with breeding.

Construction noise is reported to interfere with the communication of birds affecting feeding and protection from predators by obscuring warning signals. Refer to section 4.6 for more details on noise.

d. Electrocution

Large birds, like the red tailed hawks and the great-horned owls, face the risk of electrocution when they perch or take-off close to power lines with insufficient clearance. This occurs when the clearance between two lines is less than the wingspan of the bird or its head-to-foot length or when birds perch side to side spanning the length of the clearance between conductors. Electrocution is reported to occur frequently at transmission lines between 1 kV and 60 kV between phase-to-phase and phase-to-line conductors[23]. This is however not unique to CSP installations, it can occur in all power plants.

e. Evaporation ponds

Evaporation ponds receive the wastewater stream from boiler and condenser blow down. Birds are attracted to ponds to drink and may rest, forage, or nest in the vicinity of the ponds. They are exposed to highly saline water with a high total dissolved solid content. K. Douglas, D. Hochschild, and K. Celli [23] report that water from evaporation ponds at Harper Lake SEGS have caused the deaths of numerous waterfowls. The exact number was however not provided.

These evaporation ponds also attract insects to the site; a big factor in the increase of avian activities in the area.

4.2.2.1.2 Fatality Measurements from Power Plants

Fatality data from Nevada Solar One, Ivanpah, Dimona and Gemasolar power plants was compared for various measured periods and is as presented below.

i. Nevada Solar One (Nevada, USA)

In 1986, at the 10 MW Nevada Solar One plant in the Mojave Desert a 6 month, weekly survey was undertaken randomly over the full solar field. 70 bird fatalities of 26 species were detected in 40 weeks. 13 birds had died due to falling after heavy singeing of their feathers while 53 had died after collision with the mirrors[32]. There were 1.9 – 2.2 bird fatalities per week out of 314 live birds counted in the vicinity at the time of the survey.

Aerial foragers were more susceptible to singeing owing to their feeding habits. It was however noted that at the time of the study there were numerous swifts and swallows migrating through the area combined with extended testing and standby positioning of the heliostats, representing higher rate of standby fluxes leading to higher risks for birds. The site was also located next to an alfalfa farm with irrigated fields that attracted insects, which then attract birds.

ii. Ivanpah Solar Electric Generating System (ISEGS) (San Bernardino County, California, USA)

At the 392MW ISEGS plant, 471 avian fatalities were recorded in the 30 months from January 2012 to June 2014. As can be observed in Figure 4-11, the bulk of these (425 cases) were recorded during the pre-commissioning periods and early months of operation [9]. Ivanpah achieved its first synchronisation with the grid on the 24th of September 2013[37].

In its first six months of operation from Jan 2014 to June 2014, the plant experienced 321 avian fatalities (of which 8 were bats) with a low of 17 in February and a high of 97 in April [10].

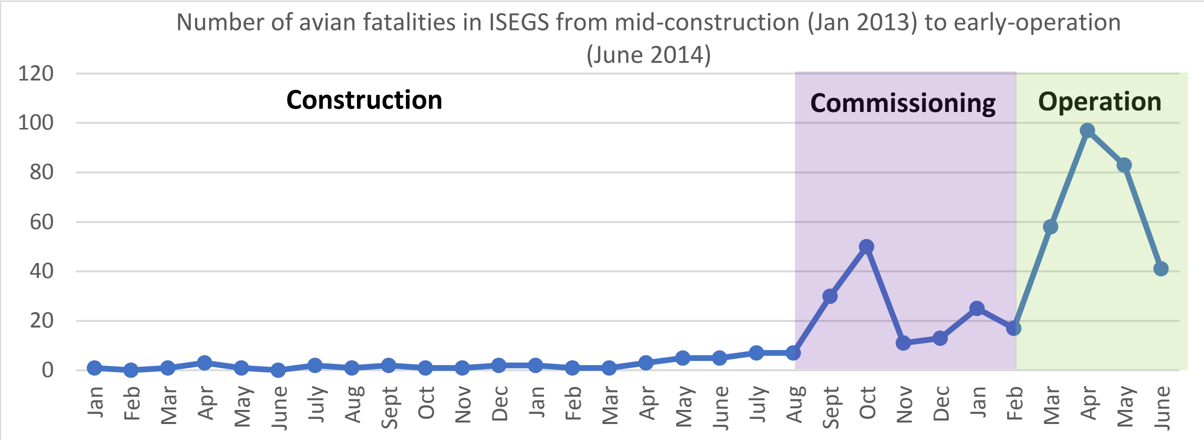
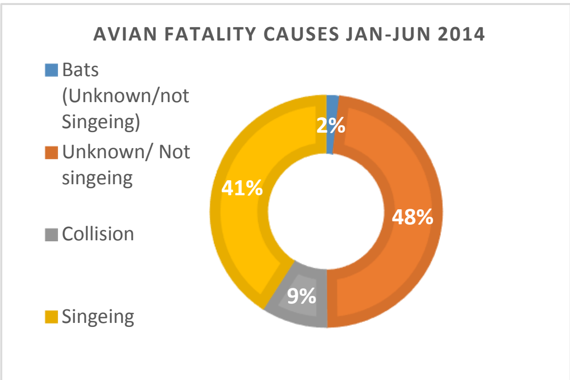


Figure 4-11: Graph of avian fatalities at the Ivanpah Power plant from Jan 2013 to June 2014. A sharp increase in fatalities is observed during pre-commissioning (shown in purple) and during initial operation (shown in green) [Data source:[38], [39]]

As can be seen in Figure 4-12 singeing / flux injuries and unknown causes were responsible for the bulk of fatalities at Ivanpah between January and June 2014. The unknown causes are designated after microscopic analysis failed to detect neither singeing (curling, charring or melting of feathers) nor collision with plant structures and when feather spots are found on the heliostat field [40].



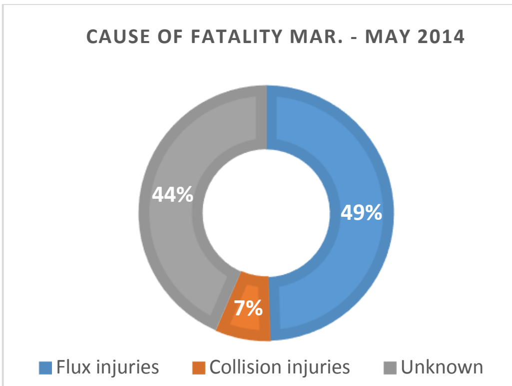


Figure 4-12: Left: Causes of the 321 avian fatalities at Ivanpah SEGS between Jan and June 2014. Right: Causes of avian mortality between March and May 2014. Both sets show flux injuries as the leading known cause of fatalities. Unknown causes are however also significant requiring further attention [Data Source:[39], [40]]

Aerial foragers are at highest risk as shown in Figure 4-13 as they are most likely to be attracted to the insects attracted to bright light close to the receiver[23].

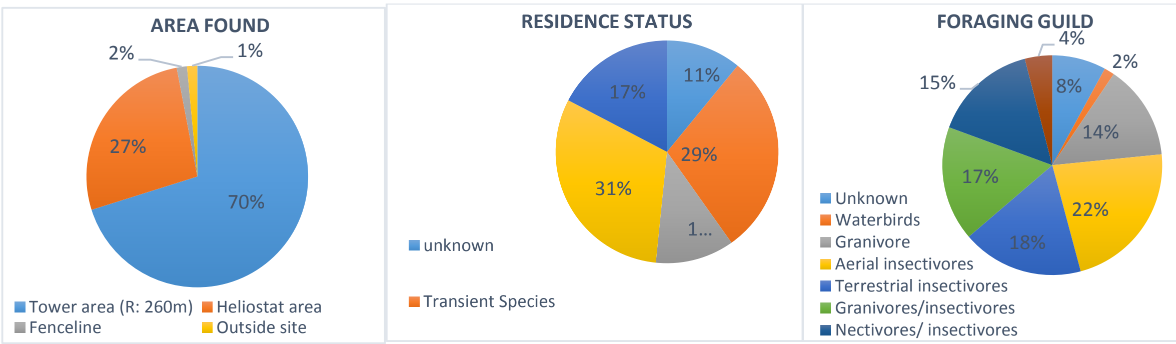


Figure 4-13: Breakdown of the fatalities in Ivanpah between March and May 2014 by Area Found, Residence Status of the bird and foraging guild. Most fatalities occurred in the tower area, were mostly migratory species passing through the area and were mostly aerial insectivores [Data source [40]]

There was poor correlation between high flux days and the cases of fatalities of unknown causes in the ISEGS during the March-May period [40] ruling out flux as the cause of the unknown fatalities.

iii. Dimona (Negev Desert, Israel)

The area where the 6 MW Tower plant at Dimona Solar Energy Development Centre is located is used by birds for wintering, breeding, residence and migration. Data on effects to birds was collected 5 days per week over spring and autumn, 2012 with over 10 visits, 5 times per month for 2 months in summer and winter [41].

There were 3 birds found dead over the period, none of which suffered singeing or broken limbs. The birds were migrant passerines known for their high mortality in the area. 8,540 birds of 38 species were observed with 853 flying over the plant lower than 200 m [41]. Six of these were regional and/or global endangered species including the Egyptian Vulture, Lesser Kestrel, Lanner Falcon and Griffon Vulture.

The plant operations staff also reported no bird singeing case in four years of operation [33].

iv. Gemasolar (La Monclova, Fuentes de Andalucia, Seville, Spain)

At the 19.9 MW Gemasolar a census survey was carried out within a 3 km circle in the area of the plant monthly over a year (in 2011/2012) and every two weeks over the peak bird reproduction months of April to July [42].

There were 73 species observed within 3 km of the plant with 8 nesting inside the premises and 12 species being of conservation concern. 14 species were observed in flight in the site with 6 crossing the beam from the mirror to the tower. They were however never observed crossing the beam close to the receiver where the flux is most intense.

There were no bird cadavers or injured birds detected within or around the plant boundary as at the end of the study period [42]. This is an unlikely and unrealistic result owing to the normal incidences of bird fatalities even in normal environments. The monitoring procedure, area of coverage and frequency of survey is likely inadequate.

4.2.2.1.3 Insect attraction, fatality and consequences

The bright light at the top of the tower of CSP tower plants attracts multiple insect species that face immediate incineration if flying at the top of the tower at and around the receiver [26], [32]. At the 9MW Solar One tower an average of 630 insects per hour were reported to be incinerated in the months of September and October in 1982. The actual hourly incineration numbers ranged from 0 to 5,000 insects per hour[23]. These insects are attracted by the bright lights at the tower.

The increased presence of insects at this location is reported to lead to the attraction of insectivorous birds and bats which may then face the danger of flux burns on their feathers. These birds are then reported to also attract raptors[4] that prey on them and that are also prone to solar flux injury. Birds falling on the ground within and around the CSP plants then attract land based predators that feed on them. In this way tower plants are described to behave like ecological traps[26] for birds as illustrated in Figure 4-14.

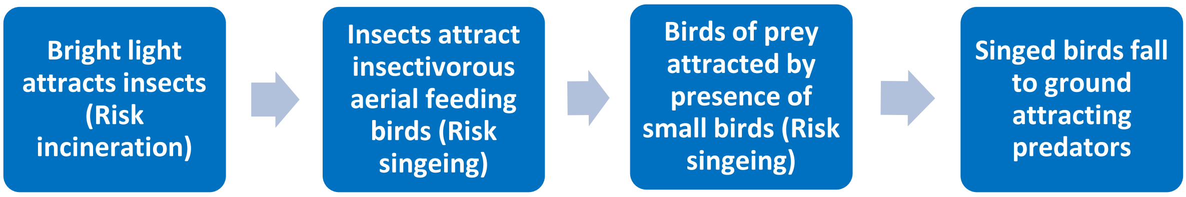


Figure 4-14: Description of the ecological trap that was found to be posed by the Ivanpah tower plant

Additionally, the risk posed to endangered insect species such as the Monarch Butterfly depicted in Figure 4-15 is likely to become of greater concern with greater deployment of CSP plants.

Figure 4-15: Photo of two Monarch Butterflies (Source: [2]). The butterfly is an endangered species in the southwest of the USA and may face incineration if it were to fly across the flux streams in tower plants.

4.2.2.1.4 Fact Checking Adverse reporting on Ivanpah bird fatalities

In August 2014 there were widely circulated reports that the Ivanpah plant would be killing hundreds of thousands of birds per year. It was also claimed that the birds were incinerated/

[4] Here refers to all birds of prey

instantly ignited upon flying into the flux streams, one every two minutes [11]. A rather exaggerated estimation of 1,000 to 28,000 per year was also reported [10].

Putting the fatalities in context, low rise buildings are reported to result in 800 million deaths of birds annually in the USA [43]. Up to 175 million bird fatalities occur in the USA due to collisions with transmission and distribution lines in general [10]. As Figure 4-11 illustrates there were 321 total deaths at Ivanpah for its first six months of operation. This could possibly translate to 1,000 deaths for the whole year of operation. Compared to buildings and transmission lines, the number is insignificant.

The observation of smoke streams every two minutes that was cited as one of the bases for the estimation is consistent with insect incinerations as birds are unlikely to be ignited instantaneously as explained in section 4.2.2.1 and section 4.2.2.1.3.

4.2.2.1.5 Risk impact

The risks to birds depend on the physiological, ecological and behavioural characteristics. The risks posed are the following:

- The take[5] of endangered avian species that are endemic to areas where CSP plants are built.
- A non-natural number of avian fatalities and disturbance of migratory flows crucial for survival of avian species and individuals.
- Loss of habitats for avian species.

4.2.2.1.6 Mitigation

Some of the mitigation measures suggested from reviewed literature are as follows.

- Netting or covering of evaporation ponds to keep birds away.
- Ensure that vertical orientation of heliostats is minimized to reduce collisions. This contrasts with the preference for this position for the reduction of flux. A suitable position to minimise flux and chances of collision should be applied.
- Incorporate avian survey and monitoring protocols to continuously assess avian life in the vicinity of the plant.
- Introduce measures that discourage bats and birds from roosting or perching in and around the condenser or power block respectively. This could be through installation of avian diverters and anti-perching systems.
- Avoid siting of tower plants close to open water or agricultural fields. These areas have been shown to have high bird populations due to the presence of open water and insects.
- Minimising the use of light at night and using red flashing strobe lights with long intervals between flashes and short flash durations to minimize collisions. Lights should also be shielded, directed downwards and turned off when not in use.
- To protect large birds it is recommended, as is the practice, that transmission lines be separated by at least the wingspan of the birds to avoid short circuiting during perching and take-off from transmission line towers.

[5] Take refers to the withdrawal or removal of avian species from its environment by way of harming, poaching, injuring or killing caused by plant operations and accidents among others

- Provision of compensatory lands and undertaking habitat restoration or reclamation of disturbed lands after construction.
- Compensation by funding conservation efforts based on the fatalities in the plants
- Increase the cleared area directly around the tower to reduce the active habitat at the site
- Recommendation to suspend operation of the tower plant during peak migration periods for some species. This will however adversely affect the feasibility of the plant by directly restricting export of electricity and thus income.

4.2.2.2 Land-Based Species

Animal species that inhabit the lands in and around sites for CSP plants may be exposed risks ranging from loss of habitat to fatality. This is related to increased human activity and site preparation.

4.2.2.2.1 Occurrence of Risks

The risks to animals occur in instances such as loss of habitat, fatality, injury and predation. These occurrences are as listed below.

a. Loss of habitat

The development of CSP power plants and their related infrastructure including access roads and transmission lines may cause the disruption of migration routes and habitat fragmentation.

The desert tortoise, an important species in the southwest USA, lives in burrows in flat alluvial fans. A study carried out at twenty-nine palms in the Mojave desert revealed that these animals are above ground 45% of the time during a productive year and 20% during a drought year[30]. This makes them and their burrows hard to detect when planning for location of a CSP plant. The tortoises colour also camouflages them in the dry land environments making them hard to detect.

The noise introduced during construction and movements during operation also disturbs the tortoise, as is the case with birds. Land clearing and other activities during site preparation and upon establishment of the facilities have been found to reduce the habitable area for tortoises. The presence of the CSP infrastructure across the area also impedes the movement of the tortoises to important areas for their nutrition or survival [30]. Together these contribute to loss of habitat for not only this species but to all species that live off resources in the plant area. The same effect can reasonably be expected at other CSP sites with different species being affected.

b. Fatality, injury and predation

The activities and movement of people at the site of CSP plants and associated infrastructures expose on site animals to various dangers. The animals may face trampling or being hit by vehicles, increased predation, entrapment and injuries. Increased human activity could also see an upsurge of take of animals from the site and its environs.

Animals that live in burrows and rock crevices among other places could be injured during the clearing and grading of land especially for development of tough plants. This would be the case if pre-construction site surveys were not comprehensive or if the animals moved into the site after these surveys. Processes requiring the use of heavy equipment may lead to destruction of burrows and injuries or fatalities to animals.

Juvenile desert tortoises (Figure 4-16) in the southwest of the USA face increased predation risks from ravens that feed on them. Ravens are reported to expand their territories with human encroachment. They follow humans and feed on garbage and road kill left in the wake of human activities [23]. Tortoise mortality may increase when there is a lot of movement of vehicles on access roads to plant site as is typical during construction. The tortoises may be attracted by the water used in dust abatement.

Figure 4-16: Left: A Juvenile Tortoise observed walking outside the Rice solar Electric project site. It had walked into and out of the plant through an incomplete section of a tortoise exclusion fence. Right: desert tortoise shade structure installed along the Rice solar project perimeter and exclusion fence (Source: [44]).

4.2.2.2.2 Risk impact

Some of the risks as identified from the literature [23], [30] are as stated below:

- Disruption in migration routes may limit the health of wild animals by separating populations thereby preventing gene exchange and blocking access to areas of significance to their foraging and social lives.
- Loss, degradation or fragmentation of animal habitats due to increased human activities
- Invasion of non-native species of plants that affect the supply of food and increase the risk of fire.
- Changes in habitat may reduce the viability of a species by starvation, increased predation, increased mortality and decreased fecundity[6].
- Introduction of new predators that prey on the young such as ravens on juvenile desert tortoises.
- Loss of shelter and cover from predators may occur after clearing of an area in preparation for installation of plants and associated infrastructure
- Sediments from the construction sites carried downstream during flooding may disturb the burrows of some animals.
- Fossorial[7] species (small rodents and reptiles) are exposed to injuries and death during clearing and grading processes.

[6] This is the actual reproductive rate of an organism or population

4.2.2.2.3 Mitigation

The risk to land based animal species can be mitigated and reduced. Some of the measures that could be undertaken include:

- Acquisition of replacement land to connect important habitat and animal populations and compensate for loss of original habitat.
- Resettlement of resident species in the project site on alternative sites
- Designing the site for easy animal access to certain critical paths. This could be fenced under crossings that direct small animals like Tortoises or exclusionary fencing as seen in Figure 4-16 and Figure 4-17 to keep animals out of a certain area protecting them from harm.
- Enforcement of lower speed limits on project sites to reduce cases of road kill
- Collection of road kill to avoid further attraction of predators
- Training personnel on environmental awareness.

Figure 4-17: Desert tortoise exclusion fencing and crossing guards at the entrance of the Rice Solar Power plant being removed at the Northern Perimeter where gates were located. Trenches were also backfilled and the grading of the land at the road returned to its original state for use by burrowing animals (Source: [45]).

4.3 Water Resources

CSP plants require water for cooling, mirror cleaning, make up water for the steam cycle, and sanitation needs amongst others [34]–[37]. Demineralised water is used as make up water for the closed water/ steam cycle while cooling towers do not require the specially treated water.

Since areas with good DNI resources also tend to be water scarce, there is competition between various uses of water and thus water reserves need to be controlled and used sparingly based on need. Location of CSP plants and associated infrastructure may also affect natural runoff paths in dry areas.

4.3.1 Occurrence

The occurrence of the risk to the water resources as a result of the use of evaporative wet cooling systems and the possibility of obstruction of dry land streams is described in this section.

[7] Species adapted to digging and living underground

4.3.1.1 Evaporative wet cooling Systems

Cooling systems are used to reject waste heat from the thermodynamic cycle in a CSP plant. The commonly applied systems are evaporative wet cooling, dry cooling and hybrid cooling.

Evaporative wet cooling involves the rejection of waste heat to the air by evaporation of cooling water in a Wet Cooled Condenser (WCC) illustrated in Figure 4-18. The turbine exhaust steam is directed to surface condenser where it is condensed over condenser tube bundles that are cooled by the evaporation of cooling water on the tube surface.

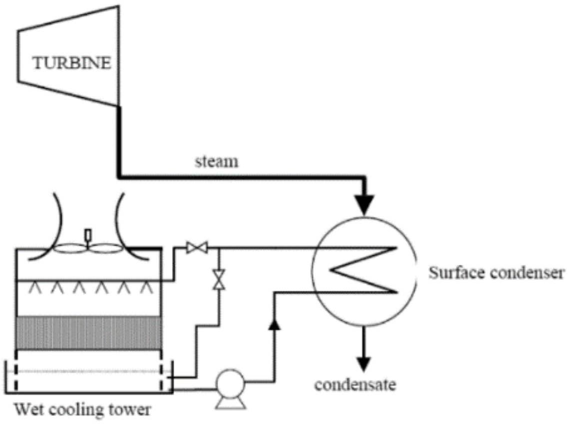


Figure 4-18: Wet cooling system conceptual design showing the flow of low quality steam to the condenser where it is cooled through the evaporation of cooling water in the cooling tower and sent back to the boiler as condensate [46]

The resulting hot water is then cooled by ambient air blown across the pipe (naturally for plants > 500 MWe or by fans) as it exits the condenser and cooling tower to return to the boiler[6]. The tower can bring water to as cool as within 5°C of the wet bulb temperature[8]. WCCs typically operate at about 10°C higher than wet-bulb temperature [47].

Evaporation accounts for the bulk of the cooling and also results in deposition of dissolved chemicals. To remove these, part of the cooling water is drained, resulting in a high salt concentration discharge called blowdown that is sent to evaporation ponds. Cooling tower design allows a cooling water total dissolved solids concentration of 4 - 5 times that of the makeup water. Some treatment chemicals may also drift into the ambient air[47]. Where it is used, wet cooling consumes from 80 to 97% of the water requirements of a CSP plant [46]–[48].

Comparison of Wet, Dry and Hybrid cooling

The switch from the commonly installed wet cooled to air cooled or Hybrid condensers will have significant effects on the costs and water consumption of CSP plants as enumerated in Table 4-1.

[8] The temperature achieved by a moistened thermometer in flowing air. It reflects the reduced temperature that can be achieved when evaporation from the surface is considered[47].

Table 4-1: Comparison of wet, dry and hybrid cooling for CSP plants

Parameter	Wet Cooling	Dry Cooling	Hybrid Cooling
Water consumption[9] (m^3 /MWhe)[47], [49] Parabolic trough: Solar tower:	 3.03 – 3.5 1.89 – 2.84[10]	 0.303 0.34	 0.378 – 1.703 0.34 – 0.945
Capital Costs [49] Trough & Trough Plant: **Unit cost of electricity** [49] Trough Plant: Tower Plant:	 Base case Base case Base case	 + 4 – 5% + 2 – 9 % + 2 – 5 %	 + 2 – 3% < + 8% < + 5%

Comparative Analysis of water use by CSP and other uses

Water use by CSP plants has understandably gained significant attention mainly in dry areas where these plants are located. In these areas, water is used in activities such as irrigation. It is thus beneficial to compare the use of water for these activities to that of running CSP plants.

As indicated in Figure 4-19 CSP has a lower water consumption density (m^3/m^2/Year) than cotton crops, fruit trees alfalfa and golf courses [47]. This however cannot be interpreted excluding the typical surface areas involved for the activities as the absolute amount of water used is essential to estimate depletion of resources.

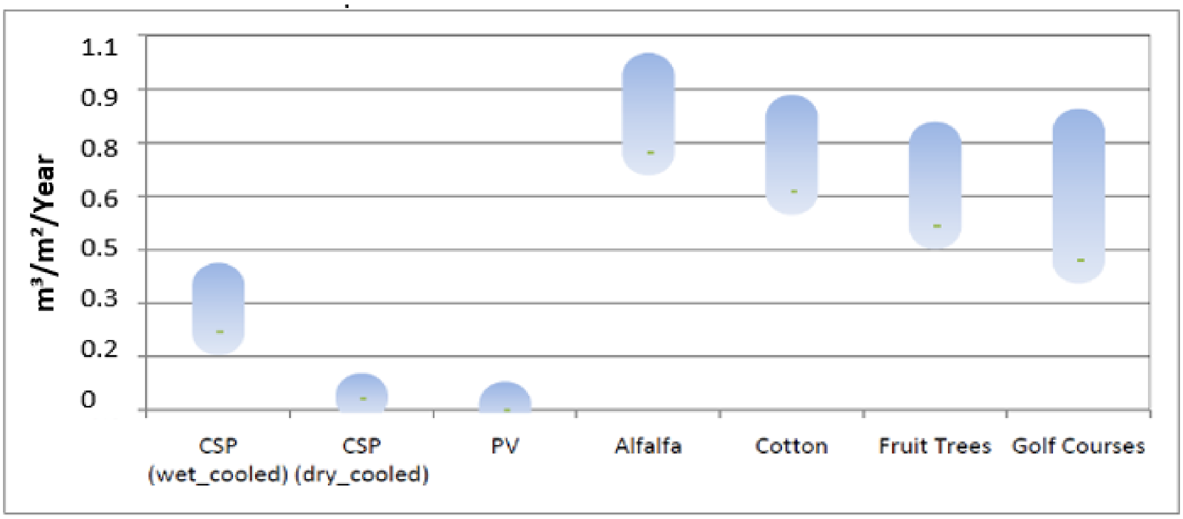


Figure 4-19: Water use by different activities in the south west of the USA[47]. CSP plants use less water per acre than agricultural and golf activities. An absolute quantity comparison would be more revealing as CSP plants use more land.

An 18-hole golf course in the CSP-significant southwest of the USA would use approx. 566,168.2 m^3 of water per year [50]. A 100 MW, 15hr fully loaded CSP wet cooled trough plant would use approx. 1,658,925 m^3/yr. and a dry cooled version of the same plant would use approx. 165,892.5 m^3/yr.

[9] The water consumption of a wet cooled coal plant is 2.2m³/ MWhe while that of a wet cooled nuclear plant is 3.2m³/MWhe. Wet cooled trough plants consume more than nuclear and coal due to lower life cycle efficiency and more frequent startup and off-design operation[47]

[10] Tower plants have higher thermal efficiency thus utilise less water than trough plants

[47].This marked decrease in water consumption by use of dry cooling implies that the CSP trough plant with dry cooling would use less water than a golf course.

4.3.1.2 Obstruction of dry Land streams

Dry lands have streams that flow in the watercourses defined by elevation of land on either sides that determine the course of the stream at the highest water level. This is illustrated in Figure 4-20. These streams may be perennial, ephemeral or intermittent. Streams recharge ground water; move nutrients, sediments and debris through their networks; and provide habitats and connectivity for species, supporting the biodiversity in dry areas [51].

Figure 4-20: Left: Watercourse boundary of a compound channel showing a low flow meandering channel in a larger watercourse Right: Alluvial fans flowing from a stream channel splitting into distributary streams. (Source: Marli Bryant Miller[51]).

Flooding may reactivate dry streams and may cause flows of up to 280 times the nominal flow. Localised rainfall patterns can also cause flow in one tributary of a stream to be larger than others, causing a shift in direction of a stream at the point of confluence[51].

A CSP plant in these areas would, as is common practice, need a hydrological survey of the proposed site. This would map watercourses, drainage and irrigation canals, streams and washes to predict storm water flows and flood hazards in the vicinity of the site. Planning to avoid blocking or unplanned diversion of streams is necessary.

4.3.2 Risk impact

The impact of the risk to the water resources as a result of the use of evaporative wet cooling systems and the possibility of obstruction of dry land streams is described in this section.

4.3.2.1 Water Use

There is a risk of diversion of much needed water resources away from other uses in water scarce regions thus introducing risk of water scarcity. This may be due to extraction from surface flows, boreholes, lakes or utility pipelines. In the extreme case water scarcity could end up affecting the food supply of the area.

4.3.2.2 Dry land streams

The disturbance of stream flows by inappropriate siting of CSP plant and associated infrastructure may act to divert flows that would then affect distribution of nutrients. This may lead to disturbance of the ecological environment of the dry areas by cutting off the flow of nutrients to downstream flora and fauna.

Onsite and offsite flooding may also result in case of blocking or diversion of flow. Diversion away from plant site may contribute to flooding during long-term flood flows in areas where no or reduced flows due to action of streams on project site, would have otherwise been expected.

4.3.3 Mitigation

The mitigation methods proposed to reduce the use of water and interference with the dry land streams are as outlined below.

4.3.3.1 Water use

- Switching to dry cooling is the most suitable option to reduce water consumption in CSP plants. As described above, this leads to 80-90% less water use. This however comes with a possible performance penalty (where design point capacity is not the target of the shift to ACC) and higher costs. A shift to dry cooling should consider an oversized air cooled condenser to guarantee similar output.
- Water use should be metered and monitored to avoid waste and to allow for improvements in efficiency of use.
- To the greatest extent possible, water should also be recycled and use of rain or grey water encouraged for activities like cooling, maintenance and dust suppression.
- The excessive extraction of water from ground water basins should be avoided

4.3.3.2 Dry land Watersheds

- Hydrological survey of stream systems, as is done in the development phase of projects, must be undertaken. The aim is to avoid significant disturbance of dry stream flows by choice of suitable site and associated infrastructure locations.
- The heliostats and trough support structures as well as tower and other buildings should be built to withstand the strongest site specific storm water scour. This includes consideration of potential erosion depth and peak water flows during 100-year storm water flows.
- Any grading and surface works done should be done in response to the identified risks on the site.
- Reuse of makeup water for mirror washing after treatment
- The use of dust palliatives during the grading processes should also ensure protection of the natural environment aside from conservation of water.

4.4 Risk to Land Use, Visual and Recreational Resources

This section describes the risk posed due to land use by CSP plants and the risk posed to visual and recreational resources by the development of CSP plants.

4.4.1 Land use

Prior to acquisition of land for projects negotiations are undertaken with the owners of the land aimed at compensation for loss of the land and its accompanying use value. However, the loss of this use-value is of concern for the local economy and as such needs to be looked into.

CSP developments occupy significant parcels of land, accommodating the power block and heliostat or collector fields. The 360 MW Plata Termosolar Pedro de Valdiva trough plant in Chile upon completion will occupy 19.8 million m^2 [52] while the Ivanpah tower plant in the USA occupies 16.2 million m^2 of land. Generally, more capacity implies more land use to accommodate an expanded solar field. The use of these lands by CSP may also have side effects such as noise and dust.

4.4.1.1 Occurrence

The results of an NREL study of the use of land by solar power plants per MW for power plants greater than 20 MW are illustrated in Table 4-2 and Table 4-3. The study adds that it is more useful to analyse CSP land use per unit of generation due to storage and effects of solar multiple[11]. These can increase the energy generated per unit of generation capacity. The study however recommends that a bigger sample size is required to draw conclusions.

Table 4-2: Total land-use requirements by CSP Technology for plants analysed by NREL (Source: [53])

Technology	No. of Projects	Capacity (MW)	Capacity-weighted average area required (m^2/MW)	Generation -weighted average area required (m^2/GWh/yr)
All CSP	25	3,747	40,468.6	14,164.0
Trough	8	1,380	38,445.1	15,782.7
Tower	14	2,358	40,468.6	12,949.9

Table 4-2 shows data for land within the enclosure of the plant including the spaces and paths in the solar field and around the power block. On the other hand, Table 4-3 gives the direct land use, defined by the land that plant facilities sit on.

Table 4-3: Direct land use requirements by CSP plants analysed by NREL (Source: [53])

Technology	No. of Projects	Capacity (MW)	Capacity-weighted average area required (m^3/MW)	Generation -weighted average area required (m^3/GWh/yr)
All CSP	18	2,218	31,160.8	10,926.5
Trough	7	851	25,090.5	10,117.1
Tower	9	1,358	36,017.0	11,331.2

[11] NREL define the solar multiple as a way to express the solar field aperture area as a function of the power cycle capacity. A solar multiple of 1 is the aperture area required to deliver sufficient thermal energy to the power cycle to drive it at its nameplate capacity under design conditions. The solar multiple is useful for optimizing the solar field size for a given power cycle capacity and location.

The use value of the land and site specific connectivity for each project determines its land-specific impact. A plant using a large parcel of non-productive land that is of little ecosystem benefit may have less impact than one using a smaller parcel in an agriculturally or ecosystem significant land.

A comparison of CSP plants with other generation facilities done by the European Academies Science Advisory Council (EASAC)[7] showed that CSP used land moderately per MWh generated compared with other technologies as shown in Table 4-4.

Additionally, visual impact comparisons were undertaken for CSP and wind and represented in m^2/MWh/Yr. representing the area over which the power plant disturbs the view divided by the energy generated in a year.

Table 4-4: Comparison of land use and visual impact of CSP plants and other generation technologies. Comparatively, CSP plants were found to use less land to generate a MWh and visually affect a lesser area compared to wind parks (source: [7])

Activity	**Land Use [m^2/(MWh/y)]**	**Visual Impact [m^2/(MWh/y)]**
Parabolic Trough solar power, Spain	11	15
Solar tower power, Spain	24	1,100
Photovoltaic power plant, Germany	56[12]	-
Wind power plant	<5	8,600
Biomass Plantation, France	550	-
Open cast mining (lignite), Germany	60	-
HV transmission lines across Europe	0.4	-

4.4.1.2 Risks impact

The risks and impact of the development of CSP plants in certain land parcels are:

- Loss of farmland
- Conflict with other land use plans dedicated to mitigating environmental effects
- Physical disruption or division of an established community
- Conflict with other natural habitat, community conservation plan or a biological opinion. Right of ways for transmission lines could for instance cross a conservation area
- Cumulatively significant impacts when many projects developed close to each other
- The use of the land may result in unmitigated noise, public health and safety issues, adverse visual impacts, generates dust or interfere with or prevent future productive uses

4.4.1.3 Mitigation

- The consideration of alternative plant layout, designs and setup can allow the selection of the most acceptable plant physical size and least disruptive configuration. This may also allow for special lands to be avoided in the designs reducing the impact of land use. The development of alternatives will however involve additional costs.
- Encourage use of low quality locations such as abandoned mining land, existing transportation and transmission corridors and brownfields[53]. The use of previously disturbed lands should

[12] PV can be installed on rooftops in which case the land use is zero as the building already exists [7]

be maximised while use of land requiring removal of shrubs and trees or requiring significant slope levelling or grading should be avoided to the extent possible [54].

Mitigation will be dependent on the pre-project use value of the land. Though most CSP plants are located in relatively dry, subprime and arid lands, these lands may provide for habitat, migration routes, transport routes and irrigated agricultural uses for stakeholders and fauna.

The analysis of the use of land for CSP projects should also be done considering the benefits of an additional local renewable energy source that boosts the local economy.

4.4.2 Visual and Recreational Resources

Desert/dry land areas are commonly used for recreational purposes including star gazing, trekking and site seeing among others. The development of CSP plants in these areas may affect these activities.

4.4.2.1 Occurrence

In the Palen Solar Electric Generation Station (PSEGS) licencing hearings (proposing a redesign of the Palen Solar Power Plant (PSPP, a trough plant) to PSEGS (a tower plant)) it was reported that the development of a trough plant would reduce the scenic value of the wilderness area. It was further added that when these plants are developed in a cluster then the impact is more significant[23].

The tower plant variant was also seen as imposing over the landscape and interrupting the scenic vista[13] of the area. Such interruption is what is observable in Figure 4-21 at the Ivanpah plant.

Figure 4-21: One of the towers in the Ivanpah power plant seen with a backdrop of hills and open scenery. Towers are adjudged to impose on scenery especially when operational and receiver is brighter than ambient lighting. (Source:[1])

[13] Scenic Vista : Refers to a view of high scenic quality perceived through and along a corridor or opening or a view from a designated scenic area[23]

CSP plants are seen to have significant effects on the scenic vista; degrade the existing visual character of the site and surroundings and produce glare and stray light that would affect day or night-time viewers[23]. Mirror cleaning operations carried out at night have also been identified as causes of stray light in the night time [6].

4.4.2.2 Risks impact

A study was undertaken by the University of Idaho on the reasons for visiting the nearby Joshua Tree National park. It revealed that 90% of the visitors to the park visited it for the uninterrupted landscape and the 65% for the dark starry night skies that would be interrupted by lit plant facilities at the proposed Palen CSP plant close to the park [23].

The permitting process for the shift from a trough plant to a tower plant at Palen found that some of the tower-specific risks posed would be;

- Domination of the landscape by the brightness of the tower demanding attention and showing high levels of visual contrast up to 16 kms away
- Light pollution from the mandatory aviation strobe lights and operational lights.
- Sharp glare from the shielding structures below and above the receiver
- Significant visual impact due to the contrast between graded and non-graded soils after the demobilisation of facilities at the end of life

The switch from PSPP to a PSEGS was rejected by the CEC due to, among others[14], significant and immitigable direct impacts on the scenic resources of the area [23]. This was mainly linked to the brightness of the tower.

4.4.2.3 Mitigation

Although the imposing nature of CSP plants on the landscape cannot be avoided, its impact can be reduced by several mitigation measures as described below[23], [55].

- The impact on visual resources in the development of access roads and transmission line right of way may be mitigated by choosing less disruptive designs as illustrated in Figure 4-22.
- Surfaces of structures and buildings can be painted with the landscape colours to reduce contrast and intrusion.
- Re-vegetation of disturbed soils to the extent possible.
- Use of non-specular and non-reflective transmission line conductors and non-refractive, non-reflective insulators should be used to reduce reflections.

[14] The switch was denied due to significant and immitigable effects on Visual resources, cultural resources and biological resources.

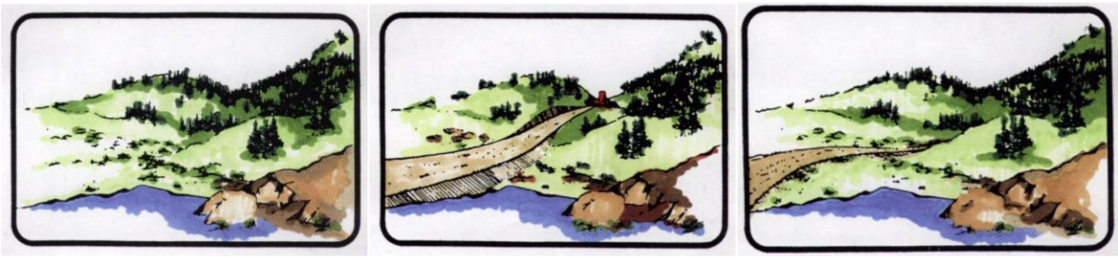


Figure 4-22: An example of mitigation for visual impact in the development of an access road. Left: the undisturbed existing site where a road is planned to be built. Centre: The proposed construction plan of the site shown to cut right through the hills in the background. Right: the mitigated option. It meanders around the hill causing less visual impact from the road (source:[55]).

- Light pollution may be reduced by installing the lighting such that reflectors and lamps are not visible beyond project site by pointing them downwards and having down pointing shades; avoiding illumination of the night time sky except for aviation safety; and ensuring minimal illumination of the project site and its vicinity.
- Where the power plant is close to a road, the provision of roadside screening, trees, cactus or tall vegetation along the edges of the road is recommended to reduce visual impact and chances of glare.
- The restoration of the project site to its original condition at the end of the project is also recommended. This includes restoring the land forms, natural vegetative community, hydraulic systems, visual resources and wildlife habitats.

4.5 Risk Worker Health and Safety

The occurrences, risks impact and mitigation measures related to worker health and safety are described in this section.

4.5.1 Occurrence

The risk to worker health and safety in CSP plants is mainly due to the Heat transfer fluid, and accidents that may occur. These are outlined below.

4.5.1.1 Thermal oil Leaks, Fire and Explosions

Thermal oil refers to the fluid used in parabolic trough plants to transfer heat energy from the concentrated solar irradiation to the thermodynamic cycle. The HTF system is typically a closed loop system at high temperatures and pressure. Leakages may occur due to inappropriate maintenance or poor design. These leakages occur at valves, flexible hoses, ball joints, rotary joints pump seals or instrument manifolds[56].

Leakages have the potential of causing fire or explosions, as was the case in Solar one plant in 1986[57]. In this incident an explosion occurred after an accumulation of Heptane gas at the backup heater ignited and blasted a hole in the HTF tank setting fire to over 900,000 litres of mineral oil. In 1999 at the same plant, human error is reported to have caused the temperature of the HTF to exceed the safe limit leading to explosions captured in Figure 4-23. About 3.4 million litres of therminol was burned, but the fire was contained before it reached adjacent sulphuric acid and caustic soda tanks[58]. Fortunately in both cases there were no casualties.

Figure 4-23: Explosion at Daggett SEGS II caused by overheating, vaporisation and ignition of the thermal oil [59]

The leaking and explosion problem is most severe with synthetic fuels. Molten salts used for thermal storage quickly solidify when they leak owing to their high freezing points of about 238°C. These salts are also the type commonly used in the production of fertilizer thus do not pose any risk to the soil. Synthetic oil leaks pose a high fire risk. The HTF is mostly a eutectic mix of biphenyl and biphenyl-ether that goes to the soil and is partly absorbed by plants that may be eaten by humans and animals.

4.5.1.2 Accidents

Accidents may also occur during the construction of CSP plants due to various reasons such as breakage of mirrors during mounting, or as happened recently at the CSP plant in South Africa, bad weather (severe storm with high wind speeds) was said to have caused the collapse of a crane[60]. The collapsed crane illustrated in **Figure** 4-24 lead to the death of two employees and injuries to seven others.

Figure 4-24: Collapsed Crane at the Khi Solar One project in Upington, South Africa on the 3rd of November, 2014. Two people lost their lives and seven were injured. The tower is visible and the collapsed crane lays on the ground over part of a container-office (Source: [61]).

4.5.2 Risk impact

The potential impacts of the occurrence of the risk to worker health and safety are as outlined below.

4.5.2.1 Worker injury or Fatality

Workers may get injured or lose their lives when incidents such as fire occur.

4.5.2.2 Possibility of long term health complications

The prolonged inhalation of leaked hot gaseous thermal oil may have some long term health effects on workers at CSP trough plants. However, no research assessing this was available at the time of preparation of this thesis.

The short-term inhalation of gaseous thermal oil was considered to not present an acute health risk but produced an irritation to the eyes and upper respiratory tract. The inhalation of a eutectic mixture of biphenyl and diphenyl ether (7 – 10 ppm or 50 -71 mg/m³) was found to cause nausea while the presence of biphenyl caused a vomiting sensation in humans. Systemic toxicity for humans was estimated to occur with continuous exposures above the no observable adverse effect level (NOAEL) of 35mg/m³. In cases of systemic toxicity rats that were tested were found to lose weight after 20 exposures of diphenyl ether for 7 hours/day in 31 – 33 days at 20 ppm[62].

4.5.3 Mitigation

- Development of a fire management plan and provision of firefighting and prevention equipment and designs.
- Strict adherence to occupational health and safety guidelines of the country where the plant is built. This should include emergency procedures for spills of HTF and other hazardous substances in the plant.
- Provision of personal protective equipment such as anti-glare goggles and gas masks or protective clothing to prevent contact with leaking HTF or inhalation of fumes.
- Continuous training on safe operation of machinery and equipment
- Suspension of activities on site during extreme weather conditions
- Design of heliostats with shatterproof or laminated glass to reduce chances of cuts in case of breakages

4.6 Risk due to Noise on the Acoustic Environment

CSP plants produce noise to the surrounding environments. The occurrences, risks and mitigation measures related to the noise are described in this section.

4.6.1 Occurrence

The noise at CSP plants is due to use of heavy equipment and during activities such as steam blow downs as described in this section.

4.6.1.1 Steam blow downs

Steam blow downs are undertaken to clean the piping after erection and assembly of the feed water and steam systems. They are done to remove accumulated rust, scale welding spatter and construction debris that if not removed would destroy the steam turbine upon start-up. High pressure steam is passed through the piping whose end is open to the atmosphere, flushing and thus cleaning the piping.

High pressure steam blow downs are reported to result in noise of up to 130 dBA at 15 meters. These are usually carried out for 2 - 3 minutes several times a day for 2 - 3 weeks. These can however be attenuated by the use of a silencer to 89 dBA at 15 meters[23]. The OSHA guidelines of the US department of labour recommend that impulse noise should not exceed 140 dB [63]. Additionally they recommend maximum noise levels for a given duration of exposure as in Table 4-5. Exceeding these limits of exposure may lead to permanent loss of hearing ability.

Table 4-5: Permissible noise exposure levels per day as defined by US OSHA [63]

Daily duration of Exposure (Hrs)	8	6	4	3	2	1.5	1	0.5	≤ 0.25
Sound Level (dBA)	90	92	95	97	100	102	105	110	115

4.6.1.2 Use of Heavy Equipment

This refers to the noise generated by machinery in use during construction and noise from plant components during operation. Equipment like bulldozers and pile drivers during construction and pumps and dry cooling fans in the operation phase will produce significant noise. An idling bulldozer is reported to produce a sound of 85 dBA while pile driving is reported to cause noise of about 101 dBA [6]. The noise from the fan of air cooled condensers could range from 79.3 dBA to 106 dBA [64]. For comparison, the noise from a jet engine taking off is 140 dBA, a ringing alarm clock is 80 dBA and a running motorcycle is 100 dBA[65].

Table 4-6: World Bank Noise Abatement Guidelines for various times in the day and town zones[66]

	Maximum allowable log equivalent Noise (hourly measurements), in dB(A)	
Receptor	Day	Night
	(07:00 – 22:00)	(22:00 – 07:00)
Residential, institutional, educational	55	45
Industrial and Commercial	70	70

The World Bank pollution prevention abatement handbook recommends that noise abatement methods should achieve the noise levels outside the project property boundary as defined in Table 4-6 for one hourly exposure, or a maximum increase of 3 dBA above background levels [66]. It is plausible that this limit would be exceeded during construction.

4.6.2 Risk impact

Some of the risks posed by the noise in CSP plants include;

- Possible damage to the hearing ability of workers and animals in the vicinity
- Interference with human and animal life in the area through difficulties in communication and disruptive sounds. In birds this could interfere with protection from predators and mating rituals.

4.6.3 Mitigation

Some of the proposed mitigation measures are;

- Enforcement of standard industry noise abatement measures including mufflers and silencers.
- Use of a low pressure technique for steam blows to release the pressure over a continuous period of up to 36 hours and reduce blow down noise [23].
- Provision of hearing protection aides to workers: this is suggested to be enforced actively when the sound levels are ≥ 85 dB over 8 hours or where a peak of 140 dB or where the average maximum is 110dB. The protective devices should be able to reduce the noise to less than 85dB
- Using less noisy equipment: Preferring electric and hydraulic powered equipment to diesel and pneumatic powered equipment which are generally noisier. The use of vibration isolating equipment like rubber mats and springs between noisy equipment could also help reduce noise in boiler rooms and ducting [6].
- Barrier Protection: this is the putting up of purpose built barriers to check noise emitted from equipment. According to Lahmeyer database enclosing noisy equipment could result in an 8 - 10 dB reduction in noise level [6]. These barriers could be acoustically treated with thick layers of sound-absorptive materials like fibre glass or wool.
- Enhancing the maintenance of equipment: equipment should be well lubricated and maintained to curb any increase in noise due to equipment condition. Checks for worn bearings, loose parts, imbalance in rotating parts and blunt cutting faces should be done. Mufflers silencers and vibration isolators should also be maintained in good condition.
- Proper scheduling of work activities: effective location and time planning of noisy equipment and their run times can reduce the effects of noise. This equipment should be positioned farthest away from sound-sensitive areas like homes and nests. Noisy jobs on-site could also be scheduled optimally over the course of the workday to reduce peaks and exposure times.

4.7 Miscellaneous Risks

The other additional risks identified during the study were summarised as in Table 4-7.

Table 4-7: Summary of additional Environmental and Social Risks in the Development of CSP plants

Environmental and Social Risk	Occurrence	Risk impact	Mitigation
Risk to Social Economics	- Insufficient Involvement of local populations in development of projects - Non-comprehensive Social and Economic Assessment (SEA)	- Loss or disruption of socio-economic activities - Disruption of Social cultural activities - Water shortages leading to food insecurity and social instability - Demonstrations and upheaval in the project area	- Gain social acceptance of the project by engagement of the persons affected by project - Undertaking a comprehensive study of the social economic and political conditions - Local manufacture and assembly of conventional components - Ensure use of quality local supplies of goods and services, staff and subcontractors - CSP projects create jobs during construction and operation. These benefit the local economy.
Risk to Air Quality[6]	- Auxiliary conventional boiler emissions - Construction dust - Emissions from emergency Diesel engines for Fire pumps - Vehicles on site during construction and operation	- Air Pollution by dust during construction - Emission of GHGs from auxiliary boiler - Particulate matter in air: Larger particles as fugitive dust and small PM2.5 including SOx and	- Implementation of adequate dust abatement methods that do not involve excessive consumption of water. - Preference for Natural gas backup boilers and good combustion tuning practices - Limit particulate matter emissions for

Environmental and Social Risk	Occurrence	Risk impact	Mitigation
		NOx [38]	the boiler and engines in the specifications to acceptable levels such as < 0.006gr/sdcf and < 0.05gr/sdcf[15] respectively in California[67]. - Implementing specific limits on certain emissions such as 500 ppmv[16] for SO_2 and 2000 ppmv for CO_2 - Use of ultra-low sulphur diesel for emergency engines (sulphur content ≤ 0.0015%)[67] - Covering vehicles that are used to transport bulk loose materials - Shut down of equipment on site when not in use.
Risk Posed by Waste and Hazardous Material Management [6]	- Blowdown from cooling towers and resulting evaporation pond sludge - Steam turbine lube oil flushes producing waste oil (used transmission fluid, motor oil and antifreeze) - Hydro-test water releases - Heat Transfer Fluid leaks (see Section 1) - Construction waste such as scrap metal, oily rags,	- Potential health and fire hazards to plants, animals and humans in the vicinity - Spread of trash in the area posing negative visual impact - Degradation of the soil quality	- Covering evaporation ponds with a net - Sending hazardous and non-recyclable waste to hazardous waste or solid waste disposal facilities as appropriate - Segregation and recycling of waste - Routing drains that could potentially contain oil to an oil and water separator. Extracting the oil and sending it for recycling - Monitoring for oil or lubricant spills and extraction of affected soils

[15] gr/sdcf – Grains per standard cubic feet
[16] Ppmv – Parts per million by volume

Environmental and Social Risk	Occurrence	Risk impact	Mitigation
	solvents, paint and insulation material		
Risk to Cultural Resources[6][68][23]	- Development of plant in the vicinity of culturally significant sites. - Change in the visual nature of culturally significant sites including the introduction of glare (mainly tower) - Side effects of plant developments such as increased noise and traffic obstruction	- Disturbance, disruption or destruction of culturally significant areas, resources or activities	- Engage local cultural experts during project development to ensure avoidance of threats to sensitive cultural resources - Minimising the visual impacts by reduction of contrasts and repetition of elements of form, line, colour and texture. - Incorporation of long term monitoring efforts
Risk to Geological Resources [23]	- Plant components or transmission lines and access roads located in a geologically sensitive area like fault lines	- Initiation of geological activity like faulting, ground shaking, liquefaction[17], rock falls, cave-ins, landslides, hydro and dynamic compaction caused by foundation works, grading or weight of plant components (troughs/ heliostats, tower, Steam turbine, transmission lines among others)	- A geotechnical survey before plant development would be expected to ensure plants are not located at sensitive areas to the extent possible - These are expected to be fully addressed by the above survey.
Risk to Land Traffic and	- Movement of construction and decommissioning-related	- Obstruction of traffic - Increase of dust	- Minimise movement of construction vehicles at peak traffic hours.

[17] Liquefaction: a condition in which a saturated cohesion-less soil may lose shear strength because of sudden increase in pore water pressure caused by an earthquake [23]

Environmental and Social Risk	Occurrence	Risk impact	Mitigation
Transportation	heavy vehicles may disrupt normal transportation - Glare from mirrors distracting drivers	- Distraction of drivers close to CSP plants - Annoying after images to viewers from glare	- Incorporation of a blocking façade such as planting a column of trees on the side of the roads within close proximity to plants. This would block the reflections incident on the road
Risk to Paleontological Resources[23]	- Plant components or transmission lines and access roads located in paleontological significant areas	- Disruption of historical artefacts, fossils and remnants in alluvial formations in vicinity of project facilities. These may be encountered during grading and road and transmission line works.	- Worker training by palaeontologists to identify sensitive areas/ finds - Monitoring of earthworks by a paleontological resource specialist
Risk to Public Health and Safety	- HTF fuel leak and explosion	- Fire, damage of property and possible fatalities (See section 1)	- Develop plants away from populations or with a buffer.
Public Opinion Risk (Adverse Publicity) (see also Section 4.2.2.1.44.2.2.1.4	- Adverse and / or non-factual coverage of environmental and social risks in the media	- Long term impact on future licencing or extension of licenses and regulations. - Complications in accessing financing - Public protests against project - Post-commissioning requirement for further investment in tests and external reviews	- Making available documents and reports pertaining to the risks during all phases of the project - Sensitisation on the real magnitude of the risks and proper, publicised and factual responses to reporting. - Openness to scrutiny - Stakeholder involvement at all stages of development and including the local communities - Incorporation of concerns of local groups and regular flow of information.

5 Ranking of the Key Environmental and Social Risks

In this section the results of the risk analysis process carried out following the procedure outlined in Section 2.2.2 are presented. Explanations behind the ranks for each risk are given as well as the inter-risk ranking for the sixteen (16) surveyed risks.

5.1 Individual Risk Ranking

The identified risks were analysed and scored by independent engineers and the average of their ranking on a scale of Low to High are as highlighted in Table 5-2. The ranking procedure employed is as described in section 2.2.2.2. A colour code is used as in Table 5-1.

Table 5-1: Colour code for the risk ranks

Risk Ranking	Colour Code
Low	
Low-Moderate	
Moderate	
Moderate-High	
High	

Table 5-2: Individual Risk Ranking Before Mitigation

Risk	Ranking	Comments
Risk of depletion or disruption of local Water Resources	Moderate-High	This risk is elevated due to the heavy reliance on weather and climate for the recharging of aquifers and continued flow of rivers and streams. These aquifers provide an important source of water for the residents and activities in dry land areas. Wet cooled plants have a relatively high use of water, especially the wet cooled parabolic trough plant due to its lower cycle efficiency and more frequent start-up and off-design operation (See Section 4.3)
Risk to Ecological Resources	Low-Moderate	The overall risk on Ecological resources is low-moderate. The highest risk being to avian species while low risks are posed to other animals and to plants as described below.
Risk to Avian Species	Moderate	This rank is mostly influenced by the effect of solar flux singeing on the birds in the vicinity of tower plants. This problem is not well understood and is also proving hard to effectively mitigate. While the number of fatalities has not and is not expected to be extreme, the danger of possible loss of endangered species found in dry lands increases the concern. For more details see Section 4.2.2.1.
Risk to other Plants and Animals	Low-Moderate	Non-avian animals and plants face a low-moderate risk as the animals can easily be excluded from the site by use of fencing while the plants can be relocated and replanted away from

Risk	Ranking	Comments
		possible harm where necessary. Alternative migratory paths and passages can also be designed allowing continued safe access to places important for nutrition, migrating or breeding. (See Section 4.2.1 and Section 4.2.2.2)
Risk due to Glint and Glare	Low-Moderate	The overall risk due to glint and glare is Low-moderate. The risk is particularly elevated in tower plants due to the high glint and glare at standby positions of the heliostats. Studies carried out at some plants however show that other than within the site of the plant, no major risk to eyesight is posed. An annoying after image was however recorded. For a detailed analysis refer to Section 4.1. This risk can also be avoided when safety precautions including training and use of protective equipment is undertaken.
Risk of withdrawal of Land for other uses	Low-Moderate	This risk is low-Moderate owing to the big footprint of both tower and trough plants, with the former having a larger one. The lands where the plants are located are however usually of low commercial use. Prior to commencing of projects, negotiations with the owner are undertaken that compensate them for the loss or withdrawn use value. The satisfaction of the owner is a prerequisite for project development. Refer to section 4.4.1 for more details.
Risk of disruption of Visual and recreational resources	Low-Moderate	This risk is brought about by the physical disruption on the landscape caused by siting of CSP plants. Towers and the bright light at their top impose on the scenery while both tower and trough plants generally alter the visual quality of the dry land areas. This risk is considered low moderate as a scenic view may be disrupted and while little mitigation can be undertaken, the loss of such a view is not considered highly deleterious. Even so, where the view is of high value to visitors, the development of plants at these locations could be impeded. Refer to section 4.4.2 for more details.
Risk to locational Social Economics	Low-Moderate	This risk is affected by the level of involvement, incorporation and consultation of the local community in the development and operation of plants. When this is inadequate locals may lose their income sources, ways of life amongst others. See Section 4.7 , Table 4-7 for more details. The rank given is low-moderate as CSP projects typically have a more positive impact creating more jobs, income generation opportunities, infrastructure and spurring development of local industries (goods and services).

Risk	Ranking	Comments
Risk of production of Hazardous Materials and waste	Moderate	While CSP for the most part is clean and non-hazardous some elements like the HTF, Therminol/ synthetic oil used in parabolic trough plants, are hazardous to the environment and will reduce the use-value of soils it leaks onto. Molten salts used in tower plants do not have this problem as they solidify when they leak and are also made using similar substances as fertilizer. During construction activities various wastes that are common in most construction sites are also generated. Combining the above and others leads to a moderate ranking. For further details refer to Section 4.7, Table 4-7 for more details.
Risk to Public Health	Low-Moderate	This risk is low-moderate as there are minimal dangers posed by CSP plants to public health. The most significant would be any explosion that may result due to HTF ignition. This is however containable within the site when fire safety procedures and equipment are available and are followed/used. Generally CSP plants are developed away from populations or in areas that are sparsely populated. Refer to Section 4.7, Table 4-7 for more details.
Risk to Worker Health and Safety	Moderate	The possibility and effects of leakage of synthetic oil in trough plants and its associated flammability means that the risk to employee health and safety is moderate. The leakages above however do not occur frequently and the use of Preventive Protective Equipment (PPEs) can reduce chances of burns and inhalation of hot HTF in case of leakages and reduce any glare incident on the eyes of workers. Refer to Section 4.5 for more details.
Risk to cultural resources	Low-Moderate	Where projects are located close to culturally significant sites where cultural activities are undertaken, there is a risk of disruption. This risk is however ranked as low-moderate as it can be avoided by incorporation of local cultural experts in the development of plants. Refer to Section 4.7, Table 4-7 for more details.
Risk to geological resources	Low-Moderate	Activities during construction of CSP plants may lead to ground shaking and disturbances in the structural composition of the ground at the site and its environs. This risk is low-moderate as a detailed geological survey would capture the possibility of such occurrences leading to mitigation measures or selection of an alternative site. Refer to Section 4.7, Table 4-7 for more details.
Risk to land traffic and	Low-Moderate	During construction access to the site and areas around the site

Risk	Ranking	Comments
transportation		may be disrupted by movement of people and trucks. There is also a possibility of glare during operation being incident on the wind screens of cars traveling on roads near the plants. This risk is ranked low-moderate as the disruptions can be controlled and the incidences of glare on adjacent roads are minimal and can also be effectively mitigated. Refer to Section 4.7, Table 4-7 for more details.
Risk to air quality	Low-Moderate	The main driver for this risk is the operation of Auxiliary boilers that run on fossil fuels. This is however an optional part of the plant and does not operate full time when incorporated. Mitigation is also possible by application of air safety standards and use of ultra-low sulphur diesel as described in Table 4-7, Section 4.7. The risk here is considered low-moderate.
Risk to archaeological resources	Low-Moderate	Site preparations have the potential to interfere with archaeological resources in the area. This risk is however low-moderate as these resources can be relocated when they are detected during the carrying out of civil works in the area. Refer to Section 4.7, Table 4-7 for more details.
Risk due to Noise and on Acoustic Environment	Moderate	The activities during construction including drilling and grading of the land and use of heavy equipment like bulldozers introduces noise greater than ambient levels. Hydraulic tests, pumps and fans used in dry cooling also produce significant noise in CSP plants (refer to section 4.6.1.24.6.1). A rank of moderate is given as this noise can be reduced by using of various sound muffling or silencing technologies and systems as described in Section 4.6.

5.2 Inter-Risk Ranking

The ranks for the risks before and after mitigation are given in this section.

5.2.1 Ranking before mitigation

Table 5-3 shows the ranking of the 16 surveyed risks before any mitigation is undertaken. The risk of depletion or disruption of local water resources was adjudged to be the highest while the risk to geological resources was the lowest amongst the risks surveyed. The risk to ecological resources was determined as the average of the risk to avian species and the risk to non-avian animals, and plants.

Table 5-3: Risk Ranking before mitigation

Position / Rank	Reviewed Risk
1	Risk of Depletion or Disruption of Local Water Resources
2	Risk to Worker Health and Safety
3	Risk to Avian Species
4	Risk of Production of Hazardous Materials and Waste
5	Risk due to Noise and on Acoustic Environment
6	Risk of Disruption of Visual and Recreational Resources
7	Risk to Ecological Resources
8	Risk to Locational Social Economics
9	Risk to Public Health
10	Risk due to Glint and Glare
11	Risk of Withdrawal of Land for Other Uses
12	Risk to Archaeological Resources
13	Risk to other Plants and Animals
14	Risk to Land Traffic and Transportation
15	Risk to Cultural Resources
16	Risk to Air Quality
17	Risk to Geological Resources

Note: The risks ranked from position six (6) down to seventeen (17) are all ranked as low-moderate and their rank is based on their different scores all within the low-moderate range.

5.2.2 Ranking after mitigation

Table 5-4 shows the ranking of the risks after possible mitigation is undertaken. The risk of depletion or disruption of local water resources was adjudged to be the highest while the risk to other animals and plants was the lowest amongst the risks surveyed.

Table 5-4: Risk Ranking after mitigation

Position / Rank	Reviewed Risk
1	Risk of Depletion or Disruption of Local Water Resources
2	Risk to Avian Species
3	Risk to Worker Health and Safety
4	Risk due to Noise and on Acoustic Environment
5	Risk of Disruption of Visual and Recreational Resources
6	Risk of Production of Hazardous Materials and Waste
7	Risk to Air Quality
8	Risk to Public Health
9	Risk to Locational Social Economics
10	Risk due to Glint and Glare
11	Risk to Ecological Resources
12	Risk to Cultural Resources
13	Risk to Archaeological Resources
14	Risk of Withdrawal of Land for Other Uses
15	Risk to Land Traffic and Transportation
16	Risk to Geological Resources
17	Risk to other Plants and Animals

6 Discussion

This section analyses the results from the survey using raw scores, comments from the surveyed engineers and literature review. The top six risks and the impact of mitigation are further analysed. The section concludes with an opinion of the risks or associated mitigation measures that may lead to termination of projects.

6.1 The top six risks

The ranking of the risks revealed that the top six risks in the development of CSP plants before mitigation were as illustrated in Table 6-2. This rank is driven by the estimated likelihood of occurrence and the unmitigated impact.

The risk to local water resources was ranked as the most significant risk before mitigation. Surveyed experts indicated a high impact where mitigation is not done and a moderately high chance of occurrence and cost of mitigation. This could be due to the sensitivity of water as a resource and the unpredictable nature of weather and possible climate change and the effects it may have on water availability. The use of water by wet cooling plants that are the most implemented cooling systems, as described in section 4.3.1.1 also contributes to this high rank. The knowledge levels over this risk and effectiveness of mitigation in practice were considered moderate. This meant that the risk retained the first position, even after mitigation as is described in Table 6-2.

Table 6-1: Average detailed score per factor for the top six of surveyed risks before mitigation

RANK	SURVEYED RISK	OF	IF	UIF	MIF	MCF
1	Risk of depletion or disruption of local Water Resources	Moderate-High	Moderate	High	Moderate	Moderate-High
2	Risk to Worker Health and Safety	Moderate	Low-Moderate	Moderate-High	Low-Moderate	Low-Moderate
3	Risk to Avian Species	Moderate	Moderate	Moderate	Moderate	Moderate
4	Risk of production of Hazardous Materials and waste	Low-Moderate	Low-Moderate	Moderate	Low-Moderate	Moderate
5	Risk due to Noise and on Acoustic Environment	Low-Moderate	Low-Moderate	Moderate	Low-Moderate	Moderate
6	Risk of disruption of Visual and recreational resources	Moderate	Low	Low-Moderate	Moderate	Low-Moderate

Where: OF: - Occurrence Factor IF: - Ignorance Factor MCF: - Mitigation Cost Factor
UIF: - Unmitigated Impact Factor MIF: - Mitigation Ineffectiveness Factor

The risk to worker health and safety with a moderately high impact before mitigation and a moderate rate of occurrence was ranked overall moderate and in the second position before mitigation. This rank was largely due to the dangers of leakage of the heat transfer fluids operating at high temperature and pressure and occurrence of leaks as described in section 4.5.1.1. This risk moved to position three after mitigation as it was adjudged to be a well-known risk with effective mitigation strategies that were seen to be of low-moderate cost. Its overall risk rank after mitigation however remained moderate.

In the third position before mitigation with an overall risk score of moderate was the risk to avian species. The occurrence and impact of this risk was seen to be moderate. This was likely driven by the avian fatalities recorded compared to structures like low rise buildings and transmission lines (see section 4.2.2.1.4). However, after mitigation this risk moved up to position two and retained a moderate overall rank owing to insufficient knowledge and experience with it and moderately effective mitigation strategies so far developed combined with an expected moderate cost of mitigation efforts. A significant number of the avian fatalities in CSP plants surveyed remain of unknown cause as described in section 4.2.2.1.2.

The risk of production of hazardous materials and waste before mitigation was ranked at position four with an overall risk ranking of moderate. A moderate ranking was given for the unmitigated risk score driven by perception of the hazards posed by substances such as therminol and blowdown water. This risk moves to the sixth position after mitigation with an improved overall risk ranking of low-moderate.

Table 6-2: Position and ranking of the reviewed risks before and after mitigation

Reviewed Risk	Rank and Position before mitigation		Rank and Position after mitigation
Risk of Depletion or Disruption of Local Water Resources	1	→	1
Risk to Worker Health and Safety	2	→	3
Risk to Avian Species	3	→	2
Risk of Production of Hazardous Materials and Waste	4	→	6
Risk due to Noise on Acoustic Environment	5	→	4
Risk of Disruption of Visual and Recreational Resources	6	→	5
Risk to Ecological Resources	7	→	11
Risk to Locational Social Economics	8	→	9
Risk to Public Health	9	→	8
Risk due to Glint and Glare	10	→	10
Risk of Withdrawal of Land for Other Uses	11	→	14
Risk to Archaeological Resources	12	→	13
Risk to other Animals and Plants	13	→	17
Risk to Land Traffic and Transportation	14	→	15
Risk to Cultural Resources	15	→	12
Risk to Air Quality	16	→	7
Risk to Geological Resources	17	→	16

The risk due to noise on the acoustic environment before mitigation was ranked fifth with an overall risk ranking of moderate. The impact without mitigation was ranked as moderate. This is linked to the higher than ambient noise levels expected during construction that may affect animal life and humans and to components like fans in dry cooling. The occurrence of this risk was however seen as low-moderate. This risk was ranked at position four with an overall score of low moderate after mitigation largely due to the perceived moderate costs of mitigation efforts.

The sixth ranked risk before mitigation was the risk of disruption of visual and recreational resources. This risk had an overall risk ranking of low-moderate. The rank was driven by a moderate risk of occurrence of disruptions to scenery due to CSP plants. This, as described in section 4.4.2.1, is due to perceptions of the aesthetic value of plant structures in contrast to the natural environment and glare introduced into the area. This risk moves to the fifth position with a rank of low-moderate mainly due to the ineffectiveness of mitigation efforts.

6.2 Impact of Mitigation

The change in rank of the risks after mitigation was considered and is as illustrated in Table 6-2. The top six risks still remain in the top six, though all but the risk to depletion or disruption of water resources change positions. The details of their changes are as described in section 6.1.

The risks ranked 7th to 17th had minor differences in their scores and as such slight changes after mitigation resulted in significant movement up or down the ranking. The risk to air quality recorded the biggest movement from 16th to 7th after mitigation. This was driven by a higher perceived cost of mitigation including air filters where auxiliary heating systems are applied. The risk to other animals and plants reduced moving four places from 13th to 17th. This was driven by adjudged highly effective mitigation efforts that include relocation of significant plants and creation of migration paths for animals.

The risk due to glint and glare on eyes of viewers remained in the 10th position after mitigation. It had a perceived moderately high knowledge level in the field, moderate mitigation effectiveness and a low-moderate mitigation cost.

6.3 Risks that could potentially lead to project termination

The risks identified above are all potentially capable of stopping CSP projects from being undertaken. This is dependent on several factors including the local regulations; site specific social and environmental conditions; cost of the mitigation; severity of the risk at the specific site and the cumulative effect of several risks. Nevertheless there are a few real and perceived risks that stand out at this current state of development of CSP projects. These include the risk to avian species posed by fluxes from tower plant heliostats, the risk to water resources where evaporative wet cooled trough plants are used, and public concerns.

The risk posed by tower plants to avian species is heightened when the specific site is located close to agricultural fields, water bodies or in significant migratory paths. This risk is of greater concern when endangered bird species are to be found within the area. While the number of fatalities so far have been minimal, the visibility of the death of birds, and in the author's opinion, the inaccurate reporting that had been done in 2014 in the USA is a point of concern. The effects that such coverage has to communities, lobby groups and eventually to the law makers of the concerned regions cannot be overlooked. Not only can this result in more requirements during permitting, but it will also introduce new costs in the survey, monitoring and prevention of fatalities. The mitigation measures like deterrents and anti-perching devices in the current state do not seem to solve the problem. The monitoring efforts are however being improved.

A related issue that is yet to gain much attention is the high number of insect incinerations at tower plants. Though the numbers may fluctuate depending on the availability of insects within the site, the hourly totals can be in the thousands. These occurrences are visible as a smoke coming from the area around the receiver. Insects are attracted to bright light at the tower which appears as a result of glare on, or around the receiver. The plausibility of termination of a project due to the incineration of insects depends on the significance of the insect in the biodiversity of the area and its existential status as a species. This case has however not arisen in any project so far.

The risk to water resources has the potential to cause termination of a project due to the importance of water as a resource. Though CSP plants do not utilise as much water as agricultural uses in the affected areas, evaporative wet cooling has been cited to use high amounts of water. Stakeholder perceptions over the use of water for power plants is expected to be less favourable as compared to the use of water for agriculture regardless of the amounts involved. This would then draw much public and regulatory attention that may not be beneficial to the project. For projects in areas where water scarcity is an issue a switch to dry cooling and undertaking of further water conservation measures will be necessary.

Cumulative risks may also lead to project termination. In the request for a redesign from a trough to a tower plant at the Palen power plant, a combination of three risks caused the permit to be rejected. The determination was that there was significant and immitigable effects on visual resources, cultural resources and biological resources. This proposed plant was to be located close to a national park whose scenic and recreational value was adjudged to be under threat.

Finally, with all these risks the way the community and the greater public view these potential risks has a great ability to cause termination of the project. The opinion of these stakeholders is likely to be shifted by media coverage and community feelings of involvement in the development of the project. Where the communities do not feel sufficiently involved or that their concerns not being addressed, the project may face opposition leading to possible termination. The concerns of the community and the risks as they see them need to be incorporated in the development of projects.

7 Conclusions and Comments

The overall environmental and social risks in the development of CSP projects were found to be generally low-moderate, with twelve of the seventeen reviewed risks ranked as low-moderate before mitigation and fourteen given the same rank after mitigation. The highest overall score was moderate-high for the risk to water resources before mitigation, while the lowest overall score was moderately low for the risk to other (non-avian) animals and plants both before and after mitigation.

The six most important risks after known mitigation efforts were respectively found to be the risk of depletion or disruption of local Water Resources, the risk to Avian Species, the risk to Worker Health and Safety, the risk due to Noise and on Acoustic Environment, the risk of disruption of Visual and recreational resources and the risk of production of Hazardous Materials and waste.

Despite the low-moderate ranking of the risks posed by CSP development, it is important to note that issues such as avian fatality and water resource risks need to be better understood and more efforts towards their avoidance or mitigation undertaken. Continuously reviewed methodologies and measures to minimise these risks need to be incorporated into environmental and social management plans for projects. This will help avoid complications in licencing and degradation of environmental and social conditions.

The bulk of the risks surveyed in this study are commonly covered during project development in various regulatory and funding requirements. This is through undertaking of activities such as environmental and social impact assessments, geo-technical surveys and hydrological studies amongst others.

It is also important to ensure that the perceptions of local communities of these risks are incorporated in the mitigation planning. The involvement of stakeholders at all levels in the resolution and planning for projects is essential for successful implementation of CSP projects.

8 Outlook

In the author's opinion, it is likely that the permitting processes for CSP worldwide will get more stringent in the coming years. This is expected to follow developments in California, propelled by more awareness of real and perceived risks as reported in the print and electronic media. The risk posed by shifting public opinion that then affects the regulation should not be overlooked and deliberate efforts should be undertaken to make public the facts about certain risks.

Barring development of any unforeseen risks, the risk levels of CSP developments is expected to move closer to a score of low. This is predicated on increased knowledge in and experience with the technologies and the risks. The more awareness and monitoring efforts that will be developed, the more effective the mitigation efforts are expected to become and the lower the expected risk scores.

The author foresees much more emphasis and efforts being required on the mitigation of environmental and social risks in the development of CSP. In the short-term the avian risks and risks to water resources are expected to draw the most attention.

It would be of benefit that this work is improved in future by focusing and investigating deeper on the risks for specific CSP technologies as more information and more plant data becomes available. More data is expected to be available on the risk to avian species and insects in tower plants given the continued development of these plants in countries such as South Africa, Morocco and Chile. A deeper analysis of the health effects of therminol leaks and long term inhalation to the health of workers in trough plants would also be beneficial.

9 References

[1] cnet, “Ivanpah solar starts delivering electricity (pictures),” 2014. [Online]. Available: http://www.cnet.com/pictures/ivanpah-solar-plant-starts-delivering-electricity-pictures/10/.

[2] The Nature Store, “The King of Butterflies -The Monarch Butterfly,” 2013. [Online]. Available: http://www.monarch-butterfly.com/. [Accessed: 18-Feb-2015].

[3] T. B. Johansson, N. Nakicenovic, A. Patwardhan, L. Gomez-Echeverri, D. J. Arent, R. Banerjee, S. M. Benson, D. H. Bouille, A. Brew-Hammond, A. Cherp, S. T. Coelho, L. Emberson, M. J. Figueroa, A. Grubler, K. He, M. Jaccard, S. Kahn Ribeiro, S. Karekezi, E. D. Larson, Z. Li, S. McDade, L. K. Mytelka, S. Pachauri, K. Riahi, J. Rockström, H.-H. Rogner, J. Roy, R. N. Schock, R. Sims, K. R. Smith, W. C. Turkenburg, D. Ürge-Vorsatz, F. von Hippel, and K. Yeager, “Global Energy Assessment: Toward a Sustainable Future,” *Glob. Energy Assess. Towar. a Sustain. Futur.*, pp. 3–93, 2012.

[4] Bp, “BP Statistical Review of World Energy June 2013,” 2013.

[5] I. Pérez, “Concentrated Solar Thermal Power : Technology trends and costs,” 2012, no. April.

[6] Lahmeyer, “Lahmeyer Database,” 2011.

[7] easac, “Concentrating solar power : its potential contribution to a sustainable energy future,” 2011.

[8] T. Félix M, “Solar Thermal Power. Key Concepts & Overview,” 2014.

[9] M. M. Aman, K. H. Solangi, M. S. Hossain, a. Badarudin, G. B. Jasmon, H. Mokhlis, a. H. a. Bakar, and S. . Kazi, “A review of Safety, Health and Environmental (SHE) issues of solar energy system,” *Renew. Sustain. Energy Rev.*, vol. 41, pp. 1190–1204, 2015.

[10] S. A. Diehn, “Mass bird fatalities at solar park cause concern,” *Biodiversity - Deutsche Welle*, 2014. [Online]. Available: http://www.dw.de/mass-bird-fatalities-at-solar-park-cause-concern/a-17871219. [Accessed: 28-Jan-2015].

[11] S. Anthony, “California’s new solar power plant is actually a death ray that’s incinerating birds mid-flight,” 2014. [Online]. Available: http://www.extremetech.com/extreme/188328-californias-new-solar-power-plant-is-actually-a-death-ray-thats-incinerating-birds-mid-flight. [Accessed: 28-Jan-2015].

[12] NRG Energy inc., “Ivanpah: The facts Behind the Headlines,” 2014. [Online]. Available: http://www.nrg.com/news/executive-blog/post/ivanpah-the-facts-behind-the-headlines. [Accessed: 01-Feb-2015].

[13] CSP World, “Brightsource responds to critics about bird deaths at Ivanpah CSP plant,” 2014. [Online]. Available: http://www.csp-world.com/news/20140820/001368/brightsource-responds-critics-about-bird-deaths-ivanpah-csp-plant. [Accessed: 01-Feb-2015].

[14] UNEP & BASE, “Environmental Due Diligence (EDD) Of Renewable Energy Projects GUIDELINES for Solar Thermal Energy Systems,” 2008.

[15] International Finance Corporation (IFC), “Performance Standards on Environmental and Social Sustainability,” 2012.

[16] Equator Principles Association, “Equator Principles,” 2011. [Online]. Available: http://www.equator-principles.com/. [Accessed: 08-Dec-2014].

[17] Equator Principles Association, “THE EQUATOR PRINCIPLES,” no. June, 2013.

[18] A. C. Bell and Z. A. Kearns, “U.S. Species Plan Could ‘Zone Out’ Half of California’s Desert Solar,” *Solar Industry Magazine*, 2014. [Online]. Available: http://www.solarindustrymag.com/issues/SI1411/FEAT_04_U-S-Species-Plan-Could-Zone-Out-Half-Of-California-s-Desert-Solar.html. [Accessed: 08-Dec-2014].

[19] REAT, “Draft Desert Renewable Energy Conservation Plan. Executive Summary,” 2014.

[20] C. K. Ho, C. M. Ghanbari, and R. B. Diver, “Methodology to Assess Potential Glint and Glare Hazards From Concentrating Solar Power Plants: Analytical Models and Experimental Validation,” *J. Sol. Energy Eng.*, vol. 133, no. 3, p. 031021, 2011.

[21] C. K. Ho, C. A. Sims, and J. M. Christian, “Evaluation of Glare at the Ivanpah Solar Electric Generating System,” Albuquerque, New Mexico, 2014.

[22] T. . Brumleve, “Eye Hazard and Glint Evaluation for the 5-MW Solar Thermal Test Facility, SAND76-8002,” Livermore, Carlifornia, 1977.

[23] K. Douglas, D. Hochschild, and K. Celli, “PALEN SOLAR ELECTRIC GENERATING SYSTEM Presiding Member ’ s Proposed Decision,” 2013.

[24] C. K. Ho, “Relieveing a glaring problem,” *Solar Today*, 2013. [Online]. Available: http://solartoday.org/2013/04/relieving-glaring-problem/. [Accessed: 10-Oct-2014].

[25] C. K. Ho, C. M. Ghanbari, and R. B. Diver, “HAZARD ANALYSES OF GLINT AND GLARE FROM CONCENTRATING SOLAR POWER PLANTS,” 2009.

[26] R. A. Kagan, T. C. Viner, P. W. Trail, and E. O. Espinoza, “Avian Mortality at Solar Energy Facilities in Southern California: A Preliminary Analysis.” National Fish and Wildlife Forensics Laboratory, Ashland, Oregon, 2014.

[27] Mogism, “Tamarisk,” 2014. [Online]. Available: http://en.wikipedia.org/wiki/Tamarix. [Accessed: 13-Nov-2014].

[28] H. Schneider, “#FloraFaunaFridays: The fuzz over tthe Barstow Wooly Sunflower,” 2013. [Online]. Available: http://www.werc.usgs.gov/outreach.aspx?RecordID=165. [Accessed: 13-Nov-2014].

[29] redorbit, “Cymopterus deserticola Brandegee desert springparsley,” 1992.

[30] R. Kwartin, S. Alexander, M. Anderson, J. Collins, C. Lamson, G. Martin, L. Mcalpine, D. Moreno, and J. Patterson, “Solar Energy Development on Department of Defense Installations in the Mojave and Colorado Deserts,” 2012.

[31] University of Walkato, “Flight feathers,” 2011. [Online]. Available: http://www.sciencelearn.org.nz/Contexts/Flight/Sci-Media/Images/Flight-feathers. [Accessed: 03-Nov-2014].

[32] R. W. Schreiber and W. D. Wagner, “AVIAN MORTALITY AT A SOLAR ENERGY POWER PLANT,” vol. 57, no. 2, pp. 135–141, 1986.

[33] Brightsource, “CEC Joint Workshop. Flux Impacts on Avian Species,” 2012.

[34] S. Taggart, “Parabolic troughs: Concentrating Solar Power (CSP)’s quiet achiever,” 2008. [Online]. Available: http://www.renewableenergyfocus.com/view/3390/parabolic-troughs-concentrating-solar-power-csp-s-quiet-achiever/. [Accessed: 22-Oct-2014].

[35] xcitefun, “World’s First Commercial Solar Power Tower,” 2013. [Online]. Available: http://forum.xcitefun.net/worlds-first-commercial-solar-power-tower-t87804.html. [Accessed: 22-Oct-2014].

[36] KIC InnoEnergy, “Thermal Energy Storage (TES) for Concentrating Solar Power (CSP) Plants,” 2014. [Online]. Available: http://www.kic-innoenergy.com/innovationproject/our-innovation-projects/tesconsol/. [Accessed: 22-Oct-2014].

[37] NRG Energy inc., “Ivanpah Solar Electric Generating System Reaches ‘ First Sync ’ Milestone,” 2014. [Online]. Available: http://www.brightsourceenergy.com/first-sync#.VGR-t8nP7wk. [Accessed: 13-Nov-2014].

[38] Galati Blek LLP, “Avian Mortality Information at Various Solar Projects in the US,” 2014.

[39] Galati Blek LLP, “Summary of ISEGS Bird and Bat Mortality - January through June 2014,” 2014.

[40] H.T. Harvey & Associates, “IVANPAH SOLAR ELECTRIC GENERATING SYSTEM AVIAN & BAT MONITORING PLAN 2014 SPRING REPORT (23 MARCH 2014 – 22 MAY 2014),” Nipton, California, 2014.

[41] Z. Labinger, “Assesment of Potential impacts to birds from a solar thermal power plant, Dimona, Israel.” Tel Aviv, Israel, 2012.
[42] J. M. Pleguezuelos, “Environmental Impact of The GEMASOLAR Thermosolar Plant on the bird community in the Monclova Surrounding Area (Fuentes de Andalucia, Seville, Spain),” Granada, 2012.
[43] S. R. Loss, T. Will, S. S. Loss, and P. P. Marra, “Bird–building collisions in the United States: Estimates of annual mortality and species vulnerability,” *Condor*, vol. 116, no. 1, pp. 8–23, Feb. 2014.
[44] Rice Solar, “Rice Solar Energy Project Monthly Compliance report No. 1 Aug-Sept 2013,” 2013.
[45] Rice Solar, “Rice Solar Energy Project: Monthly compliance report No. 10 June 2014,” 2014.
[46] USA DOE, “Concentrating Solar Power Commercial Application Study : Reducing Water Consumption of Concentrating Solar Power Electricity Generation Report to Congress,” 2006.
[47] C. S. Turchi, M. J. Wagner, and C. F. Kutscher, “Water Use in Parabolic Trough Power Plants : Summary Results from WorleyParsons ’,” 2010.
[48] M. Hogan, “The secret to low-water-use, high-efficiency concentrating solar power,” 2009. [Online]. Available: http://thinkprogress.org/climate/2009/04/29/204025/csp-concentrating-solar-power-heller-water-use/. [Accessed: 14-Oct-2014].
[49] A. Poullikkas, I. Hadjipaschalis, and G. Kourtis, “A comparative overview of wet and dry cooling systems for Rankine cycle based CSP plants,” vol. 1, 2013.
[50] G. T. Lyman and E. Programs, “How Much Water Does Golf Use and Where Does It Come From ?,” no. 214418, pp. 1–2, 2012.
[51] K. Vyverberg, “A Review of Stream Processes and Forms in Dryland Watersheds,” no. December 2010, 2010.
[52] NREL, “Pedro de Valdivia,” 2014. [Online]. Available: http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=252. [Accessed: 08-Dec-2014].
[53] S. Ong, C. Campbell, P. Denholm, R. Margolis, and G. Heath, “Land-Use Requirements for Solar Power Plants in the United States,” 2013.
[54] US DOI, US BLM, and US DOE, “Final Programmatic Environmental Impact statement (PIES) for Solar Energy Development in Six South-western States,” Arizona, California, Colorado, Nevada, New Mexico, and Utah., 2012.
[55] BLM, “BLM Manual 8431 - Visual Resource Constrast Rating,” 1986.
[56] A. Mengotti, C. Richardson, D. Georgescu, J. A. Otero, M. A. Patier, S. Morris, H. S. B. Engineering, R. Radevsky, C. Taylor, and A. Sponsor, “Solar Thermal Power Plant,” 2014.
[57] Associated Press, “Explosion, fire hits Solar One plant,” *The Telegraph*, Daggett, p. 14, 31-Aug-1986.
[58] Associated Press, “Solar Tank Explodes at SEGS II Power Plant,” *Los Angeles Times*, Daggett, 27-Feb-1999.
[59] Basins and Range Watch, “Explosion Dangers: Solar Industrial Projects and Schools do not mix!,” 2009. [Online]. Available: http://www.basinandrangewatch.org/AV-SolarMill-scoping-Aug2009.html. [Accessed: 05-Feb-2015].
[60] CSP Today, “Weekly Intelligence Brief: November 3-10,” 2014. [Online]. Available: http://social.csptoday.com/markets/weekly-intelligence-brief-november-3-10. [Accessed: 05-Feb-2015].
[61] Heavy Lift News, “SA Fatal Crane accident update and better pictures,” 2014. [Online]. Available: http://www.heavyliftnews.com/accidents/sa-crane-fatal-accident-update-and-better-pictures. [Accessed: 05-Feb-2015].

[62] European Commission, “Recommendation from the Scientific Committee on Occupational Exposure Limits for Diphenyl ether,” 2012.

[63] US OSHA, “OSHA Regulations (Standards - 29 CFR),” 2008. [Online]. Available: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=9735. [Accessed: 02-Feb-2015].

[64] R. Giammaruti and S. Jess, “The Cost of Noise,” 2008.

[65] Noise Help, “Noise Level Chart,” 2010. [Online]. Available: http://www.noisehelp.com/noise-level-chart.html. [Accessed: 02-Feb-2015].

[66] T. W. B. Group, *Pollution Prevention and Abatement Handbook Toward Cleaner Production*, no. April. 1999.

[67] CEC, “FINAL DETERMINATION OF COMPLIANCE FROM MOJAVE DESERT AIR QUALTIY MANAGEMENT DISTRICT - IVANPAH SOLAR ELECTRIC GENERATING SYSTEM (07-AFC-5),” Sacramento, Carlifornia, 2009.

[68] K. L. Wescott, “CHALLENGES IN ADDRESSING THE ENVIRONMENTAL IMPACTS OF UTILITY-SCALE SOLAR ENERGY DEVELOPMENT ON HISTORIC PROPERTIES IN THE SOUTH-WESTERN UNITED,” 2011.

Annex A Sample Filled Score sheet

#	Risk (Trough and Tower Plants only)	OF	IF	UIF	MIF	MCF	MORS	NMORS
1	Risk of depletion or disruption of local Water Resources	Moderate	Low-Moderate	High	Moderate	Moderate-High	Moderate	Moderate-High
2	*Risk to Ecological Resources*	Low-Moderate	Moderate	Moderate	Low-Moderate	Low	Low-Moderate	Low-Moderate
2a	Risk to Avian Species	Moderate	Moderate-High	Moderate-High	Moderate	Low-Moderate	Moderate	Moderate
2b	Risk to other Plants and Animals	Low-Moderate	Moderate	Moderate	Low-Moderate	Low	Low-Moderate	Low-Moderate
3	Risk due to Glint and Glare	Low-Moderate	Low-Moderate	Moderate	Low-Moderate	Low	Low-Moderate	Low-Moderate
4	Risk of withdrawal of Land for other uses	Low-Moderate	Low	Low-Moderate	Low-Moderate	Low	Low	Low-Moderate
5	Risk of disruption of Visual and recreational resources	Low	Low	Moderate	Moderate	Low	Low	Low-Moderate
6	Risk to locational Social Economics	Low-Moderate	Low-Moderate	Low-Moderate	Low	Low-Moderate	Low	Low-Moderate
7	Risk of production of Hazardous Materials and waste	Low	Low	Low-Moderate	Low	Low-Moderate	Low	Low
8	Risk to Public Health	Low	Low	Low-Moderate	Low	Low	Low	Low
9	Risk to Worker Health and Safety	Low	Low	Moderate	Low	Low	Low	Low-Moderate
10	Risk to cultural resources	Low-Moderate	Low-Moderate	Low-Moderate	Low	Low-Moderate	Low	Low-Moderate
11	Risk to geological resources	Low	Low	Low-Moderate	Low-Moderate	Low	Low	Low
12	Risk to land traffic and transportation	Low	Low	Moderate-High	Low	Low-Moderate	Low	Low-Moderate
13	Risk to air quality	Low	Low	Low-Moderate	Low	Low	Low	Low
14	Risk to archaeological resources	Low-Moderate	Low-Moderate	High	Low-Moderate	Low-Moderate	Low-Moderate	Moderate
15	Risk due to Noise and on Acoustic Environment	Low	Low	Moderate	Low	Low-Moderate	Low	Low-Moderate

An Analysis of Key Environmental and Social Risks in the Development of Concentrated Solar Power Projects

George A. Otieno[#1], Alexander E. Loosen[*2]

[#]*Carl Von Ossietzky Universität,*
Ammerländer Heerstraße 114-118, 26129 Oldenburg, Germany

[1]george.aluru@uni-oldenburg.de

[*]*Lahmeyer International GmbH*
Friedberger Straße 173, 61118 Bad Vilbel, Germany

[2]alexander.loosen@de.lahmeyer.com

Abstract— Concentrated Solar Power projects have impact on environment and social conditions in areas where they are installed. This is due to their large physical scale and the technology. This research set out to investigate the environmental and social risks in the development of such projects and rank these risks from highest to lowest. The risks were analysed for parabolic trough and tower technologies only.

A literature review was undertaken, identifying seventeen risks that were then proposed to six CSP experts for scoring. The risks were scored based of five factors in a five tier scale. The scores from the experts were cumulated to develop an overall rank of the identified risks.

The risk of disruption of local water resources was found to represent the highest risk before and after mitigation with a score of moderate-high and moderate respectively. This score is linked to the importance of water in water scarce regions typified by the best regions for CSP.

The risks to avian species, to worker health and safety, due to noise on the environment, to visual and recreational resources and due to production of hazardous materials and waste completed the top six.

***Keywords*—** Concentrated Solar Power (CSP), Environmental and Social (E&S) Risks, expert survey, water resources, visual resources, avian fatality and worker health and safety.

I. INTRODUCTION

Energy project development has an impact on the environment and social conditions in the areas being developed. Large scale projects are expected to have larger impacts than small scale projects.

Conventional plants such as coal and fuel oil plants have higher greenhouse gas emissions estimated at 400 - 1000g of CO_2 eq./kWh compared to 15 - 20 g of CO_2 eq./kWh for Concentrated Solar Power, CSP [1]. The huge reduction in emissions however does not mean that renewable energy technologies, here CSP, do not have impacts on the environment and social conditions.

The development of CSP plants, a renewable energy technology, has generated some Environmental and Social (E&S) risks. These risks are mainly a result of the large physical size of commercial CSP projects and the technology employed in CSP.

This research sets out to analyse and rank the E&S risks in the development of CSP projects. The two technologies that comprise the most deployed and the greatest pipeline are analysed. These are parabolic trough and tower plants.

Parabolic trough plants have parallel rows of curved mirrors that concentrate irradiation from the Sun onto a receiver as illustrated in

Figure 1. The receiver is an absorber tube that may have synthetic oil or steam flowing in it. This fluid is heated and then passed through a heat exchanger to produce steam that is used to run a Rankine cycle and generate electricity.

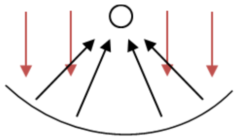


Figure 1: Schematic of a row of a trough plant[2]

Tower plants have a field of mirrors (heliostats) that concentrate the Sun's irradiation onto a central tower, atop which the receiver is located, as illustrated in Figure 2. At the receiver, molten salts can be heated and through a heat exchanger used to produce steam. Optionally, water can be directly heated to produce steam. This steam is then used in a Rankine cycle to run a turbine and produce electricity.

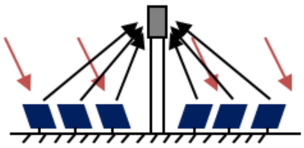


Figure 2: Schematic diagram of a tower plant[2]

E&S risks in energy projects such as CSP are managed through a combination of government E&S policies and donor policies such as the IFC performance standards on environmental and social sustainability and the equator principles. These have minimum requirements such as the undertaking of an Environmental and Social Impact Assessment (ESIA) that aim to predict, quantify and mitigate E&S effects of power projects.

This research aims to identify the E&S risks posed by CSP projects, the impact and their possible mitigation measures. This information and an expert survey is then used to develop a rank of the risks from the most to the least significant at the current state of technology and knowledge. An analysis of the ranking of the identified risks then follows.

The methodology adopted for the research is detailed in Section 2.

II. Methodology

This methodology adopted for this study involved five steps: a) Identification of the E&S risks b) Development of a survey tool c) Survey of experts d) Cumulation of results e) Analysis and presentation of results.

A. Identification of Environmental and Social Risks

The E&S risks where identified after the review of literature related to the development of CSP projects. Risks were identified after review of project filings, Environmental and Social Impact reports, scientific papers and strategic plans.

The projects whose official E&S project documents were reviewed include Ivanpah Solar Electric Generating System, Rice Solar Energy Project, Nevada Solar One and Palen Solar Electric Generating System among others whose project filings were freely accessible at the California Energy Commission.

Where official project documents were insufficient, other publicly available reports were used to augment the available information.

A total of seventeen risks were identified comprising; 1) Risk of depletion or disruption of local water resources 2) Risk due to noise 3) Risk to archaeological resources 4) Risk to air quality 5) Risk due to glint and glare 6) Risk of disruption of visual and recreational resources 7) Risk to avian species 8) Risk to other animals and plants 9) Risk of withdrawal of land for other uses 10) Risk to locational social economics 11) Risk of production of hazardous materials and waste 12) Risk to public health 13) Risk to cultural resources 14) Risk to geological resources 15) Risk to land traffic and transportation 16) Risk to geological resources 17) Risk to ecological resources.

B. Development of Survey Tool

A survey tool to be used by experts to qualitatively rank the identified risks for five factors on a five-tier scale; Low [L], Low-Moderate [L-M], Moderate [M], Moderate-High [M-H] and High [H]. The five factors used to score each risk were as follows:

1) Occurrence *Factor (OF):* This factor accounted for the probability that the scored risk will occur. A score of *'Low'* implied the lowest likelihood of occurrence while a score of *'High'* implied the highest likelihood.

2) Ignorance Factor (IF): This factor accounted for the level of knowledge and experience in the identified risk in the industry. A score of *'Low'* indicated the lowest risk due to the highest knowledge and experience while a score of *'High'* indicated the highest risk due to minimal knowledge and experience.

3) Unmitigated Risk Impact Factor (UIF): This factor accounted for the impact of the identified risk if no mitigation measures are undertaken. A score of *'Low'* indicated the lowest impact while a score of *'High'* indicated the highest impact.

4) Mitigation Ineffectiveness Factor (MIF): this factor accounted for the availability of and extent to which the available mitigation measures overcame the risk under review. A score of *'Low'* implied a lower risk due to high effectiveness of the mitigation measures while a score of '*High*' implied a high risk due to ineffective or unavailable mitigation measures.

5) *Mitigation Cost Factor* (MCF): This factor accounted for the cost of the mitigation as compared to the cost of the project. A score of *'Low'* implied the lowest comparative cost of mitigation while a score of *'High'* implied the highest comparative cost.

These factors were developed to cover, in the broadest way, all the major aspects that influence the risks and their mitigation. The broken down factors were used to ensure separate judgements are made for important aspects of the risk and its mitigation, thus increasing accuracy.

It was necessary to measure some factors such as effectiveness of mitigation in the negative, measured as ineffectiveness, so as to ensure the highest overall score corresponded to the highest risk.

C. Survey of CSP Experts

A total of six experts in CSP, including the authors, were surveyed for the sixteen identified risks using the five factors in a colour-coded qualitative score sheet matrix. The experts were identified from references known to the authors.

The survey was qualitative in nature with experts required to independently rank the risks using the described five-tier score based on their knowledge and experience.

The ranking was done considering the cumulative risk of trough and tower plants, cumulatively over construction, operation and decommissioning, producing a single score that is then taken to represent the score for CSP.

D. Conversion and Cumulation of Results

The qualitative score for each factor was converted to a quantitative score defined by the colour code and values illustrated in Table 1.

TABLE I
Risk Score Factor Conversion

Qualitative Score	Value
Low	0.1
Low-Moderate	0.3
Moderate	0.5
Moderate-High	0.7
High	0.9

The scores from the experts for each factor were then used to calculate the overall score for each risk before and after mitigation. The Non-Mitigated Overall Risk Score (NMORS) was evaluated for each risk using Equation 1.

Equation 1: $NMORS = OF * IF$

Where:

OF - Occurrence Factor

IF - Ignorance Factor

The Mitigated Overall Risk Score (MORS) was evaluated using Equation 2.

Equation 2: MORS = OF * IF * UIF * MIF * MCF

Where:

OF - Occurrence Factor
IF - Ignorance Factor
UIF - Unmitigated Impact Factor
MIF - Mitigation Ineffectiveness Factor
MCF - Mitigation Cost Factor

The NMORS and MORS for each risk were then also ranked on a five-tier colour-coded scale from Low to High based on an optimised scale illustrated in Table 2. This ensured generation of a qualitative overall risk score.

The overall scores (NMORS and MORS) for each risk from the surveyed experts were then averaged to determine the score for the risk.

TABLE II
NMORS AND MORS CONVERSION TABLES

NMORS	Value
Low	x < 0.05
Low-Mod.	0.05 ≥ x <0.17
Moderate	0.17≥ x <0.37
Mod.-High	0.37 ≥ x <0.65
High	x ≥ 0.65

MORS	Value
Low	x < 0.001
Low-Mod.	0.001 ≥ x <0.017
Moderate	0.017 ≥ x <0.1
Mod.-High	0.1 ≥ x <0.379
High	x ≥ 0.379

Where: NMORS – Non-Mitigated Overall Risk Score
MORS – Mitigated Overall Risk Score

The overall inter-risk ranking was then evaluated using the quantitative value of NMORS for non-mitigated rank and the quantitative value of MORS for mitigated rank.

E. Analysis and Presentation of Results

The risks are then tabulated from the highest to the lowest overall score before and after mitigation. An analysis of the reasons for rank and the changes after mitigation is done. The relation to trough or tower for the identified risk is also indicated.

The risk scores for the risk to avian species and the risk to other animals and plants were averaged for each factor to generate the risk to ecological resources, the seventeenth risk.

III. RESULTS

The overall ranking of the risks before and after mitigation was as illustrated in Table 3. The colours qualitatively represent the overall score from low to high while the number is the position of the risk in comparison to other surveyed risks. Position one (1) is the most significant risk while position seventeen (17) is the least significant.

TABLE III
RISK RANKING AND POSITION BEFORE AND AFTER MITIGATION

Reviewed Risk	Position and Score Before Mitigation	Position and Score After Mitigation
Risk of Depletion / Disruption of Local Water Resources	1	1
Risk to Worker Health and Safety	2	3
Risk to Avian Species	3	2
Risk of Production of Hazardous Materials and Waste	4	6
Risk due to Noise on Acoustic Environment	5	4
Risk of Disruption of Visual and Recreational Resources	6	5
Risk to Ecological Resources	7	11
Risk to Locational Social Economics	8	9
Risk to Public Health	9	8
Risk due to Glint and Glare	10	10
Risk of Withdrawal of Land for Other Uses	11	14
Risk to Archaeological Resources	12	13
Risk to other Animals and Plants	13	17
Risk to Land Traffic and Transportation	14	15
Risk to Cultural Resources	15	12
Risk to Air Quality	16	7
Risk to Geological Resources	17	16

Table 4 shows an extract of the raw average factor scores for the top six risks before and after mitigation. The scores are the average of the individual scores of each of the surveyed persons.

TABLE IV
RAW AVERAGE SCORES PER FACTOR FOR THE TOP SIX RISKS

	Reviewed Risk	OF	IF	UIF	MIF	MCF
1	Risk of depletion / disruption of local Water Resources	M-H	M	H	M	M-H
2	Risk to Worker Health and Safety	M	L-M	M-H	L-M	L-M
3	Risk to Avian Species	M	M	M	M	M
4	Risk of production of Hazardous Materials and waste	L-M	L-M	M	L-M	M
5	Risk due to Noise on local Acoustic Environment	L-M	L-M	M	L-M	M
6	Risk of disruption of Visual and recreational resources	M	L	L-M	M	L-M

Where:

OF – Occurrence Factor L – Low
IF – Ignorance Factor L-M – Low-Moderate
UIF – Unmitigated Impact Factor M – Moderate
MIF – Mitigation Ineffectiveness Factor M-H – Moderate-High
MCF – Mitigation Cost Factor H – High

IV. Discussion

The top six risks are analysed for this study giving their ranking and an explanation incorporating their occurrence, impact, mitigation. Summary comments on the ranking are then given.

A. Top six risks

1) Risk of depletion or disruption of water resources

The risk to water resources was scored as moderate-high and at position 1 before mitigation, with the same position after mitigation, but with an improved score at moderate.

The water resource risk is related to the use of water in CSP plants. The main uses being cooling, mirror cleaning and make-up water for the steam cycle. Areas with good direct normal irradiation values also tend to be water scarce, increasing the local value of water as a resource.

The highest consumption of water in CSP plants is in the cooling system. Water consumption for cooling ranges from 80 to 97% of water requirements where evaporative wet cooling systems are used [3]–[5]. In an evaporative wet cooled condenser illustrated in Figure 3, turbine exhaust steam is directed to a surface condenser where it is condensed in tube bundles cooled by the evaporation of cooling water on the tube surface. The resulting hot water is further cooled by blowing air over tubes containing it before it is sent back to the boiler to complete the cycle. Evaporation is responsible for the bulk of the cooling [4].

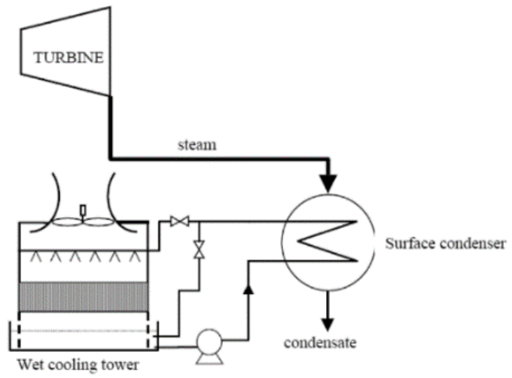


Figure 3: Schematic diagram of a wet cooled condenser [3]

Compared to other generation technologies with cooling systems, as illustrated in Table 5 [6], wet cooled trough plants use more water than wet cooled nuclear and natural gas combined cycle plant and 5% less water than a wet cooled coal plant for every unit of energy generated. This is attributable to the lower cycle efficiency in trough plants related to lower operating temperatures.

TABLE V
WATER USE OF GENERATION TECHNOLOGIES WITH COOLING SYSTEMS

Technology	Sub-type	Max. water consumption (m^3/MWh_e)	
		Wet cooling tower	Dry cooling
Geothermal	Binary	15	1
	Enhanced (EGS)	19.5	6.730
Concentrated Solar Power	Trough	4	0.299
	Tower	3.3	0.098
Nuclear	Generic	3.2	-
Natural Gas	Combined Cycle	1.1	0.015
Coal	Generic	4.2	-
	Supercritical	2.3	-

The relatively high consumption of water in CSP exposes the technology to issues regarding its risk of disruption/ depletion water resources in dry, water-scarce areas. This is despite the fact that CSP plants use less water than some agricultural crops like cotton, fruit trees and alfalfa in the USA [4]. Simulations done on SAM also indicate that a 100MW, 15hr fully loaded dry cooled trough plant would use approximately 166,000 m^3/yr. compared to water use for maintenance of an 18-hole golf course that would need approximately 566,000 m^3/yr. [7]. A wet cooled plant of the same size would however use significantly more water, approximately 1,660,000 m^3 /yr.

From the survey, the unmitigated impact on water resources was considered high with a moderate-high likelihood of occurrence. These were linked to the importance of water as a commodity in dry areas and consumption by wet cooled plants. The understanding of the risk was adjudged to be moderate due to the possibility of extreme changes in local climate after proper hydrological studies.

The switch to dry cooling system will lead to at least a ten-fold reduction in water consumption. Experts view the mitigation as being of moderate effect. The switch will also imply a performance penalty of 2 – 5% [8] and an increased unit cost of electricity of 2 - 9% [9]. Survey results point to a moderate-high cost of mitigation which from literature is estimated to be a 4 – 5% increase in capital costs [9].

2) Worker Health and Safety

The risk to worker health and safety was scored as moderate and at position 2 before mitigation improving to position 3 after mitigation with the same score of moderate.

This risk is driven by thermal oil as applied as Heat Transfer Fluid (HTF) in trough plants and the possibility of occurrence of accidents on site.

The commonly applied type of thermal oil is a eutectic mixture of diphenyl and diphenyl-ether. The HTF system is usually in a closed loop system a high temperatures and pressure and may leak when there insufficient maintenance or poor design. These leaks are likely to occur at valves, ball joints, rotary joints, instrument manifolds, pump seals and flexible hoses [10].

Leaked HTF has the potential of causing fire or explosions as was the case in SEGS II in 1999. Human error was reported to have caused overheating of the HTF beyond the safe limit leading to its vaporisation and explosion captured in Figure 4. About 3400 $m^3$of thermal oil was burned before the fire was contained [11]. Fortunately in this incident there were no casualties.

Figure 4: Fire after an explosion at Daggett SEGS II [12]

The short-term inhalation of thermal oil was considered not to present an acute health risk, but may produce an irritation of the eyes and upper respiratory tract. Inhalation of thermal oil was also found to cause nausea and the presence of diphenyl in the mixture was found to cause a vomiting sensation in humans. Systemic toxicity in humans was estimated to occur with continuous exposures above the no observable adverse effect level (NOAEL) of 35 mg/m^3[13].

Accidents may also happen in the site of CSP plant leading to injuries or fatalities. This could be from breakage of mirrors during mounting, or bad weather leading to collapse of structures like cranes as happened in Khi Solar one in November of 2014. The latter unfortunately led to two fatalities and seven injuries [14].

Figure 5: Collapsed Crane at Khi Solar One site, Upington, South Africa [15]

From the survey, the impact of this risk without mitigation was found to be moderate-high with an occurrence likelihood of moderate. The risk was however viewed as well understood with mitigation measures that are low-moderate in cost and moderate-high in effectiveness.

Continuous monitoring of the HTF piping for leaks and undertaking of repairs can reduce the incidences of leakages. This risk can also be mitigated by use of preventive protective equipment (PPE) that would reduce the chances of burns and inhalation of hot thermal oil when undertaking works on site. The design of heliostats with shatterproof or laminated glass is also seen as a means of reducing injuries related to mirror breakage.

Glare on site is assessed to be an insignificant risk to workers' eyesight. Measures at Ivanpah revealed that glare onsite is within the limits of safe irradiance for the eyes, only likely to produce an annoying after image that disappears after some seconds [16]. As such, glare is not seen as a major worker health issue. The use of anti-glare glasses should however be encouraged to mitigate any possible high glint or glare levels.

3) Risk to Avian Species

The risk to avian species was scored as moderate and at position 3 before mitigation, jumping to position 2 after mitigation with the same score of moderate.

CSP plants are seen to expose avian species to risk of injury or fatality associated with collision with plant structures and flux injuries among others.

Collision occurs when the structures are invisible, deceptive or confusing to birds [17]. Collision with the mirror faces of trough plants is more likely due to the continuous surface reflection that is thought by birds to be the sky or a water body[17]. Tower plants however appear as patches on the ground and are not as confusing. A visual comparison of the two technologies is as observed in Figure 6.

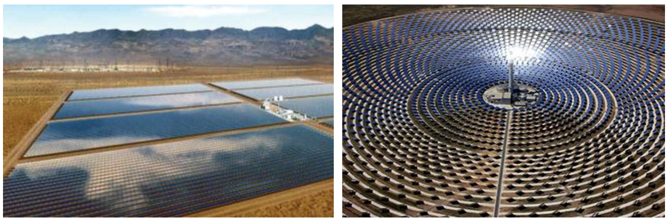


Figure 6: Aerial views of trough and tower plant mirror fields [18] [19]

In tower plants, flux streams generated when the Sun's irradiation is concentrated on the receiver or at standby positions, as can be observed in Figure 7, pose the threat of singeing[1] to birds.

Figure 7: Picture of flux streams and glare at Ivanpah SEGS [16]

Survey results indicate a moderate occurrence and impact of avian fatality. When compared to other incidences of avian fatality, the number of fatalities in CSP plants is not

[1] Singeing here refers to the partial burning of flight feathers

significant. Fatality measurements from Ivanpah SEGS from Jan 2013 – July 2014 indicate 471 fatalities of which 321 were in the first six months of operation Jan-June 2014 [20], [21], related to periods of high standby fluxes. This number is low in comparison to the up to 175 million bird fatalities per year estimated for collision with low rise buildings in the USA [22].

From the survey, it is also opined that the risk of avian fatalities at tower plants is moderately understood. The data from Ivanpah for the first six months of operation depicted in Figure 8 shows that 48% of the fatalities are of unknown cases, indicating a need for better monitoring and more understanding of this issue.

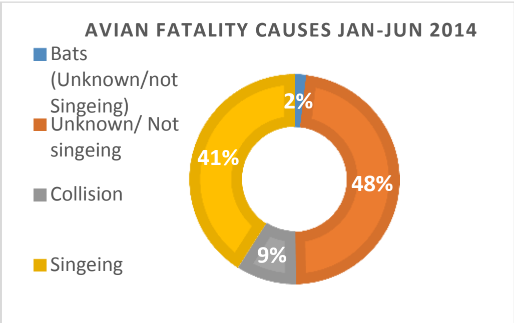


Figure 8: Chart showing distribution of avian fatalities at Ivanpah [21]

The risk posed to avian species is likely to be exacerbated where the specific project site is frequented by endangered species. While the numbers may not be high, the loss of such individuals is to be considered significant. This risk is also expected to vary depending on the ecological significance of a given project site. Sites on migratory paths or common nesting and breeding areas are likely to pose a higher risk than those not close to such areas.

A related issue to avian risk is the incineration of flying insects at tower plants, appearing as small smoke plumes round the top of the tower. Insects are attracted by the bright light at the top of the tower plant and face immediate incineration. At the 9 MW Solar one plant the numbers ranged from 0 to 5000 insects per hour with an average of 630 insects per hour [23]. Holding site conditions constant, a bigger installed capacity, 100 MW, would imply a larger insect toll. The risk and impact of insect incinerations is however related to the importance of the particular insect species to the ecology, or its state of abundance.

The presence of insects close to the tower attracts insectivorous birds whose presence then attracts birds of prey. Both sets of birds face the risk of singeing and falling to the ground further attracting land based predators[17].

Mitigation measures such as installation of anti-perching devices and location of sites away from agricultural lands prone to high insect populations have been suggested. Incorporation of avian monitoring plans within projects is also suggested as a way to monitor and address issues related to avian species. Mitigation effectiveness at its current state is however viewed as moderate with a low-moderate cost.

4) *Hazardous material and waste*

The risk due to production of hazardous material and waste was scored as moderate and at position 4 before mitigation improving to position 6 after mitigation with a score of low-moderate.

The use of thermal oil and its leakage, handling and disposal, blow down from the boiler and cooling towers and hydro-test water releases are the main drivers of this risk. As described in risk 2, thermal oil may leak exposing workers to possible fire and health risks, and contaminating the soil on which it seeps.

Steam blow down water from cleaning of the boiler and cooling tower in CSP plants contains high amount of dissolved solids making it saline. This water is typically directed to evaporation ponds where the salts are collected and disposed [2]. Drinking of this water may lead to death of birds as was reported at the Harper Lake SEGS where fatalities of waterfowls were reported [23].

Hydro tests are performed to test the pipe work in CSP plants upon completion of assembly of the plant. These tests involve flushing the pipework with water to check the integrity of the piping and may carry particles of welding spatter, dirt and construction debris that may have been left during assembly. This water is often exposed and exits into the site drainage[2]. These foreign particles introduce waste into the ground and soils where they settle.

From the survey, this risk is considered to be well understood and of a low-moderate likelihood of occurrence due to extensive experience in management of such waste. The unmitigated impact is considered moderate.

The mitigation measures are adjudged to be of moderate-high effectiveness and of moderate cost. These measures include the covering of evaporation ponds with nets to prevent access to birds, routing drains that could potentially contain oil to a separator for extraction and recycling, and the sending of hazardous and non-recyclable wastes to hazardous and solid waste disposal facilities as appropriate.

5) *Noise on Local Acoustic environment*

The risk due to noise on the local acoustic environment was scored as moderate and at position 5 before mitigation jumping to position 4 after mitigation with a score of low-moderate. Noise from CSP plants is mainly from high pressure steam blow downs and the use of heavy equipment.

High pressure steam blow downs reportedly result in noise of 130 dBA at 15 meters and may be carried out for 2-3 minutes several times a day for 2 – 3 weeks. This noise may however be attenuated by use of silencers to 89 dBA [23]. The US department of labour recommends that impulse noise should not exceed 140 dBA and continuous exposure limits range from 90dBA for 8 hour exposure to 115 dBA for 15 minute exposure [24]. In addition the maximum allowable hourly noise by the World Bank noise abatement guidelines ranges from 45 dBA outside facilities in residential and institutional areas in the night to 70 dBA outside facilities in industrial and commercial areas for both day and night[25].

Heavy equipment used on site also introduces noise. An idling bulldozer is reported to result in noise of 85dBA while pile driving could result in noise of 101 dBA[2]. The noise from fans of air cooled condensers could range from 80 dBA to 106 dBA [26].

Depending on periods of exposure this noise may lead to damages to the hearing abilities of persons close or on site. The noise may also interfere with animal life introducing difficulties in communication or interfering with rituals surrounding protection from predators and mating[23].

From the survey, the likelihood of occurrence of this risk is adjudged to be low-moderate and is seen to have a moderate impact without mitigation. The risk is also well known with wide experience in the industry.

Mitigation measures including the use of low pressure steam blow down techniques that reduce noise by releasing the pressure over longer periods and provision of hearing protection aides where persons are exposed to sound levels are ≥ 85 dB over 8 hours or where a peak of 140 dB or where the average maximum is 110dB. The implementation of barrier protection around noisy equipment and preference of less noisy hydraulic and electric equipment as opposed to noisy pneumatic equipment is also recommended [2].

The mitigation measures were found to be of moderate-high effectiveness and of moderate cost.

6) Disruption of visual and recreational resources

The risk of disruption of visual and recreational resources was scored as low-moderate and at position 6 before mitigation jumping to position 5 after mitigation with the same score of low-moderate.

The development of CSP projects in the often open spaces in dry lands is seen as degrading the scenic value of these lands[23]. Tower plants are particularly adjudged to introduce distracting glare that takes away the viewers' attention from the surroundings. Such interruption is as observable for a viewer interested in the hills behind the Ivanpah tower in Figure 9.

Figure 9: A picture of one of three towers at Ivanpah with a backdrop of hills and open scenery[27]

The risk posed to visual resources was one of the three reasons, the others being the risk to biological and cultural resources, that combined to cause the rejection of a proposal to redesign the Palen solar power plant from a trough plant to a tower plant [23]. These risks were adjudged to be significant and immitigable. It is however also noteworthy that this plant was to be located close to a national park that was popular for star gazing, an activity that was felt would be affected by night time lighting at the proposed plant.

Some of the other issues raised for CSP plants are the visual impact related to grading of lands and light pollution from aviation warning strobe lights.

From the survey, this risk was viewed as having a moderate risk of occurrence and a low-moderate impact. The experts opined that the risk is well understood in the industry though mitigation measures were seen to be of moderate effectiveness.

Some of these measures include the use of less visually disruptive designs for plant structures, using camouflage painting to reduce contrasts with surroundings, re-vegetation of disturbed soils, planting a column of trees along plant perimeter where plant is close to a road to reduce glare and restoration of the project site to its original condition at the end of the project [23], [28]. These mitigation measures were viewed as being of low-moderate cost.

In overall, this risk is considered low moderate as a scenic view may be disrupted and while little mitigation can be undertaken, the loss of such a view is not considered highly deleterious.

B. Comments on ranking

The risks ranked 7th to 17th had minor differences in their quantitative overall scores and as such slight changes after mitigation resulted in significant movement up or down the ranking. The risk to air quality recorded the biggest movement from 16th to 7th after mitigation. This was driven by a higher perceived cost of mitigation including air filters where auxiliary heating systems are applied.

The risk to other animals and plants reduced moving four places from 13th to 17th. This was driven by adjudged highly effective mitigation efforts that include relocation of significant plants and creation of migration paths for animals.

The ranking system allowed the experts to fill out their risk score by getting into detailed aspects of what would contribute to the overall ranking of the risk.

V. Conclusions

The overall environmental and social risks in the development of CSP projects were found to be generally low-moderate, with twelve of the seventeen reviewed risks ranked as low-moderate before mitigation and fourteen given the same rank after mitigation.

The six most important risks after mitigation were found to be the risk of depletion or disruption of local water resources, the risk to avian species, the risk to worker health and safety, the risk due to noise and on acoustic environment, the risk of disruption of visual and recreational resources and the risk of production of hazardous materials and waste respectively.

In spite of the low-moderate ranking of the risks posed by CSP development, it is important to note that some risks still need to be better understood and more efforts towards their avoidance or mitigation undertaken. These include the risk to avian and insect species, long term risks posed by inhalation of thermal oil and the risk to water resources considering possibility of local climate changes.

It should also be noted that these findings represent a general view of the E&S risk posed by CSP and should not be interpreted as applicable to specific project sites. The importance of each risk for a specific site and technology, and cumulative effects of various risks must be investigated and appropriate ranking undertaken when planning mitigation.

ACKNOWLEDGMENT

The authors would like to acknowledge the assistance of the team at Lahmeyer International GmbH that proved crucial in completing this work. We also acknowledge the open access to project filings at the California Energy Commission from which extensive information was retrieved.

We are also grateful for the support of our friends, loved ones and families for the support they gave us during the undertaking of this work.

REFERENCES

[1] M. M. Aman, K. H. Solangi, M. S. Hossain, a. Badarudin, G. B. Jasmon, H. Mokhlis, a. H. a. Bakar, and S. . Kazi, “A review of Safety, Health and Environmental (SHE) issues of solar energy system,” *Renew. Sustain. Energy Rev.*, vol. 41, pp. 1190–1204, 2015.

[2] Lahmeyer, “Lahmeyer Database,” 2011.

[3] USA DOE, “Concentrating Solar Power Commercial Application Study : Reducing Water Consumption of Concentrating Solar Power Electricity Generation Report to Congress,” 2006.

[4] C. S. Turchi, M. J. Wagner, and C. F. Kutscher, “Water Use in Parabolic Trough Power Plants : Summary Results from WorleyParsons ’,” 2010.

[5] M. Hogan, “The secret to low-water-use, high-efficiency concentrating solar power,” 2009. [Online]. Available: http://thinkprogress.org/climate/2009/04/29/204025/csp-concentrating-solar-power-heller-water-use/. [Accessed: 14-Oct-2014].

[6] J. Macknick, R. Newmark, G. Heath, and K. C. Hallett, “A review of operational water consumption and withdrawal factors for electricity generating technologies,” *Environ. Res. Lett.*, vol. 7, no. March, p. 045802, 2012.

[7] G. T. Lyman and E. Programs, “How Much Water Does Golf Use and Where Does It Come From ?,” no. 214418, pp. 1–2, 2012.

[8] J. Macknick, R. Newmark, G. Heath, and K. C. Hallett, “Areview of operational water consumption and withdrawal factors for electricity generating technologies,” *Environ. Res. Lett.*, vol. 7, no. March, p. 045802, 2012.

[9] A. Poullikkas, I. Hadjipaschalis, and G. Kourtis, “A comparative overview of wet and dry cooling systems for Rankine cycle based CSP plants,” vol. 1, 2013.

[10] A. Mengotti, C. Richardson, D. Georgescu, J. A. Otero, M. A. Patier, S. Morris, H. S. B. Engineering, R. Radevsky, C. Taylor, and A. Sponsor, “Solar Thermal Power Plant,” 2014.

[11] Associated Press, “Solar Tank Explodes at SEGS II Power Plant,” *Los Angeles Times*, Daggett, 27-Feb-1999.

[12] Basins and Range Watch, “Explosion Dangers: Solar Industrial Projects and Schools do not mix!,” 2009. [Online]. Available: http://www.basinandrangewatch.org/AV-SolarMill-scoping-Aug2009.html. [Accessed: 05-Feb-2015].

[13] European Commission, “Recommendation from the Scientific Committee on Occupational Exposure Limits for Diphenyl ether,” 2012.

[14] CSP Today, “Weekly Intelligence Brief: November 3-10,” 2014. [Online]. Available: http://social.csptoday.com/markets/weekly-intelligence-brief-november-3-10. [Accessed: 05-Feb-2015].

[15] Heavy Lift News, “SA Fatal Crane accident update and better pictures,” 2014. [Online]. Available: http://www.heavyliftnews.com/accidents/sa-crane-fatal-accident-update-and-better-pictures. [Accessed: 05-Feb-2015].

[16] C. K. Ho, C. A. Sims, and J. M. Christian, “Evaluation of Glare at the Ivanpah Solar Electric Generating System,” Albuquerque, New Mexico, 2014.

[17] R. A. Kagan, T. C. Viner, P. W. Trail, and E. O. Espinoza, “Avian Mortality at Solar Energy Facilities in Southern California: A Preliminary Analysis.” National Fish and Wildlife Forensics Laboratory, Ashland, Oregon, 2014.

[18] S. Taggart, “Parabolic troughs: Concentrating Solar Power (CSP)’s quiet achiever,” 2008. [Online]. Available: http://www.renewableenergyfocus.com/view/3390/parabolic-troughs-concentrating-solar-power-csp-s-quiet-achiever/. [Accessed: 22-Oct-2014].

[19] xcitefun, “World’s First Commercial Solar Power Tower,” 2013. [Online]. Available: http://forum.xcitefun.net/worlds-first-commercial-solar-power-tower-t87804.html. [Accessed: 22-Oct-2014].

[20] Galati Blek LLP, “Avian Mortality Information at Various Solar Projects in the US,” 2014.

[21] Galati Blek LLP, “Summary of ISEGS Bird and Bat Mortality - January through June 2014,” 2014.

[22] S. R. Loss, T. Will, S. S. Loss, and P. P. Marra, “Bird–building collisions in the United States: Estimates of annual mortality and species vulnerability,” *Condor*, vol. 116, no. 1, pp. 8–23, Feb. 2014.

[23] K. Douglas, D. Hochschild, and K. Celli, “PALEN SOLAR ELECTRIC GENERATING SYSTEM Presiding Member ’ s Proposed Decision,” 2013.

[24] US OSHA, “OSHA Regulations (Standards - 29 CFR),” 2008. [Online]. Available: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=9735. [Accessed: 02-Feb-2015].

[25] T. W. B. Group, *Pollution Prevention and Abatement Handbook Toward Cleaner Production*, no. April. 1999.

[26] R. Giammaruti and S. Jess, “The Cost of Noise,” 2008.

[27] cnet, “Ivanpah solar starts delivering electricity (pictures),” 2014. [Online]. Available: http://www.cnet.com/pictures/ivanpah-solar-plant-starts-delivering-electricity-pictures/10/.

[28] BLM, “BLM Manual 8431 - Visual Resource Constrast Rating,” 1986.