



DSPACE

<https://dspace.org/>

Managing health and safety in South Africa's renewable energy power plants

Sloan, Mark James

2024

University of the Witwatersrand, Johannesburg

<https://hdl.handle.net/10539/44370>

Sloan, Mark James. (2024). Managing health and safety in South Africa's renewable energy power plants [Master's dissertation, University of the Witwatersrand, Johannesburg].

<https://hdl.handle.net/10539/44370>

Managing health and safety in South Africa's renewable energy power plants

Mark James Sloan

**A research report submitted to the Faculty of Commerce, Law and
Management, University of the Witwatersrand, in partial fulfilment of the
requirements for the degree of Master of Management in the field of
energy leadership**

Johannesburg, 2024

ABSTRACT

The study explores the suitability of the South African Occupational Health and Safety Act Number 85 of 1993 (OHS Act) and its Regulations in their ability to appropriately support the management of people from hazards to health and safety within utility-scale renewable energy (RE) power plants in South Africa. The study includes the country's three leading RE technologies that are in-service and connected to the national electrification grid, covering solar photovoltaic (PV), concentrated solar power (CSP) and wind power plants. Semi-structured interviews are used to collect the opinions and experiences of respondents. Each power plant's operations are assessed from a health and safety hazard management perspective. This is followed by an evaluation of the OHS Act and its Regulations to determine their suitability in appropriately supporting the management of their fundamental intention of ensuring health and safety within solar PV, CSP and wind power plants. The study shows that these RE power plants do not present any health and safety hazards unique to these sectors under normal operating conditions. However, it does highlight several areas where the OHS Act and its Regulations are not entirely appropriate in managing people from hazards to health and safety within these RE power plants. The study identifies the importance of continually maintaining the OHS Act and its Regulations in line with technological advancements.

KEY WORDS

Concentrated solar power plants, Degradation, Failure, Health and safety, In-service, Machinery, National grid, OHS Act No. 85 of 1993 and Regulations, Renewable energy power plants, Solar photovoltaic power plants, Utility-scale, Wind power plants.

DECLARATION

I, Mark James Sloan, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in the field of energy leadership at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Name: Mark James Sloan

Signature: 

Signed at18 Phoenix Avenue, Morehill, Benoni.....

On the 12th day of July 2024

DEDICATION

I dedicate my efforts from this study to my two beautiful daughters, Aurora and Lilly-Jo. I love you with all my being.

ACKNOWLEDGEMENTS

I want to thank my family for their tireless support during this journey. To my partner Joanne, thank you for enduring another period filled by my absence. I am grateful for the countless discussions we shared. I thank my eldest daughter, Aurora, for your never-ending encouragement and optimism. You never once stopped believing in me and kept telling me “you got this, Dad” even when I felt I didn't. I thank my youngest daughter, Lilly-Jo, for secretly supporting me, although you would never admit it. Listening to my commentary at the end of each day was support enough. To those always by my side, Roxy, Coco, and Amber, thank you for your unquestioning love and the many walks. To my dear friend Mark, thank you for the endless phone calls, regardless of how far apart we were. Your encouragement and understanding were unwavering. Finally, to the many others who may feel their support was minor and insignificant, I thank you; it was always appreciated.

Without you all, I would not have been able to complete this journey. For this, I give you thanks.

TABLE OF CONTENTS

ABSTRACT	ii
DECLARATION.....	iii
DEDICATION	iv
ACKNOWLEDGEMENTS.....	v
LIST OF TABLES.....	x
LIST OF FIGURES	xi
LIST OF ACRONYMS	xii
CHAPTER 1. INTRODUCTION	1
1.1 PURPOSE OF THE STUDY	1
1.2 CONTEXT OF THE STUDY.....	1
1.3 RESEARCH PROBLEM	3
1.4 RESEARCH OBJECTIVES.....	4
1.4.1 OBJECTIVE NUMBER 1.....	4
1.4.2 OBJECTIVE NUMBER 2.....	4
1.5 SIGNIFICANCE OF THE STUDY	4
1.5.1 OHS ACT'S ADVISORY COUNCIL	5
1.5.2 USERS, OWNERS, LEADERS, AND MANAGEMENT	5
1.5.3 INVESTORS AND INSURANCE COMPANIES.....	6
1.5.4 GENERAL CITIZENS	6
1.6 DELIMITATIONS OF THE STUDY.....	6
1.7 DEFINITION OF TERMS	7
1.7.1 MACHINERY.....	7
1.7.2 OCCUPATIONAL HEALTH AND SAFETY ACT.....	7
1.7.3 PLANT.....	8
1.8 ASSUMPTIONS	8
1.9 STRUCTURE OF THE REPORT.....	8
CHAPTER 2. LITERATURE REVIEW.....	10
2.1 INTRODUCTION	10
2.2 BACKGROUND DISCUSSION	11
2.3 IN-SERVICE HEALTH AND SAFETY RISKS AT UTILITY-SCALE RE POWER PLANTS	14
2.3.1 SOLAR PV POWER PLANTS.....	14

2.3.2	CSP POWER PLANTS	17
2.3.3	WIND POWER PLANTS	23
2.3.4	PROPOSITION 1	27
2.4	MANAGING IN-SERVICE HEALTH AND SAFETY HAZARDS AT UTILITY-SCALE RE POWER PLANTS WITH THE OHS ACT	28
2.4.1	MANAGING HEALTH AND SAFETY WITH THE USA OHS ACT	29
2.4.2	MANAGING HEALTH AND SAFETY WITH THE RSA OHS ACT	34
2.4.1	PROPOSITION 2	40
2.5	CONCLUSION OF LITERATURE REVIEW	41
2.5.1	PROPOSITION 1	41
2.5.2	PROPOSITION 2	42

CHAPTER 3. RESEARCH METHODOLOGY44

3.1	RESEARCH APPROACH	45
3.2	RESEARCH DESIGN	45
3.3	DATA COLLECTION METHODS	48
3.4	POPULATION AND SAMPLE.....	49
3.4.1	POPULATION	49
3.4.2	SAMPLE AND SAMPLING METHOD	50
3.5	THE RESEARCH INSTRUMENT	52
3.6	PROCEDURE FOR DATA COLLECTION.....	56
3.7	DATA ANALYSIS AND INTERPRETATION	58
3.8	LIMITATIONS OF THE STUDY.....	63
3.9	TRUSTWORTHINESS	64
3.9.1	TRANSFERABILITY.....	65
3.9.2	CREDIBILITY	66
3.9.3	DEPENDABILITY	66
3.9.4	CONFIRMABILITY.....	67
3.10	ETHICAL CONSIDERATIONS.....	68
3.11	CONSISTENCY TABLE.....	70

CHAPTER 4. FINDINGS AND DISCUSSION73

4.1	INTRODUCTION	73
4.2	FINDINGS AND DISCUSSION PERTAINING TO PROPOSITION 1	74
4.2.1	CLOSED-ENDED QUESTIONS ON UNIQUE HAZARDS	74
4.2.2	OPEN-ENDED QUESTIONS ON UNIQUE HAZARDS.....	77
4.2.2.1	THEME 1: UNIQUE HAZARDS.....	77
4.2.3	CONCLUSION PERTAINING TO PROPOSITION 1.....	80
4.3	FINDINGS AND DISCUSSION PERTAINING TO PROPOSITION 2	80
4.3.1	CLOSED-ENDED QUESTIONS ON THE APPROPRIATENESS OF THE OHS ACT.....	81
4.3.2	OPEN-ENDED QUESTIONS ON THE APPROPRIATENESS OF THE OHS ACT	84
4.3.2.1	THEME 2: REGULATIONS THAT ARE TOO STRINGENT	84
4.3.2.2	THEME 3: DEFICIENCIES WITHIN THE OHS ACT AND REGULATIONS	93
4.3.3	CONCLUSION PERTAINING TO PROPOSITION 2.....	108
4.4	SUMMARY OF THE FINDINGS	111
4.5	COMPARISON OF LITERATURE REVIEW AND OWN FINDINGS.....	114

CHAPTER 5. CONCLUSIONS & RECOMMENDATIONS.....117

5.1	INTRODUCTION	117
5.2	CONCLUSIONS REGARDING RESEARCH OBJECTIVE 1	117
5.3	CONCLUSIONS REGARDING RESEARCH OBJECTIVE 2	118
5.4	RECOMMENDATIONS	123
5.4.1	OHS ACT'S ADVISORY COUNCIL	123
5.4.2	USERS, OWNERS, LEADERS, AND MANAGEMENT	124
5.4.3	INVESTORS AND INSURANCE COMPANIES.....	125
5.4.4	GENERAL CITIZENS	125
5.5	SUGGESTIONS FOR FURTHER RESEARCH	125

REFERENCES	127
APPENDIX A: Probable hazards at a solar PV power plant	137
APPENDIX B: Risk assessment of a solar PV power plant.....	144
APPENDIX C: Hazards at wind power plants	146
APPENDIX D: Sections of the USA OHS Act of 1970	149
APPENDIX E: Sections of the General Industry Standard	151
APPENDIX F: Sections of the South African OHS Act	153
APPENDIX G: Regulations supporting the OHS Act	156
APPENDIX H: Solar PV power plants in South Africa	158
APPENDIX I: Solar CSP plants in South Africa.....	162
APPENDIX J: Wind power plants in South Africa.....	163
APPENDIX K: Interview guide	165
APPENDIX L: Cover letter for the study	215
APPENDIX M: Consent form for the study	218
APPENDIX N: Data collection matrix	219
APPENDIX O: Characterising the respondents	224
APPENDIX P: Ethics clearance certificate for the study	229

LIST OF TABLES

Table 1. Summary of the sub-sections of the standard number 1910.269 (United States Department of Labor, n.d.-c)	33
Table 2. Consistency table: Research objectives and propositions.....	42
Table 3. Consistency table: Research objectives, propositions, data collection and data analysis	71
Table 4. Consistency table: Research questions, propositions and findings..	115
Table 5. Consistency table: Research questions, conclusions and contribution to knowledge	121
Table 6. Characterising the interviews	224
Table 7. Characterising the respondents	225
Table 8. Characterising the RE power plants	226

LIST OF FIGURES

Figure 1: Classification of CSP technologies (Khan et al., 2023)	19
Figure 2: Primary components of a wind turbine (Manwell et al., 2009)	24
Figure 3: The USA's occupational health and safety management framework of main entities (Occupational Safety and Health Administration, 2014; The National Institute for Occupational Safety and Health, 2023; United States Department of Labor, n.d.-a; US OSH Act of 1970)	29
Figure 4: Research process flow chart	47
Figure 5: Data collection process	57
Figure 6: Thematic map	73
Figure 7: Overall support for proposition number 1 per respondent	75
Figure 8: Overall support for proposition number 1 per question	75
Figure 9: Support for proposition number 1 per RE technology type	76
Figure 10: Overall support for proposition number 2 per respondent	81
Figure 11: Overall support for proposition number 2 per question	81
Figure 12: Support for proposition number 2 per RE technology type	83

LIST OF ACRONYMS

CSP	Concentrated solar power
GW	Gigawatt
GWh	Gigawatt hour
IEP	Integrated Energy Plan
IPP	Independent power producer
IRP	Integrated Resource Plan
MW	Megawatt
NDP	National Development Plan
NIP	National Infrastructure Plan
OHS Act	Occupational Health and Safety Act No. 85 of 1993
PV	Photovoltaic
RE	Renewable energy
REIPPPP	Renewable Energy Independent Power Producers' Procurement Programme
WPEP	White Paper on the Energy Policy of the Republic of South Africa
WPREP	White Paper on the Renewable Energy Policy of the Republic of South Africa

CHAPTER 1. INTRODUCTION

1.1 Purpose of the study

This qualitative study explores the suitability of the South African Occupational Health and Safety Act, Number 85 of 1993 (OHS Act) and its Regulations in their ability to appropriately support the management of people from hazards to health and safety within utility-scale renewable energy (RE) power plants supplying electricity to the South African national grid.

1.2 Context of the study

South Africa receives its electrification from Eskom Holdings SOC Limited (Eskom), a large state-owned power utility responsible for managing the country's electricity network (Eskom, 2023). This includes electricity generated by Eskom and independent power plants and its transmission and distribution (Eskom, 2023; Republic of South Africa, 2019a). As a result, the electricity produced by these power plants is connected to Eskom's national grid, allowing its transmission and distribution to consumers via a system of interconnected power lines and control equipment (Eskom, 2021). South Africa's electricity generation mix is dominated by fossil fuel technologies, illustrated by their significant contribution of 96% from 212 818 gigawatt hours (GWh) in 2020, with renewable electricity generation in the same period only contributing the remaining 4% (International Renewable Energy Agency, 2022).

South Africa identified the need to diversify from its fossil fuel-dependent position to a more environmentally sustainable energy mix in its 1998 White Paper on the Energy Policy of the Republic of South Africa (WPEP) (Republic of South Africa, 1998). The WPEP provides the energy sector with general direction on national strategy and policy objectives as observed within various national energy-related plans (Republic of South Africa, 1998). One of these national plans is the Integrated Resource Plan (IRP), which provides an electricity infrastructure development plan that balances forecasted demand with preferred generation

technologies (Republic of South Africa, 2019a). The IRP includes utility-scale, grid-connected RE within the forecasted energy mix, with its long-term capacity plan focusing on solar photovoltaic (PV), concentrated solar power (CSP) and wind (Republic of South Africa, 2019a).

South Africa started incorporating RE within their energy mix in 2014, where utility-scale, grid-connected solar PV and wind supplied 1008 and 1057 GWh, respectively (International Energy Agency, 2023). In 2016, CSP was added, which supplied 498 GWh (International Energy Agency, 2023). The growth in the supply of RE from solar PV, wind and CSP continued, and in 2020, they supplied 3603, 5937 and 1428 GWh to the national grid, respectively (International Energy Agency, 2023). This growth is scheduled to continue through 2030, as mapped out in the IRP, where solar PV, wind and CSP are forecasted to represent a combined 24.7% of the country's electricity supply (Republic of South Africa, 2019a).

As expected, introducing these new RE technologies has caused disruptive changes within South Africa's energy sector in a short period (Republic of South Africa, 2019c). The National Infrastructure Plan (NIP) suggests that the rapid rate of technological change and innovation in the energy sector is at a rate never seen before in its history (Republic of South Africa, 2022b). The WPEP and the White Paper on the RE Policy of the Republic of South Africa (WPREP) both indicate that the RE applications not utilised in the country at the time of their writing in 1998 and 2004, respectively, would require establishing standards, guidelines, and codes of practice for their appropriate usage (Republic of South Africa, 1998, 2004a). As solar PV, wind and CSP are all new technologies not previously applied to utility-scale, grid-connected electricity generation, it is reasonable to suggest that these industrial operations or plants were not considered in standards and legislation before their introduction in 2014.

With the current and scheduled proliferation of solar PV, CSP and wind power plants in South Africa, consideration for their potential effect on the environment as contained within the Constitution of the Republic of South Africa, 1996, is required. The Bill of Rights within the Constitution states that everyone has the right to an environment that is not harmful to their well-being (Republic of South

Africa, 2009a). Therefore, building upon the WPEP and WPREP positions for establishing standards, guidelines, and codes of practice for the appropriate usage of RE applications, the matter of managing the health and safety of personnel associated with these new industrial plants requires consideration. In South Africa, the OHS Act, provides for such matters and aims to ensure the health and safety of all people from hazards associated with plant and machinery (Republic of South Africa, 1993). As RE power plants fall under the OSH Act's definition of machinery as they transform natural energies into electricity, they are considered industrial plants or the OHS Act definition of simply "plant" (Republic of South Africa, 1993).

1.3 Research problem

The research problem is to explore the suitability of the OHS Act and its Regulation's ability to appropriately support the management of people from hazards to health and safety at in-service utility-scale RE power plants. The study considered South Africa's three leading RE technologies connected to the national grid: solar PV, CSP and wind power plants (International Energy Agency, 2023).

South Africa introduced these new technologies as utility-scale and grid-connected, starting with solar PV and wind in 2014, with CSP only following in 2016 (International Energy Agency, 2023). The intended growth in applying these new technologies is provided within the country's IRP, where solar PV, wind, and CSP are forecasted to represent 24.7% of South Africa's electricity supply by 2030 (Republic of South Africa, 2019a).

The method for ensuring the health and safety of all people from hazards associated with using plant and machinery in South Africa is contained within the OHS Act (Republic of South Africa, 1993). The OHS Act was assented to in 1993, commenced on the 1st of January 1994 and remains current today (Republic of South Africa, 1993). The OHS Act provides for the Minister to add Regulations that may be deemed necessary to support the provisions of the Act (Republic of South Africa, 1993). Various Regulations exist; however, none are written

explicitly for utility-scale RE power plants (LexisNexis, 2022). A mixture of these Regulations can generally be applied to RE power plants, including the General Administrative Regulations, General Safety Regulations, General Machinery Regulations, and Electrical Machinery Regulations of 2011 (LexisNexis, 2022).

As South Africa introduced these disruptive RE technologies more than 20 years after the OHS Act was enacted, it is considered reasonable to confirm its continued suitability. Within this context, the study explores the suitability of the OHS Act and its Regulation's ability to appropriately support the management of people from hazards to health and safety within utility-scale RE power plants supplying electricity to the South African national grid.

1.4 Research objectives

The objectives for the study are provided below.

1.4.1 *Objective number 1*

Identify health and safety hazards unique to in-service, grid-connected, utility-scale solar PV, CSP and wind power plants.

1.4.2 *Objective number 2*

Evaluate the suitability of the South African OHS Act and its Regulations to appropriately support the management of people from hazards to health and safety within utility-scale, in-service, solar PV, CSP and wind power plants supplying electricity to the South African national grid.

1.5 Significance of the study

The significance of the research is anchored in determining whether the South African OHS Act and its Regulations appropriately support the mitigation of hazards to health and safety at in-service, utility-scale, grid-connected RE power plants. As leaders manage people and their safety, the suitability and appropriateness of the OHS Act and its Regulations in supporting the

management of their health and safety from hazards associated with in-service, utility-scale RE power plants is of vital importance. As South Africa introduced these technologies more than 20 years after the OHS Act was enacted, it was considered reasonable to explore its continued suitability.

South Africa's WPEP and WPREP both identified that RE applications not utilised in the country at the time of their writing in 1998 and 2004, respectively, would require the establishment of standards, guidelines, and codes of practice for their appropriate usage (Republic of South Africa, 1998, 2004a). The study, therefore, responds to this by exploring the continued suitability of the South African OHS Act and its Regulation's ability to manage people from hazards to health and safety at these RE power plants.

Various stakeholders that may benefit from the study are provided below.

1.5.1 *OHS Act's Advisory Council*

The study may provide the OHS Acts Advisory Council with an improved understanding of the hazards to health and safety unique to the operation of in-service, utility-scale, solar PV, CSP and wind power plants. The study may also provide the OHS Acts Advisory Council with an indication of the suitability of the South African OHS Act and its Regulations in mitigating hazards to health and safety unique to the operation of these RE power plants.

1.5.2 *Users, owners, leaders, and management*

The study may provide users, owners, leaders, and management with an improved understanding of the hazards to health and safety unique to the operation of in-service, utility-scale, solar PV, CSP and wind power plants. The study may also indicate the suitability of the South African OHS Act and its Regulations in mitigating hazards to health and safety unique to the operation of these RE power plants.

1.5.3 *Investors and insurance companies*

The study may provide investors and insurance companies with an improved understanding of the requirements prescribed by the OHS Act and its Regulations for mitigating hazards to health and safety during the operation of in-service, utility-scale, solar PV, CSP and wind power plants.

1.5.4 *General citizens*

The study may clarify to South Africa's general citizens the suitability of the South African OHS Act and its Regulations in mitigating hazards to health and safety unique to the operation of these RE power plants.

1.6 Delimitations of the study

It was considered appropriate only to include in-service, utility-scale RE power plants supplying electricity to the South African national grid for the three leading RE technologies of solar PV, CSP and wind power plants. This position was directed by the IRP's focus and forecasts that these three technologies will contribute approximately 25% of South Africa's utility-scale electricity supply by 2030 (Republic of South Africa, 2019a). The limitation to South Africa was directed by the country's recent adoption of these technologies. Another aspect considered appropriate for inclusion was the OHS Act, Number 85 of 1993 and its Regulations, as this Act governs health and safety associated with plant and machinery in South Africa.

In terms of excluding or delimiting certain aspects from the study, it was considered reasonable to focus on in-service power plants and the impact these RE technologies may have on hazards to health and safety. This required excluding characteristics associated with their design, manufacturing, construction, erection, and commissioning. Therefore, "in-service" refers to the power plant's normal operating conditions, routine maintenance, and inspection activities. Regarding wind power plants, offshore technologies were excluded as South Africa only has onshore power plants (Independent Power Producers Office, 2023a). To provide a boundary point for the study and the electricity

supplied by the RE technologies, it was considered suitable to apply the terminal point as the location where the RE power plant feeds into the substation before entering the national grid. This was considered appropriate as substations form part of conventional power plants' connections to the national grid and should not introduce any new hazards to health and safety. Finally, excluding all other legislation outside of and not directly linked to the above scope was considered reasonable to avoid legal complexities.

1.7 Definition of terms

Definitions contained within the OHS Act shall be quoted directly so as not to deviate from the intended understanding.

1.7.1 *Machinery*

As contained within the OHS Act:

Machinery means any article or combination of articles assembled, arranged or connected and which is used or intended to be used for converting any form of energy to performing work or which is used or intended to be used, whether incidental thereto or not, for developing, receiving, storing, containing, confining, transforming, transmitting, transferring or controlling any form of energy (Republic of South Africa, 1993, p. 4)

1.7.2 *Occupational Health and Safety Act*

As contained within the OHS Act:

To provide for the health and safety of persons at work and for the health and safety of persons in connection with the use of plant and machinery; the protection of persons other than persons at work against hazards to health and safety arising out of or in connection with the activities of persons at work; to establish an advisory council for occupational health

and safety; and to provide for matters connected therewith (Republic of South Africa, 1993, p. 2).

1.7.3 ***Plant***

As contained within the OHS Act:

Plant includes fixtures, fittings, implements, equipment, tools and appliances, and anything which is used for any purpose in connection with such plant (Republic of South Africa, 1993, p. 6).

1.8 Assumptions

The study is not grounded in any assumptions that may impact the outcome or value of the research.

1.9 Structure of the report

The remainder of this research report consists of four additional chapters. In Chapter 2, a literature review covers a contextual background discussion and applicable literature that responds to each research objective. The chapter concludes with a proposition for each objective. Chapter 3 follows, where the research methodology applied to the study is detailed. This covers the generic qualitative approach and details the data collection methodology and demographics of respondents. The chapter defines how a six-phase approach to the qualitative thematic analysis was conducted. The chapter concludes by providing methods to improve trustworthiness while maintaining its ethical position. Chapter 4 provides the study's findings, analysis, and discussion. It commences with a thematic map. An overall indication of the level of support for each proposition is provided. This is followed by the thematic analysis, where the propositions were not fully supported. A conclusion is provided for each proposition based on the study's findings. The final chapter (5) provides a conclusion for each research question. A consistency table is included that illustrates the research objectives and the literature-based propositions with the

conclusions based on the findings from this study. Key differences between the literature-based propositions and the current study's findings are provided. The chapter concludes with recommendations and suggestions for further research. Following these chapters are the references and appendices.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

A global trend in electricity generation is shifting away from fossil fuels in favour of more sustainable methods. This is illustrated by the International Energy Agency's main forecast that the growth in renewable electricity capacity over the five years of 2022-2027 is set to match that of the preceding 20 years (International Energy Agency, 2022). However, compared with historical methods of burning fossil fuels and nuclear power generation, the industrial operations associated with electricity generation from these renewable energy (RE) technologies are not of a comparable level of maturity (Palmer, 2018). Within South Africa, this is highlighted by the recent introduction of utility-scale, grid-connected RE technologies to its energy mix in 2014 (International Energy Agency, 2023). Introducing these new RE technologies is accompanied by a similar shift in employment practices that affect the type of jobs, tasks, and associated hazards (Mulloy et al., 2013). Deploying these RE technologies requires the appropriate support to be provided by various stakeholders and policymakers alike. However, consideration should also be provided to support the management responsible for dealing with operational hazards to health and safety unique to these technologies.

The literature review begins with a background discussion (2.2) that provides further context for South Africa's recent roll out of utility-scale RE technologies. This is followed by a literature review addressing the objectives presented in Chapter 1. The first objective covers in-service health and safety hazards at utility-scale RE power plants (2.3). This section was divided into three subsections that address each of the selected RE technologies of solar photovoltaic (PV), concentrated solar power (CSP) and wind power plants. The review includes the technologies operations and health and safety hazards encountered in the literature and concludes with a single proposition. This is followed by exploring the second objective, covering the management of people from in-service health and safety hazards at utility-scale RE power plants with the South African Occupational Health and Safety Act, Number 85 of 1993 (OHS Act)

(2.4). This section draws on how the first country in the world to apply utility scale RE power plants manages its approach to health and safety. Specific topics and methods used to mitigate risks to health and safety are identified. These are then followed by an evaluation of the South African OHS Act and Regulations while considering the operational health and safety hazards and the United States of America's (USA's) approach. The section is then concluded with a single proposition on the appropriateness of the OHS Act. Finally, the literature review is summarised in the conclusion (2.5), where the two propositions are re-affirmed, and a consistency table is provided to link the research question to the research objectives and propositions.

2.2 Background discussion

South Africa identified the need to diversify from its fossil fuel-dependent position to a more environmentally sustainable energy mix in its 1998 White Paper on the Energy Policy of the Republic of South Africa (WPEP) (Republic of South Africa, 1998). The WPEP states that the government's policy on RE is to provide for the equitable investment of national resources, particularly considering South Africa's natural abundance of solar and wind (Republic of South Africa, 1998). The WPEP continues to provide the energy sector with general direction on national strategy and policy objectives that are observed within various national energy-related plans (Republic of South Africa, 1998). The adoption of the WPEP's intention can be observed within these national plans, such as the Integrated Energy Plan (IEP), the White Paper on the RE Policy of the Republic of South Africa (WPREP), the Integrated Resource Plan (IRP), the National Development Plan (NDP), and the National Infrastructure Plan (NIP).

The background to South Africa's gradual drive to roll out RE through these varied national energy-related plans since the publishing of the WPEP illustrates the complex and interrelated nature of these changes as initiated within the WPEP and requires a brief mention. Following the WPEP, the IEP was first published in 2003 and then replaced by the IEP published in 2016, which indicates the future energy landscape and its technologies that guide energy investment (Republic of South Africa, 2016). The WPREP followed in 2004 and aims to provide the

government's vision, policy principles, strategic goals and objectives on RE, and actions to realise its inclusion in the country's energy mix (Republic of South Africa, 2004a). The IRP was first published in 2011 and then replaced by the IRP published in 2019. There is currently a revised IRP dated 2023 that has been published for public comment in January 2024. As the 2023 revision has not been published for implementation, any reference to the IRP in this study refers to the 2019 version. The IRP aims to provide an electricity infrastructure development plan that balances forecasted demand with preferred generation technologies (Republic of South Africa, 2019a). The IRP refers to RE within the energy mix, including solar PV, wind, CSP with storage, biomass and biogas (Republic of South Africa, 2019a). The long-term capacity plan primarily focuses on solar PV, CSP and wind, with biomass and biogas only allocated to address a short-term capacity gap (Republic of South Africa, 2019a). The NDP followed with a long-term plan that identifies the desired future position for the country where poverty is eliminated, unemployment and inequality are reduced, the standard of living is improved, and the role that the energy sector will play in sustainably achieving this scenario to mitigate climate change (The Presidency of the Republic of South Africa, 2012). Finally, the NIP was first published in 2012 and then replaced by the NIP published in 2022 to provide a dynamic approach to infrastructure development in various industry sectors, including the energy sector, and it establishes the foundation for achieving the NDPs vision (Republic of South Africa, 2022b).

From the above discussion, it is observed that South Africa has progressed the position of the WPEP of 1998 by utilising the energy sector to drive economic growth while adding RE to its energy mix. Renewable energy was introduced by a shift from the country's monopolistic approach to electricity generation by mobilising investment from private independent power producers (IPPs) (Eberhard et al., 2014; Pollet et al., 2015; Republic of South Africa, 2016). This shift was achieved through the establishment of the RE Independent Power Producers Procurement Programme (REIPPPP) by the Department of Energy (DOE) (Eberhard et al., 2014; Pollet et al., 2015; Republic of South Africa, 2016). The REIPPPP is facilitated by the DOE's IPP unit, established by the DOE, and the National Treasury's public-private partnership (Eberhard et al., 2014). Aligned

with the IRP, the REIPPPP has procured specified RE types and capacities from IPPs in a series of bid windows, with the first being in 2012 and the latest being bid window seven in December 2023 (Eberhard et al., 2014; Independent Power Producers Office, 2023b; Pollet et al., 2015).

Before the REIPPPP, South Africa had no commercially operated utility-scale, grid-connected solar PV or CSP power plants (International Energy Agency, 2023). The same can be said for wind power generation, except for the Darling wind power plant, which was established as a small demonstration project that started supplying electricity to the national grid in 2008 (International Energy Agency, 2023; Republic of South Africa, 2016). The REIPPPP began to yield results in 2014, where utility-scale, grid-connected solar PV and wind supplied 1008 and 1057 Gigawatt hours to the national grid, with CSP following in 2016 (International Energy Agency, 2023). The growth in the supply of RE from solar PV, wind and CSP has continued and is forecasted to represent approximately 25% of the country's electricity supply by 2030 (Republic of South Africa, 2019a).

To illustrate the extent of South Africa's development of these three RE technologies as utility-scale grid-connected power plants, data from the facilitators of the REIPPPP shall be considered (Eberhard et al., 2014; Pollet et al., 2015; Republic of South Africa, 2016). The available data only includes up-to-bid window four, while bid window seven was issued in December 2023 (Independent Power Producers Office, 2023b). South Africa has 44 fully operational solar PV power plants with a combined capacity of 2287 megawatts (MW) connected to the national grid (Independent Power Producers Office, 2023a). In addition, the country has six fully operational CSP power plants with a combined capacity of 500 MW connected to the national grid, all equipped with a minimum thermal energy storage (TES) of three hours (Independent Power Producers Office, 2023a). Finally, the country has 33 fully operational wind power plants with a combined capacity of 3343 MW connected to the national grid (Independent Power Producers Office, 2023a).

2.3 In-service health and safety risks at utility-scale RE power plants

With the introduction of RE technologies and sustainable power plants, ensuring that people are appropriately managed to safeguard them from potential hazards exists (Kumar & Sudhakar, 2015). These RE plants can be categorised as standalone distributed systems with less than 1 MW or larger centralised systems greater than 1 MW (Hernandez et al., 2014). These larger centralised systems are typical of utility-scale RE power plants connected to and supplying national electricity grids (Hernandez et al., 2014; Luque & Hegedus, 2003). As encountered in other industrial operations, once these RE power plants have been designed and constructed, they are commissioned and handed over to owners, users, or operators to manage the operation and maintenance of the plant (Price et al., 2020). Therefore, consideration is required during this in-service period to manage and maintain these plants appropriately. This requires consideration for managing people from environments which may have the potential to be harmful to their well-being. It is, therefore, essential to understand hazards to health and safety to manage people from them appropriately. The following sections will focus on solar PV, CSP and wind power plants.

2.3.1 *Solar PV power plants*

It is generally understood that solar PV technologies harness energy from the sun by converting its light shining onto PV solar cells within panels into direct current electricity (Luque & Hegedus, 2003; Mertens, 2014). Application of this technology on utility-scale, grid-connected power plants requires the connection of many of these solar panels (Kumar & Sudhakar, 2015; Mertens, 2014). This was applied to the world's first utility-scale solar PV power plant, which was introduced in 1982 in California, USA (Luque & Hegedus, 2003). The application of solar PV power plants is versatile due to their modularity (Mertens, 2014). Solar PV power plants can be ground-mounted or floating (Sahu et al., 2016). There are various types of ground-mounted solar PV, based on mounting the solar panels either on fixed or tracking systems (Guerin, 2017; Mertens, 2014). Floating

solar PV power plants use bodies of water where their solar panels are mounted upon floating pontoons (Sahu et al., 2016).

Solar PV power plants comprise various components, including panels, panel mounting structures, electrical cabling and connections, inverters and other electrical control and regulating equipment (Mertens, 2014; Parida et al., 2011). In addition, floating solar PV power plants require additional components such as pontoons, floats and mooring systems (Sahu et al., 2016). The simplicity of solar PV power plants is that they do not require any fuel or moving parts and continuously produce electricity when the sunlight shines (Mulloy et al., 2013). However, utility-scale solar PV power plants require large spatial footprints for the many solar panels necessary to harness the sun's energy, which is viewed unfavourably (Aman et al., 2015; Bezdek, 1993; Mertens, 2014). This can be illustrated by a study of a 100 MW grid-connected utility-scale solar PV power plant in Australia that installed 1.36 million solar panels that spanned an area of 250 hectares (Guerin, 2017).

Solar PV power plants do not require extensive interventions on an ongoing basis, as illustrated by the Springerville, 3.5 MW grid-connected power plant in the USA (which was fully commissioned in 2004) that operates without personnel on-site (Moore & Post, 2008). At the Springerville power plant, most monitoring and operational interventions are performed remotely, and personnel are only dispatched for on-site maintenance as directed from the remote diagnostics, with plant maintenance and inspections scheduled annually (Moore & Post, 2008).

Considering the in-service operation of these solar PV power plants from a hazard to health and safety perspective, it was observed that the available literature was found to be limited. Various studies supported this position through a direct statement or observed content limitations (Aman et al., 2015; Bezdek, 1993; Erten et al., 2022; Hernandez et al., 2014; Kamenopoulos & Tsoutsos, 2015). One such study by Kamenopoulos and Tsoutsos (2015), which covered the safe operation and maintenance of solar PV systems, stated that data and publications on accidents were globally lacking. These limitations may partly be attributed to the fact that the first utility-scale solar PV power plant of 1 MW was only established in 1982 in the USA (Luque & Hegedus, 2003).

An approach to assess the safety, health and environmental impact of RE technologies, which included solar PV, CSP and wind power, was observed in a study by Bezdek (1993), where the complete value chain was assessed. The study indicated that limited experience in applying RE technologies (at the time of writing) presented a range of uncertainty in identifying hazards associated with health and safety (Bezdek, 1993). Although the hazards were not specified, they were noted as not being negligible (Bezdek, 1993). Furthering this approach, in a study of the environmental impacts of utility-scale solar PV and CSP by Hernandez et al. (2014), the stages of construction, operation, and decommissioning were considered using a life cycle approach. It was noted, however, that the study only briefly included the impact of these technologies on human health from an air quality perspective (Hernandez et al., 2014). These were followed by a similar life cycle approach, where Aman et al. (2015) divided the RE technologies application of solar PV and CSP into manufacturing, operation and decommissioning. Concerns were noted for safety, health and environmental impacts within the manufacturing and decommissioning stages; however, none were discussed for the operational stage (Aman et al., 2015).

A European study covering the in-service operational phase of RE power plants was conducted by Kamenopoulos and Tsoutsos (2015). The safe operation and maintenance of solar PV systems were considered, and a baseline of probable hazards to health and safety was compiled from prior literature (Kamenopoulos & Tsoutsos, 2015). The hazards identified were divided by their source as technological, natural or human (Kamenopoulos & Tsoutsos, 2015). The listed hazards presented within the study have been summarised in Appendix A. After reviewing the sources Kamenopoulos and Tsoutsos (2015) referenced for each hazard, applicability and deserved inclusion or exclusion from this study were indicated within Appendix A.

Following these studies, Guerin (2017) compiled a health, safety, environmental, and community risk assessment in a case study of a 100 MW grid-connected utility-scale solar PV power plant in Australia. The assessment covered the construction and operational stages of the power plant (Guerin, 2017). The in-service operational risks to health and safety were extracted from the health,

safety, environmental, and community risk assessment and summarised in Appendix B. When evaluating these in-service operational risks to health and safety identified by Guerin (2017), it was found to include all but one of the relevant and applicable hazards from those compiled from prior literature by Kamenopoulos and Tsoutsos (2015) and as reflected in Appendix A. The only hazard that was excluded was the one associated with rodents causing damage to electrical wiring (Shumake et al., 2000).

The Australian case study compared the development of utility-scale solar power plants to other construction work methodologies observed in earthworks, civil, structural, trenching and electrical works (Guerin, 2017). This position builds upon the prior study's reference to using occupational health and safety lessons from other industries in the RE sector due to the limited amount of information available on operational hazards (Mulloy et al., 2013). Considering the risks and hazards to health and safety in the operation and maintenance phases of the case study's power plant, as summarised in Appendix B, comparing the solar power plant to other industrial sectors was considered reasonable as no unique risks were identified (Guerin, 2017). It can be noted that none of the studies covered floating solar PV.

2.3.2 ***CSP power plants***

Concentrated solar power is a second form of solar technology that harnesses energy from the sun and converts it into electricity (Fernández et al., 2019; Freris & Infield, 2008; Zhang et al., 2013). As CSP produces thermal energy in its process methodology of converting solar energy, it is also called solar thermal power (Del Río et al., 2018; Freris & Infield, 2008). This thermal energy allows its system design to include some degree of dispatchability through thermal energy storage (TES), which may typically provide between three and 12 hours of electricity generation without sun (Freris & Infield, 2008; Khan et al., 2023). This TES distinguishes CSP from other forms of RE in providing a partial solution to their typical intermittent nature (Fernández et al., 2019; Khan et al., 2023). It is suggested to be a maturing technology with implementation lagging behind that of solar PV (Del Río et al., 2018; Khan et al., 2023). The first large-scale,

commercially operated CSP plant was a 10 MW demonstration plant in California, USA, named Solar One, which was commissioned in 1982 (Fernández et al., 2019; Islam et al., 2018; Khan et al., 2023).

The fundamental principles of a CSP plant include harnessing the sun's energy with mirrors that concentrate its radiation onto receivers that contain a heat transfer fluid (HTF) (Fernández et al., 2019; Freris & Infield, 2008; Khan et al., 2023). Various types of HTFs are applied in CSP plants, such as synthetic thermal oils, organic oils, molten salts, water, air, and gases, with synthetic thermal oil being the dominant choice (Awan et al., 2020; Fernández et al., 2019; Freris & Infield, 2008; Khan et al., 2023). These HTFs are contained within extensive pressure piping systems that are insulated against heat loss and used to transfer the thermal energy from the point of collection to the point of conversion in the power plant (Papaelias et al., 2016). The temperature of the HTF is elevated to the point where its thermal energy is used in a steam generator or heat exchanger, which drives a turbine that generates electricity (Freris & Infield, 2008; Khan et al., 2023). These steam generators, heat exchangers and turbines are comparable to conventional electricity-generating power plants (Fernández et al., 2019; Khan et al., 2023). The energy contained in the HTFs can be transferred to and used for TES in various forms, such as molten salt (Fernández et al., 2019; Khan et al., 2023).

The CSP plant principles can be applied in four primary methodologies, as illustrated in Figure 1 below (Fernández et al., 2019; Khan et al., 2023; Zhang et al., 2013). These methodologies are differentiated by the method of focusing the concentrated solar radiation on a central receiver or linear absorber tubes (Fernández et al., 2019; Khan et al., 2023). Point-focusing systems consist of solar power towers (SPT) and parabolic dish collectors (PDC) (Fernández et al., 2019; Khan et al., 2023). With linear focusing systems consisting of parabolic trough collectors (PTC) and linear Fresnel collectors (LFR) (Khan et al., 2023). It can be noted that PTC technologies dominate current CSP plants, comprising 77% of global installations (Awan et al., 2020; Islam et al., 2018; Khan et al., 2023; Zhang et al., 2013). This is followed by SPT technologies, which dominate CSP plants under construction and comprise 19% of global installations (Khan et

al., 2023). The balance of existing installations is LFR and PDC, which comprise approximately 4 and 0.05% of current global installations, respectively (Khan et al., 2023). Fernández et al. (2019) support the same position on market dominance, stating that PTC and SPT significantly overshadow PDC and LFR. Concentrated solar power plants are further viewed by their technology generation type, with first-generation plants not incorporating TES (Khan et al., 2023). In contrast, most second-generation power plants have included TES (Khan et al., 2023).

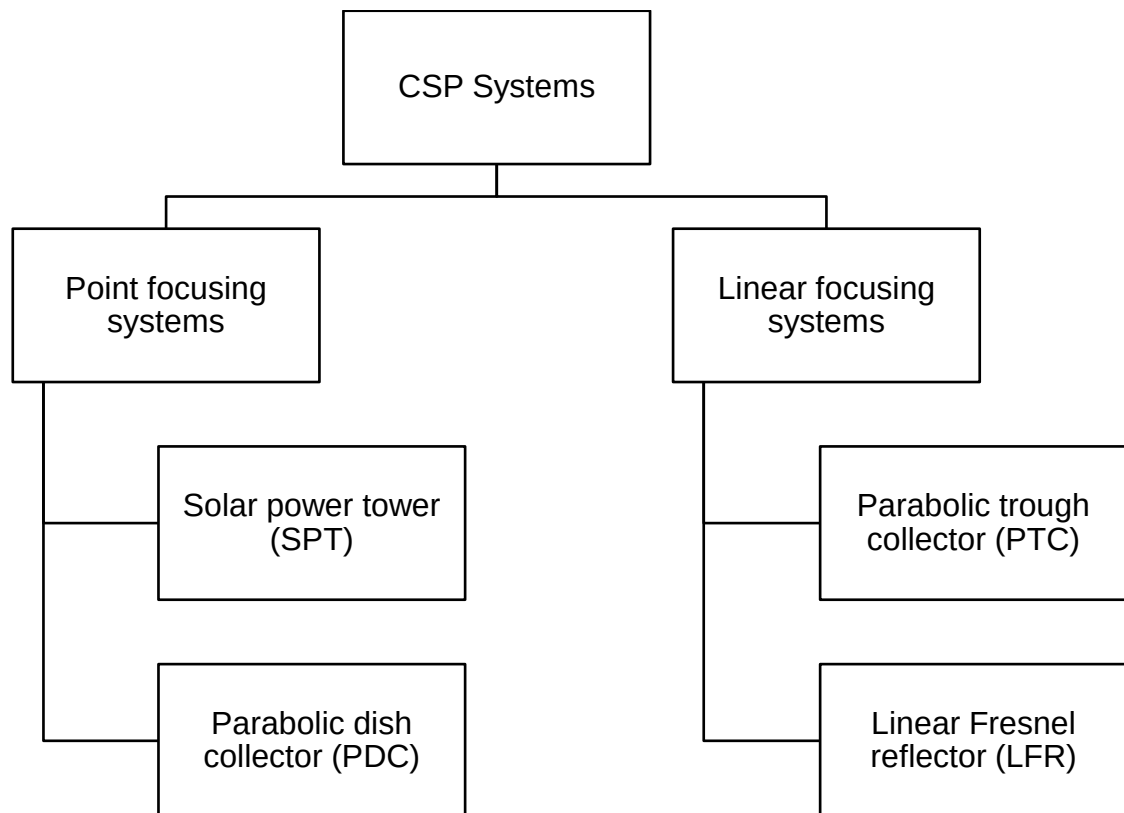


Figure 1: Classification of CSP technologies (Khan et al., 2023)

The visual indicator provided in Figure 1 illustrates how the CSP plant principles are being applied through various technologies (Khan et al., 2023). A brief overview of these will provide context for the plant health and safety applications that follow. The CSP technologies are provided in descending order of their respective market dominance of current global installations.

The PTC power plant consists of large numbers of parabolic reflectors or mirrors that are approximately 5-6 m in height by 12-13 m in length and are connected in

series to form a solar collector assembly that is typically 100-150 m in length (Awan et al., 2020; Khan et al., 2023). These solar collector assemblies are all mounted upon support frames with mechanical or hydraulic tracking devices that allow optimal solar radiation by following the sun's movement (Khan et al., 2023). Vast areas of solar collector assemblies are assembled in parallel rows that make up the CSP concentrator plant (Awan et al., 2020; Islam et al., 2018; Khan et al., 2023). The solar radiation focused by the parabolic reflectors is absorbed by a rotating receiver tube filled with a pressurised HTF and coated with ceramic metal composites to receive maximum irradiation and low emissivity (Islam et al., 2018; Khan et al., 2023; Papaelias et al., 2016). The temperature of the HTF in these piping systems is in the order of 393°C (Khan et al., 2023). These extensive piping systems deliver the HTF to the plant storage or for direct conversion of its thermal energy in the power block (Awan et al., 2020; Islam et al., 2018; Khan et al., 2023). Within the power block, energy conversion into superheated steam occurs in a steam generator or heat exchanger, which drives an electricity-generating turbine (Islam et al., 2018; Khan et al., 2023). Other associated equipment comprises water treatment plants, condensers, cooling towers, and HTF tanks (Awan et al., 2020; Khan et al., 2023).

The SPT plant is unique in that the solar energy collected from the flat sun-tracking mirrors or heliostats is directed onto a single receiver atop a tower ranging in height between 150 and 260 m (Islam et al., 2018; Khan et al., 2023). The heliostats are arranged around the solar tower in significant numbers, illustrated by the 173,000 installed on the Ivanpah 392 MW plant in California (Khan et al., 2023). The sun's solar radiation can be reflected at distances up to 1.8 km from the central tower, as found on the 100 MW Noor Energy 1 SPT in Dubai (Khan et al., 2023). The heliostats are mounted upon support frames with mechanical or hydraulic tracking devices that allow optimal solar radiation by following the movement of the sun on dual-axis trackers (Islam et al., 2018; Khan et al., 2023). The receiver atop the solar tower receives the concentrated sunlight and converts it into thermal energy within the HTF, commonly molten salt (Khan et al., 2023). The types of solar receivers are varied and primarily classified according to the state phase of the HTF as solid, liquid or gas (Khan et al., 2023). These mostly contain pressurised systems and vessels with HTF temperatures

reaching 1000°C (Khan et al., 2023). The final part of an SPT plant is referred to as the power block island, which is comparable to the PTC plant where the HTF is delivered to the plant storage or for direct conversion of its thermal energy into superheated steam in a steam generator or heat exchanger which in turn drives a turbine that generates electricity (Islam et al., 2018; Khan et al., 2023). Other associated equipment comprises hot and cold salt storage tanks and air-cooled condensers (Islam et al., 2018; Khan et al., 2023).

The LFR power plants are comparable with PTC plants, with the main exception being the arrangement of their reflectors and receivers (Khan et al., 2023). The LFR reflectors consist of long, flat, or slightly curved mirrors angled for optimal solar radiation and are ground-mounted (Islam et al., 2018; Khan et al., 2023). These similarly use single-axis tracking systems (Khan et al., 2023). The solar radiation focused by the reflectors is absorbed by a stationary receiver tube located several meters above the reflectors, also filled with pressurised HTFs (Islam et al., 2018; Khan et al., 2023). Varied receiver tube designs with multiple variants are available (Khan et al., 2023). The balance of plant and thermal transfer processes is comparable to that of PTC plant processes (Khan et al., 2023).

The final and least developed application of CSP technologies is the PDC power plants, which may also be called Stirling dish systems (Khan et al., 2023). These systems consist of large numbers of parabolic dish-shaped mirrors or reflectors that are 3.5-11 m in diameter, where each unit is called a dish system (Khan et al., 2023). Islam et al. (2018) suggest these mirror surfaces be made of silver or aluminium coatings upon glass. The reflectors concentrate the solar irradiation onto a focal point of the receiver mounted immediately above the dish and can reach temperatures between 700 and 800°C (Islam et al., 2018; Khan et al., 2023). The thermal energy is imparted onto a gas within a Stirling or Brayton thermodynamic cycle that produces mechanical work that drives a generator to create electricity (Islam et al., 2018; Khan et al., 2023). The PDC is somewhat different from other types of applications of CSP in that electricity is generated by the Sterling engine at each of the collector dish systems (Islam et al., 2018; Khan et al., 2023). An individual dish system can generate between 3 and 25 kW (Khan

et al., 2023). Each dish system comprises foundations, fabricated structures, columns, dish-shaped mirrors, Stirling engines mounted above the dish, control systems and dual tracking systems (Islam et al., 2018; Khan et al., 2023).

Considering the in-service operation of these solar CSP power plants from the perspective of managing hazards to health and safety, it was observed that the available literature was found to be limited. Various studies supported this position through a direct statement or observed content limitations (Aman et al., 2015; Bezdek, 1993; Hernandez et al., 2014). There was no consolidated data or evaluation of hazards to health and safety on CSP power plants located in the literature. The discussion below provides some perspective on hazards or potential hazards to health and safety, mostly from failure modes included in the literature.

Potential failures of the SPT tube-type receivers were identified by Rodríguez-Sánchez et al. (2014), with possible causes listed as material loss due to the corrosive nature of molten salts at elevated temperatures, cracking, fatigue, overheating and salt freezing. In a study of health monitoring of CSP power plants by Papaelias et al. (2016), plant health management was considered necessary to avoid plant failures through mechanical inspections. These were identified while considering the CSP plant system operating conditions, including high-temperature exposures, thermomechanical fatigue, creep, corrosion, and stress corrosion cracking (Papaelias et al., 2016). The study provided the potential plant location failures as absorber tubes, receivers, central tower structures and extensive piping systems (Papaelias et al., 2016). Building upon these studies, a best practices study was conducted on CSP, PTC and SPT power plants that suggested a lack of solar technology standards and that experience obtained to date should be applied in future engineering of SPTs specifically (Price et al., 2020). The study identified that equipment on the power island, such as the heat exchangers, pumps and valves, were considered conventional equipment found in industry, which was the source of most problems (Price et al., 2020). The study identified problematic areas/failures in PTC power plants as HTF degradation, pump seals, valve reliability, piping supports, collector ball/rotary joints, collector flexible hoses, collector structural failure due to wind and poor control systems

(Price et al., 2020). Regarding SPTs, problematic areas were indicated to be hot salt tank leaks and poor operator control over temperature changes, resulting in leaks in the salt steam generators (Price et al., 2020). In a recent technological advancement study of CSP by Khan et al. (2023), a potential risk to health and safety was noted as releasing harmful gases, such as nitrous oxides from molten salt used as a TES medium. This would require appropriate ventilation to avoid inhalation by plant operators (Khan et al., 2023). Khan et al. (2023) also noted the criticality of heliostat alignment in SPTs that can result in the incorrect areas being subjected to elevated temperatures. This was experienced in 2016 at the Ivanpah solar plant in California, USA, which resulted in a fire (Larson, 2016). These studies indicated potential failures aligned with CSP plant operations and may be used in managing hazards to health and safety.

2.3.3 *Wind power plants*

The movement of air masses in the atmosphere results from differential solar heating of the earth; therefore, it is interesting to note that wind energy is indirectly a form of solar energy (Freris & Infield, 2008). The natural topography of the earth's surface reduces wind speed due to frictional forces and, as such, has increased the height of wind turbine hubs above 100 m (Freris & Infield, 2008). Wind turbines make use of the kinetic energy in the wind by harnessing it with their blades and the aerodynamic force of lift when the wind forces are applied upon them, which then imparts a positive torque onto a rotating shaft, which is used for the conversion into electricity via a generator (Chan & Mo, 2017; Civera & Surace, 2022; Manwell et al., 2009; Webster et al., 2013).

Harnessing the wind to perform work is not new to humanity and dates back to between the first century BC and the third century AD (Manwell et al., 2009). The first recorded appearance was in England in the 12th century, and wind continued to evolve and grow until the Industrial Revolution (Manwell et al., 2009). Electricity from wind was first achieved in 1888 with the first megawatt-sized, utility-scale grid-connected turbine of 1.25 MW introduced in the late 1930s in the USA (Kaldellis & Zafirakis, 2011; Manwell et al., 2009). As a result of this long history, wind power plants are at greater maturity levels when compared with solar PV

and CSP (Freris & Infield, 2008). However, it is not at the level of maturity observed in other industries, such as nuclear power plants, partly due to the processes and technological changes (Karanikas et al., 2021; Palmer, 2018). Applying wind technology on utility-scale, grid-connected power plants or wind farms requires the combination of numerous locally concentrated large-capacity turbines, typically greater than 1 to 1.5 MW (Brouwer et al., 2018; Manwell et al., 2009). Various types of wind turbines exist, with the most common land-based, utility-scale type having a horizontal axis, vertical tower, three rotor blades mounted at the top of the tower with a rotational axis parallel to the ground as indicated in Figure 2 (Brouwer et al., 2018; Civera & Surace, 2022; Manwell et al., 2009; Webster et al., 2013).

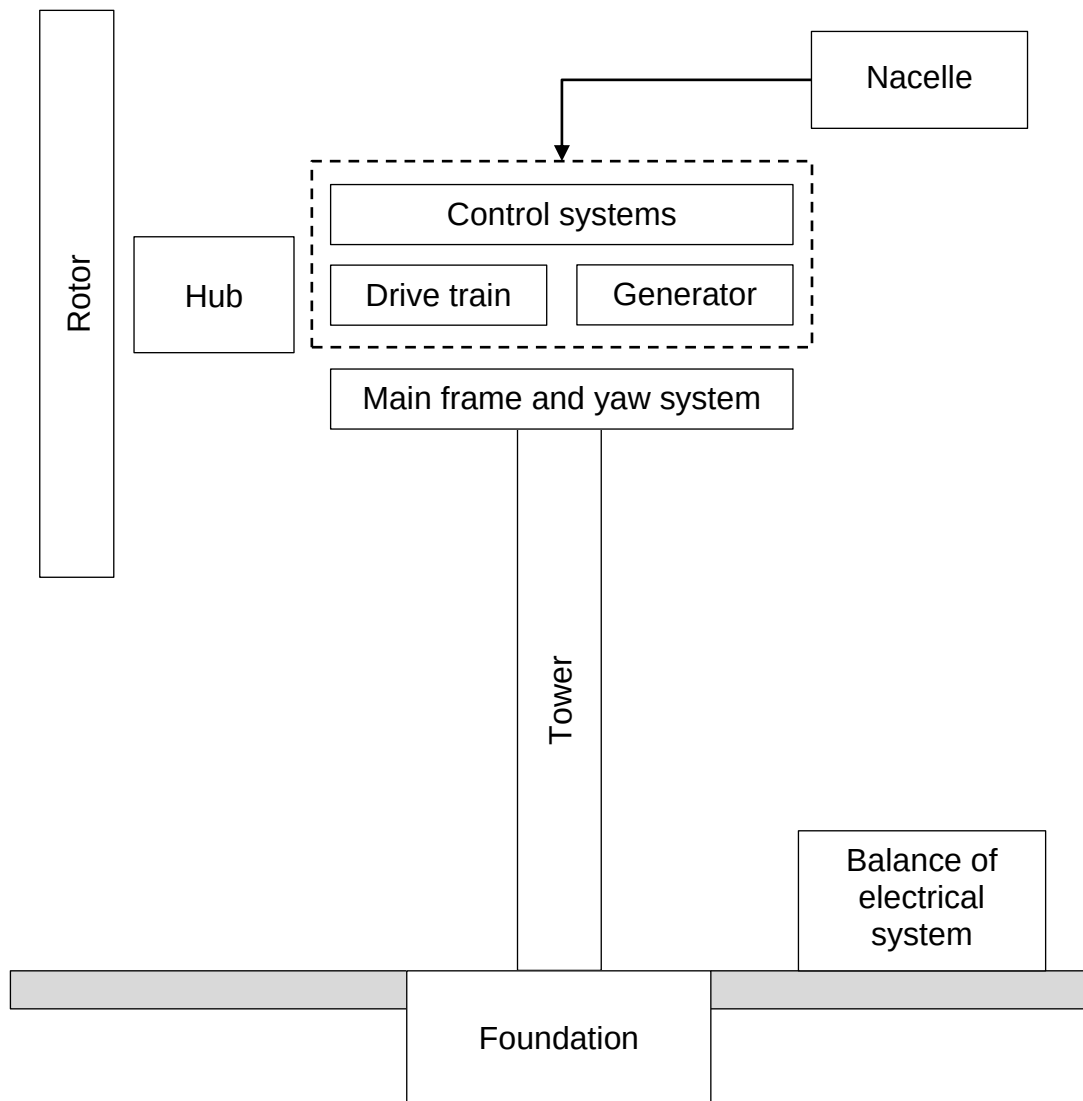


Figure 2: Primary components of a wind turbine (Manwell et al., 2009)

Considering Figure 2, the rotor harnesses the wind, forcing the turbine blades attached to the hub to rotate, which drives the rotating parts within the drive train (Manwell et al., 2009; Webster et al., 2013). The blades are typically manufactured from composites such as natural or glass fibre-reinforced polymers (Manwell et al., 2009; Olabi et al., 2021). The drive train includes the low-speed shaft, gearbox or direct drive, couplings, mechanical brake, high-speed output shaft, and the electrical turbine generator (Manwell et al., 2009; Wagner, 2020; Webster et al., 2013). Control systems cover operations, safety and electricity conversion systems (Manwell et al., 2009; Wagner, 2020). The nacelle is the turbine housing that protects the components atop the tower from the natural elements (Manwell et al., 2009). The main frame is used to mount the componentry with the yaw system using motors to orient the blades with the wind and connects the mainframe to the tower by way of a large bearing (Manwell et al., 2009). The vertical tower, manufactured from concrete or fabricated steel sections, supports the turbine at substantial heights above ground (Manwell et al., 2009; Olabi et al., 2021). The vertical tower is anchored in concrete and steel-reinforced foundations (Jeong et al., 2020; Manwell et al., 2009; Olabi et al., 2021). The balance of the electrical system includes electrical componentry and cabling (Manwell et al., 2009).

Establishing wind power plants follows stages typical of large construction projects such as design, manufacturing, transport, construction, commissioning, operation and maintenance and decommissioning (Hussain et al., 2022; Karanikas et al., 2021; Webster et al., 2013). These combined are called the wind power plant life cycle, with the operation and maintenance stage spanning the most extended period, typically 20-25 years (Hussain et al., 2022; Jeong et al., 2020; Olabi et al., 2021; Webster et al., 2013). Throughout the wind power plants life cycle, various authors have identified a limitation in available literature and data for failures and occupational health and safety hazards for workers and or the public (Brouwer et al., 2018; Hussain et al., 2022; Karanikas et al., 2021; Palmer, 2018; Webster et al., 2013). The study by Karanikas et al. (2021) indicated that the concern associated with limited literature necessitates collaboration by industry, Government, Regulators and academic institutions alike. The same concern prompted data collection by civil society such as the

Caithness Windfarm Information Forum (CWIF), which recorded global wind-related accidents; RenewableUK, which compiles a database of lessons learned; and Spain's Wind Energy Association managing a comparable database (Webster et al., 2013). However, only the CWIF collects data from all sources and freely shares access, while the other two entities only collect and share with their members (Webster et al., 2013). The data collected by CWIF was found to be currently managed and maintained by Scotland Against Spin, a non-profit organisation (Scotland Against Spin, 2021). Numerous articles were found to refer to or include the data from the CWIF (Brouwer et al., 2018; Hussain et al., 2022; Karanikas et al., 2021; Mulloy et al., 2013; Olabi et al., 2021; Palmer, 2018).

Considering the in-service operation and maintenance of these wind power plants from a health and safety management perspective, it is noted that most sites are uncrewed except for periods of maintenance or repair (Webster et al., 2013). The technology and tasks required are considered unique, but the hazards to health and safety are not (Karanikas et al., 2021; Webster et al., 2013). The hazards are comparable to those in other industrial sectors (Webster et al., 2013). However, how they are combined and the extreme working conditions may present unique challenges that must be appropriately managed (Karanikas et al., 2021; Webster et al., 2013). The literature on hazards to health and safety emanating from wind power plants was covered from four approaches. First, in no specific order, it was covered from a hazard to the health of workers' perspective (Karanikas et al., 2021; Webster et al., 2013). Secondly, it was covered from a hazard to the safety of the worker's perspective (Webster et al., 2013). Thirdly, it was covered from a risk to public safety perspective (Brouwer et al., 2018; Palmer, 2018). A fourth option was considered necessary due to the noted limited availability of literature, and this approach was viewed through the lens of component and failure modes (Brouwer et al., 2018; Olabi et al., 2021; Palmer, 2018; Webster et al., 2013). Only major component failures, such as blade and tower failures, were considered applicable, with minor failures not, although their resulting consequential damage may be relevant. The hazards from the literature as appropriate to the in-service operations stage were extracted and consolidated in Appendix C. Each hazard's potential impact was identified as affecting either

public or worker health or safety, followed by an assessment of whether the hazard types were included in the CWIF accident database.

In addition to the above review, numerous wind turbine structural failures were observed due to extreme weather events (Chen & Xu, 2016; Chou et al., 2013; Ishihara et al., 2005). This was considered a vital indicator building upon the risks to the public's safety, which needs to be managed. These failures resulted from typhoons in 2003, 2008 and 2013, respectively and consisted of numerous collapsed towers and fractured blades (Chen & Xu, 2016; Chou et al., 2013; Ishihara et al., 2005). Although the size of the wind turbines varied from 400 KW to 2 MW, the catastrophic failures were considered significant, with the smaller of the turbines still having a hub height of 36 m (Chen & Xu, 2016; Chou et al., 2013; Ishihara et al., 2005).

Finally, in-service degradation observed in the literature was considered necessary for managing hazards to health and safety through monitoring and inspections (Civera & Surace, 2022; Kuntiyawichai & Limkatanyu, 2006; Olabi et al., 2021; Yang et al., 2016). Like other large structures, wind turbines are subject to in-service degradation, compromising their ability to withstand the expected loads they were designed for (Brouwer et al., 2018; Civera & Surace, 2022; Kuntiyawichai & Limkatanyu, 2006; Olabi et al., 2021; Yang et al., 2016). The source of the in-service degradation may result from general material degradation due to time-in-service and environmental conditions as well as original manufacturing imperfections that further deteriorate during service (Brouwer et al., 2018; Kuntiyawichai & Limkatanyu, 2006; Palmer, 2018; Yang et al., 2016)

2.3.4 ***Proposition 1***

Considering the literature reviewed for in-service, grid-connected, utility-scale solar PV, CSP and wind power plants, it is proposed that these plants do not present any health and safety hazards unique to these sectors while under normal operating conditions.

2.4 Managing in-service health and safety hazards at utility-scale RE power plants with the OHS Act

With the rapid global development of RE power plants, Mulloy et al. (2013) noted the need for research and evaluation of current policies to provide health and safety assurance for workers. Numerous studies suggest that safety in RE power plants is mainly ensured through workplace occupational health and safety management (Erten et al., 2022; Hussain et al., 2022). This may include one or several international standards, such as the International Organization for Standardization (ISO) Standards, ISO 9001, ISO 14001, and ISO 45001/OHSAS-18001 (Hussain et al., 2022). Although these standards are recognised for management systems worldwide and across industry sectors, their adoption is voluntary.

When considering more prescriptive methods of assuring safety during in-service operation and maintenance of RE power plants, one may consider the policy evaluation posited by Mulloy et al. (2013), which may lead to the identification of new laws. Against this backdrop, the suitability of the applicable laws set out to ensure the health and safety of all people from hazards associated with operational RE power plants needs to be explored. The method for ensuring the health and safety of all people from hazards associated with using plant and machinery in South Africa is contained within the OHS Act (Republic of South Africa, 1993).

The following sections will explore the methods for ensuring health and safety in RE power plants in the USA and South Africa. The USA was considered an appropriate measure as they were the first in the world to apply utility-scale power plants for solar PV, CSP and wind (Fernández et al., 2019; Islam et al., 2018; Kaldellis & Zafirakis, 2011; Khan et al., 2023; Luque & Hegedus, 2003; Manwell et al., 2009). The position adopted by the USA will first be explored and then followed by a review of the South African approach.

2.4.1 *Managing health and safety with the USA OHS Act*

In the USA, the “Occupational Health and Safety Act of 1970” (US OHS Act of 1970) provides the legal framework for assuring that working environments are safe and healthy (United States [US] Occupational Safety and Health [OSH] Act of 1970). To manage workplace health and safety, amongst others, the US OHS Act of 1970 provides for the development of the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH), as illustrated in Figure 3 (US OSH Act of 1970).

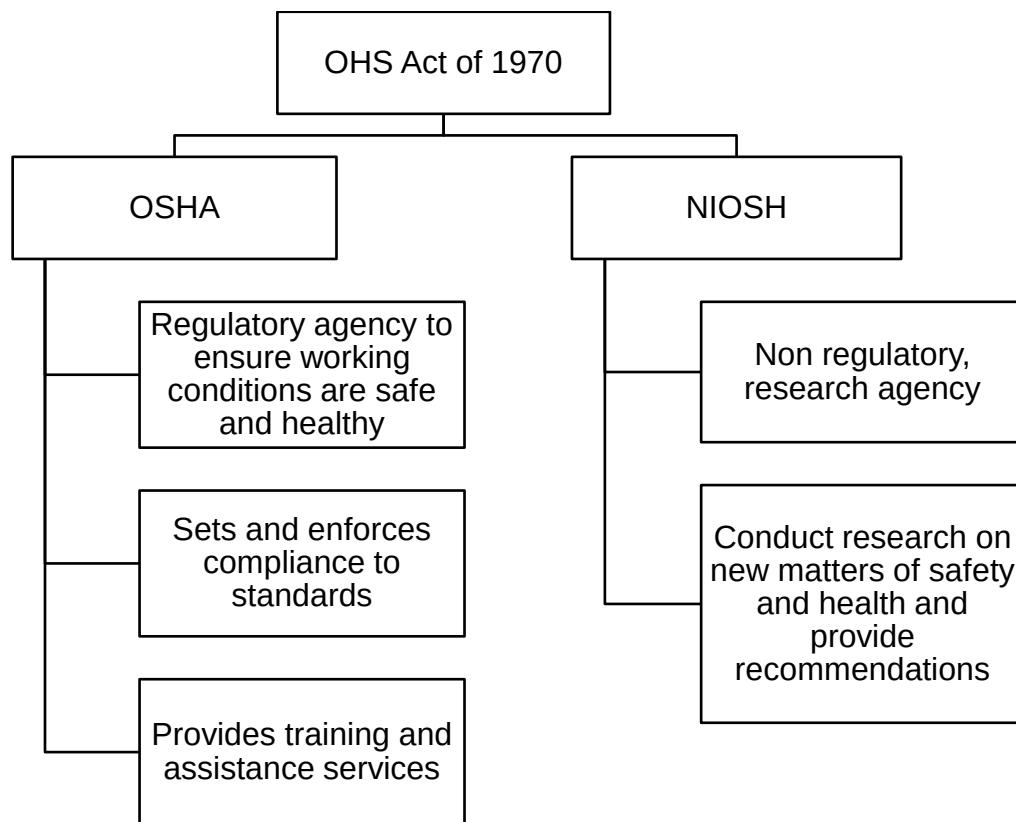


Figure 3: The USA’s occupational health and safety management framework of main entities (Occupational Safety and Health Administration, 2014; The National Institute for Occupational Safety and Health, 2023; United States Department of Labor, n.d.-a; US OSH Act of 1970)

The primary entities used to manage workplace safety in the USA are illustrated in Figure 3 (Occupational Safety and Health Administration, 2014; The National Institute for Occupational Safety and Health, 2023; United States Department of Labor, n.d.-a; US OSH Act of 1970). The US OHS Act of 1970 consists of 34

sections that comprise the legal framework (US OSH Act of 1970). A listed summary of these sections is provided within Appendix D. A single section referred to as the “General Duty Clause” (within Section 5) addresses employers’ duties to ensure employees are free from recognised hazards that may cause harm and enforces them to comply with occupational health and safety standards (US OSH Act of 1970). The Occupational Safety and Health Administration are part of the USA’s Department of Labor (DOL), and they attend to the administration of the US OHS Act of 1970’s intention by ensuring its application to achieve safe working conditions (Occupational Safety and Health Administration, 2014; United States Department of Labor, n.d.-a). In addition, they provide employers and workers with information, training and assistance services (Occupational Safety and Health Administration, 2014; United States Department of Labor, n.d.-a). Finally, OSHA is responsible for establishing, issuing and enforcing the occupational health and safety standards and the general duty clause of the US OHS Act of 1970 (Occupational Safety and Health Administration, 2014; United States Department of Labor, n.d.-a). The National Institute for Occupational Safety and Health was established as an agency focusing on research studies for the ever-changing hazards to worker safety and occupational health (The National Institute for Occupational Safety and Health, 2023). It forms part of the USA’s Centre for Disease Control and Prevention and provides recommendations for health and safety standards (The National Institute for Occupational Safety and Health, 2023). The National Institute for Occupational Safety and Health’s research identifies new hazards to health and safety resulting from new technologies and determines safe levels of human exposure to harmful substances and materials (The National Institute for Occupational Safety and Health, 2023; US OSH Act of 1970).

The USA’s position on RE jobs must be noted before further exploring the health and safety management framework. The USA’s DOL considers work associated with RE power plants a growing industry; however, they do not consider their health and safety hazards unique (United States Department of Labor, n.d.-d). Instead, the USA’s DOL suggests that the hazards to health and safety are addressed by the US OHS Act of 1970’s General Duty Clause and various OSHA standards (United States Department of Labor, n.d.-d).

Regarding the US OHS Act of 1970 and managing hazards to in-service health and safety on RE power plants, the primary mechanism is the General Duty Clause's intention from Section 5, titled "Duties" (US OSH Act of 1970). The remaining sections provide the legal framework for administering the act's intention (US OSH Act of 1970). This General Duty Clause is reverted to when hazards to health and safety are not covered by any specific Occupational Safety and Health Administration standard (United States Department of Labor, n.d.-a). The US OHS Act of 1970 pressures employers for compliance through civil penalties and, in some instances, imprisonment within Section 17, titled "Penalties" (US OSH Act of 1970). These penalties are observed to reach \$156 259 per violation, which may attract additional penalties of \$15 625 per day when not abated within prescribed timeframes (United States Department of Labor, 2022; US OSH Act of 1970). Imprisonment is included for up to one year for violations that have resulted in the death of an employee (US OSH Act of 1970). The US OSH Act of 1970 allows for specific State plans to be created by those States who wish to manage their occupational health and safety within Section 19, titled "Federal Agency Safety Programs and Responsibilities" (US OSH Act of 1970). These State plans must be approved by OSHA and meet at least the minimum requirements of the US OSH Act of 1970 (US OSH Act of 1970). The US OHS Act of 1970, Section 24, titled "Statistics," prescribes the management of data collection and analysis (US OSH Act of 1970). The OHS Act of 1970 requires an onerous level of reporting to the President at defined intervals related to sitting of Congress within Section 26, titled "Annual Report" (US OSH Act of 1970). The reporting requirements are specific and consist of all matters associated with and related to the US OHS Act of 1970 and the achievement of its purpose (US OSH Act of 1970).

Regarding the OSHA and managing hazards to in-service health and safety on RE power plants, its collaborative efforts and enforcement of the appropriate occupational health and safety standards and General Duty Clause of the US OHS Act of 1970 are the primary methods used (Occupational Safety and Health Administration, 2014; United States Department of Labor, n.d.-a). The collaborative efforts include assisting employers through training, consultation and cooperative programs (Occupational Safety and Health Administration, 2014;

United States Department of Labor, n.d.-a). In addition, when considering enforcement, the OSHA conducts many annual inspections covering various sectors while focusing on industries or operations with the most risk (United States Department of Labor, n.d.-b). In 2021, these inspections amounted to 24 333, approximately 25% below the years preceding the pandemic that resulted from the coronavirus disease of 2019 (United States Department of Labor, n.d.-b). The OSHA's occupational health and safety standards consist of the General Industry, Construction, Maritime and Agriculture Standards (Occupational Safety and Health Administration, 2014; United States Department of Labor, n.d.-d). The General Industry Standard applies to in-service health and safety on RE power plants (Occupational Safety and Health Administration, 2014; United States Department of Labor, n.d.-d). These standards form part of the USA's Code of Federal Regulations (CFR) under CFR 29, with the General Industry Standard noted as Standard number 1910 (United States Department of Labor, n.d.-c).

The General Industry Standard, number 1910, consists of 26 subparts listed from A to Z, while four are reserved and without content (United States Department of Labor, n.d.-c). A listed summary of these subparts is provided in Appendix E. As the standard title suggests, the various subparts address general industry hazards with electric power generation, transmission, and distribution contained within subpart R, titled "Special Industries," numbered 1910.269 (United States Department of Labor, n.d.-c). The listed special industries do not include RE technologies while mentioning pulp, paper, and paperboard mills, textiles, bakery equipment, laundry machinery and operations, sawmills, logging operations, telecommunications, electric power generation, transmission and distribution, and grain handling facilities (United States Department of Labor, n.d.-c).

While focusing on the special industry section titled, "electric power generation, transmission, and distribution" within subpart R (standard number 1910.269), for its applicability to the operation of in-service utility scale RE power plants. It includes the operation of electric power generation installations and related equipment for electric utilities and equivalent industrial establishments while not exempting employers from compliance with other parts of the standard (United

States Department of Labor, n.d.-c). This special industry section comprises 24 sub-sections, as provided in Table 1 (United States Department of Labor, n.d.-c).

Table 1. Summary of the sub-sections of the standard number 1910.269 (United States Department of Labor, n.d.-c)

Sub-section number	Sub-section title
1910.269(a)	General
1910.269(b)	Medical services and first aid
1910.269(c)	Job briefing
1910.269(d)	Hazardous energy control (lockout/tagout) procedure
1910.269(e)	Enclosed spaces
1910.269(f)	Excavations
1910.269(g)	Personal protective equipment
1910.269(h)	Portable ladders and platforms
1910.269(i)	Hand and portable power equipment
1910.269(j)	Live-line tools
1910.269(k)	Materials handling and storage
1910.269(l)	Working on or near exposed energised parts
1910.269(m)	Deenergizing lines and equipment for employee protection
1910.269(n)	Grounding for the protection of employees
1910.269(o)	Testing and test facilities
1910.269(p)	Mechanical equipment
1910.269(q)	Overhead lines and live-line barehand work
1910.269(r)	Line-clearance tree trimming

Sub-section number	Sub-section title
1910.269(s)	Communication facilities
1910.269(t)	Underground electrical installations
1910.269(u)	Substations
1910.269(v)	Power generation
1910.269(w)	Special conditions
1910.269(x)	Definitions

Considering the listed sub-sections within Table 1 above, it is observed that the standard (number 1910.269) makes provision for managing hazards to health and safety related to electric power generation and associated operational processes (United States Department of Labor, n.d.-c). These sub-sections provide various topics and areas requiring consideration by employers within RE power plants. A significant focus was observed on safety-related training that mentions new technologies or equipment that may change an employee's everyday safety practices (United States Department of Labor, n.d.-c). However, no specific mention of hazards to health and safety within RE power plants was observed (United States Department of Labor, n.d.-c). While it was not intended to replicate the content of the afore-noted 1910 subsections, instead, it only illustrates the extent of their coverage to appropriately support the management of people from hazards to health and safety. The USA's DOL considers health and safety hazards within RE power plants adequately addressed by the OHS Act of 1970's general duty clause and various OSHA standards (United States Department of Labor, n.d.-d).

2.4.2 Managing health and safety with the RSA OHS Act

In South Africa, the "Occupational Health and Safety Act Number 85 of 1993" (OHS Act) provides the legal framework for ensuring the health and safety of all people from hazards associated with using plant and machinery (Republic of South Africa, 1993). The OHS Act includes numerous Regulations necessary to

support the intention of the Act and provides for the development of additional ones when required (LexisNexis, 2022). These Regulations cover general and specific industry sectors, with no particular Regulations identified for RE power plants (LexisNexis, 2022). The OHS Act also requires the establishment of an advisory council (Republic of South Africa, 1993). The advisory council's tasks are varied but notably include advising the Minister of Employment and Labour (Minister) on policy related to the OHS Act and any matters related to health and safety, conducting research as necessary, and formulating standards and specifications (Republic of South Africa, 1993). Regarding standards, the OHS Act considers and incorporates international health and safety standards within it (Republic of South Africa, 1993).

The Department of Employment and Labour (DEL) administrates and enforces the OHS Act requirements (Republic of South Africa, 1993). The OHS Act provides for a chief inspector from within the DEL to meet the purpose of the Act who is appointed by the Minister (Republic of South Africa, 1993). To ensure compliance with the OHS Act, inspectors are appointed from within the DEL, who conduct investigations by visiting and entering workplaces, including places where plant and machinery are used, to evaluate levels of compliance (Republic of South Africa, 1993).

The OHS Act comprises 50 sections that form the legal framework for managing health and safety (Republic of South Africa, 1993). A listed summary of these sections is provided in Appendix F. The OHS Act prescribes duties for the workplace role players within separate sections of the Act, including employers, manufacturers and employees (Republic of South Africa, 1993). It can be noted that a significant focus on prescriptive requirements for the employer exists, including charging their chief executive officer with the responsibility of ensuring their duties are appropriately discharged (Republic of South Africa, 1993). The OHS Act includes within these duties the need to ensure that persons other than those in the workplace are not exposed to hazards to health and safety as a result of the operations or as a result of any erected article that may present a risk to their safety (Republic of South Africa, 1993). The OHS Act promotes a cooperative approach to managing health and safety by appointing health and

safety representatives within a workplace and establishing councils when their number in a workplace exceeds one (Republic of South Africa, 1993). These persons provide feedback to the employer to manage health and safety proactively and inclusively (Republic of South Africa, 1993). Further to this inclusive approach, the OHS Act prescribes reporting specific health and safety-related incidents to the DEL (Republic of South Africa, 1993). The OHS Act also presses employers for compliance through financial fines for transgressions up to R50 000 or, in some instances, imprisonment for periods up to one year or both (Republic of South Africa, 1993). When any violation or omission on behalf of the employer has the potential to lead to the death of any person, the penalties are increased to R100 000 or imprisonment for up to two years or both (Republic of South Africa, 1993). Finally, although the OHS Act is not prescriptive in its reporting requirements, it was observed that a significant number of inspections were reported by the DEL during the 2019 calendar year totalling 290 000 (Semono & Dicks, 2019).

Regarding the various Regulations that support the intention of the Act, these are grouped into four categories: general, health, mechanical and electrical (LexisNexis, 2022). A listed summary of these 23 Regulations is provided in Appendix G. In terms of the applicable Regulations to the operation of in-service utility scale RE power plants, several Regulations apply. Those directly applicable Regulations have been identified within Appendix G and are briefly discussed below. Although applicable, the General Administrative Regulations will not be discussed as they are purely administrative. It is not intended to replicate the content of the Regulations but rather to illustrate their intention to determine their ability to appropriately support the management of people from hazards to health and safety (within in-service, utility-scale, RE power plants).

The General Safety Regulations build upon the OHS Act duties of employers where the Regulations prescribe that the risks associated with the operation of machinery shall be evaluated (Republic of South Africa, 2003b). Where necessary, the employer shall ensure the situation is safe and, when not practicable, only then take steps to reduce the risk and use personal protective equipment (Republic of South Africa, 2003b). The Regulations address typical

industrial risks while providing prescriptive requirements to be met. These include working in confined spaces, elevated positions, in danger of engulfment and hot works, etc. (Republic of South Africa, 2003b).

The Environmental Regulations for Workplaces provides detailed guidance on appropriate workplace thermal requirements, lighting, windows, ventilation and housekeeping (Republic of South Africa, 2003a). In addition, a listed summary of various industry sectors specifies a minimum illuminance requirement, including within electricity-generating plants (Republic of South Africa, 2003a). Although applicable and appropriate to workplace environmental conditions, the Regulations were not considered to substantially aid in managing significant risks to health and safety within utility-scale RE power plants.

The Facilities Regulations provide detailed guidance on appropriate workplace sanitation, private facilities for safekeeping, changing rooms, dining rooms, drinking water, seating and condition of facilities (Republic of South Africa, 2004b). Although applicable and appropriate to provide suitably healthy working facilities, the Regulations were not considered to substantially aid in managing significant risks to health and safety within utility-scale RE power plants.

The Regulations for Hazardous Chemical Agents provide detailed guidance on managing workplace environments where exposure to hazardous chemical agents (HCA) is possible (Republic of South Africa, 2021). The Regulations provide extensive details on managing environments with HCAs and list exposure limits (Republic of South Africa, 2021). The method for managing HCA environments covers training, duties, assessment of potential exposures, air monitoring, medical surveillance, respirator zones, records, handling, control of exposure, personal protective equipment and facilities, maintenance of control measures, prohibitions, labelling, packaging, transportation and storage (Republic of South Africa, 2021).

The Noise Induced Hearing Loss Regulations provide detailed guidance on managing workplace environments where exposure to noise above the noise rating limit of 85dBA is possible (Republic of South Africa, 2003c). Although applicable and appropriate to provide a suitably healthy working environment, the

Regulations were considered mature as the noise hazard is a typical industrial risk across many sectors.

The Ergonomics Regulations provide detailed guidance on managing workplace ergonomics and human well-being (Republic of South Africa, 2019b). These Regulations cover the interaction of human factors in a working system, including that of plant or machinery (Republic of South Africa, 2019b). Although applicable and appropriate to provide suitably healthy working conditions, the Regulations were not considered to substantially aid in managing significant risks to health and safety within utility-scale RE power plants.

The Driven Machinery Regulations provide detailed guidance on managing various types of driven machinery (Republic of South Africa, 2015). However, the applicability to in-service utility scale RE power plants is mainly limited to the guarding requirements of rotating machinery (Republic of South Africa, 2015). Although applicable and appropriate to provide suitably safe working conditions, the Regulations were considered mature as the hazard associated with rotating machinery is a typical industrial risk across many sectors.

The General Machinery Regulations provide detailed guidance on managing general machinery (Republic of South Africa, 1988). The Regulations emphasise the supervision of machinery, where the user must appoint an employee in the full-time capacity for each premises where machinery is being used (Republic of South Africa, 1988). The person to be appointed is referred to as a competent person, and the Regulations provide options for determining such based on the sum of the power generated by the machinery (Republic of South Africa, 1988). Considering utility scale RE power plants, the Regulation's upper limit of 3 MW will be exceeded, requiring, as a minimum, a certificated engineer or graduate engineer with appropriate experience and having passed the examination on the OHS Act (Republic of South Africa, 1988). The competent person's appointment must be provided to the DEL divisional inspector (Republic of South Africa, 1988). The Regulations include requirements for the appropriate safeguarding of machinery by fencing/guarding and by ensuring that it is installed, operated, and maintained correctly to prevent exposure to hazardous conditions (Republic of South Africa, 1988). These Regulations prescribe that machinery requiring

constant attention during operation shall have a shifts man appointed with appropriate knowledge and experience to ensure safe operation (Republic of South Africa, 1988).

The Lift, Escalator and Passenger Conveyor Regulations provide detailed guidance on managing lifts that will be included inside wind turbine towers (Republic of South Africa, 2010a). These include requirements for maintenance and routine inspections during in-service operations (Republic of South Africa, 2010a). Although applicable and appropriate to provide suitably safe working conditions, the Regulations were considered mature as the hazard associated with lifts is a typical risk across many sectors. In addition to the Regulations, a code of practice (COP) written explicitly for lifts inside wind turbines was observed to supplement the Regulations (Republic of South Africa, 2022a). The DEL published this COP in 2022 (Republic of South Africa, 2022a).

The Pressure Equipment Regulations provide detailed guidance on managing various types of pressure equipment, including in-service requirements for all equipment with a design pressure equal to or greater than 50 KPa (Republic of South Africa, 2017). The applicability to in-service utility scale RE power plants is mainly limited to CSP power plant's pressure and thermal circuits (Republic of South Africa, 2017). The Regulations require imported equipment to be conformity assessed and a certificate issued (Republic of South Africa, 2017). The Regulations require all newly installed equipment to be subjected to a pre-commissioning inspection and test and that steam generators be registered with the DEL before commissioning (Republic of South Africa, 2017). Once the equipment is in operation, the Regulations require in-service inspections to be conducted at specific intervals and the equipment to be fitted with the minimum pressure and safety accessories (Republic of South Africa, 2017). The Regulations were considered mature as the hazard associated with pressure equipment is a typical industrial risk across many sectors.

The Electrical Installation Regulations provide detailed guidance on the requirements for machinery used to transmit electricity from the point of control to the point of consumption (Republic of South Africa, 2009b). The Regulations apply to electrical circuits and associated articles within the RE power plants that

meet the electrical installation description. The Regulations cover various aspects of electrical installations; however, they ultimately require every user of an electrical installation to have a certificate of compliance (Republic of South Africa, 2009b).

The Electrical Machinery Regulations provide detailed guidance on the requirements associated with electrical machinery and for those who generate (transmit or distribute) electricity (Republic of South Africa, 2011). The Regulations emphasise personal protective equipment for persons working on or near live electrical machinery or machinery that may become live (Republic of South Africa, 2011). The Regulations prescribe that work conducted on disconnected electrical machinery requires appropriate earthing for any potential discharge of any acquired or retained electrical charge (Republic of South Africa, 2011). The Regulations address electrical machinery spaces with specific requirements for switchgear and transformer premises, switchboard spaces, and electrical machinery in hazardous locations (Republic of South Africa, 2011). Furthermore, the Regulations include that all electrical machinery shall be provided with protective control gear to automatically isolate in the event of a fault (Republic of South Africa, 2011). Other areas covered by the Regulations include portable electric tools, portable electric lights, and electric fencing, which all have prescribed requirements (Republic of South Africa, 2011). Finally, the Regulations include requirements for power lines and crossings where these are to be appropriately maintained while in service in accordance with the health and safety standards used in their design and erection (Republic of South Africa, 2011). These power lines have prescribed safety clearances to be maintained and noted aspects such as preventing access and control of vegetation (Republic of South Africa, 2011). The Regulations were considered mature as hazards associated with electrical machinery are similarly mature.

2.4.1 *Proposition 2*

Considering the literature reviewed for in-service, grid-connected, utility-scale solar PV, CSP and wind power plants and the USAs position on managing hazards on these RE power plants, it is proposed that the South African OHS Act

and its Regulations appropriately support the management of people from hazards to health and safety.

2.5 Conclusion of literature review

The adoption of RE grid-connected, utility-scale power plants in South Africa was found only to have recently commenced in 2014. The IRP of 2019 provides the projected growth in RE power plants through to the year 2030, which indicates this to be significant and that solar PV, CSP and wind technologies are dominant. This recent adoption was not limited to South Africa, as illustrated within the literature on all three identified RE technologies. When exploring the literature, it was observed that studies addressing hazards to health and safety for utility-scale RE power plants were limited. This position was supported by direct statements within several of the studies encountered.

The available literature on these technologies was evaluated in terms of hazards to health and safety from an in-service perspective. It was found not to present any new risks unique to these sectors. Furthermore, this position was accurate when these RE power plants were operated under normal conditions, as numerous catastrophic structural failures of wind farms were noted during extreme weather events.

The methods and approach to managing the noted hazards to health and safety within grid-connected, utility-scale solar PV, CSP and wind power plants in the USA were explored where the US DOL considers the US OHS Act of 1970 to address these appropriately. Following this, the South African OHS Act was evaluated to determine its ability to appropriately support the management of people within these RE power plants, from hazards to health and safety. It was concluded that although the South African OHS Act pre-dates the introduction of RE power plants in the country, it was considered suitably appropriate.

2.5.1 *Proposition 1*

Considering the literature reviewed for in-service, grid-connected, utility-scale solar PV, CSP and wind power plants, it is proposed that these plants do not

present any health and safety hazards unique to these sectors while under normal operating conditions.

2.5.2 **Proposition 2**

Considering the literature reviewed for in-service, grid-connected, utility-scale solar PV, CSP and wind power plants and the USAs position on managing hazards on these RE power plants, it is proposed that the South African OHS Act and its Regulations appropriately support the management of people from hazards to health and safety.

A consistency table has been provided below that illustrates how the propositions link to the research objectives.

Table 2. Consistency table: Research objectives and propositions

Research objective number	Research objective	Proposition number	Proposition
1	Identify health and safety hazards unique to in-service, grid-connected, utility-scale solar PV, CSP and wind power plants.	1	Considering the literature reviewed for in-service, grid-connected, utility-scale solar PV, CSP and wind power plants, it is proposed that these plants do not present any health and safety hazards unique to these sectors while under normal operating conditions.
2	Evaluate the suitability of the South African OHS Act and its Regulations to appropriately support the management of people from hazards to health and safety within	2	Considering the literature reviewed for in-service, grid-connected, utility-scale solar PV, CSP and wind power plants and the USAs position on managing hazards on these RE power plants, it is proposed that

Research objective number	Research objective	Proposition number	Proposition
	utility-scale, in-service, solar PV, CSP and wind power plants supplying electricity to the South African national grid.		the South African OHS Act and its Regulations appropriately support the management of people from hazards to health and safety.

CHAPTER 3. RESEARCH METHODOLOGY

The complete research methodology that was applied in the study is provided in this chapter. Justification is provided for the selected methodology, tools, and techniques by aligning with the propositions and academic literature. The layout of the chapter provides a logical flow of the research process followed and is summarised below.

The chapter begins with a discussion supporting the study's selection of a qualitative approach (3.1). This is followed by describing the research design based on generic qualitative research, and its appropriateness, advantages, and disadvantages are discussed (3.2). The data collection methodology follows and describes the suitability for selecting the interview as the method of choice (3.3). The stratified random sampling method applied to the study's population is provided. This is followed by providing the actual sample size achieved by the study (3.4). The details of the semi-structured interview used as the research instrument are provided through discussion (3.5). The process followed for data collection is presented (3.6). The analysis was preceded by characterising the respondents with simple descriptive statistics to provide an initial indication of the extent of agreement with the closed-ended questions. This was followed by a six-phase process for assessing the open-ended questions and discussions using thematic analysis. An inductive approach was applied where coding and theme identification illustrated their appropriateness for analysing and interpreting the responses (3.7). A discussion is included that highlights the limitations encountered in the research methodology applied (3.8). The study's extent of trustworthiness is illustrated by the application of transferability, credibility, dependability, and confirmability (3.9). The methods that ensured ethical considerations were applied to the study are defined (3.10). Finally, the chapter concludes by providing a consistency table that cross-references the study's research objectives and propositions with the data collection and analysis methods (3.11).

3.1 Research approach

The study had two propositions that required exploring the understanding of the users' (of in-service, grid-connected, utility-scale solar photovoltaic (PV), concentrated solar power (CSP), and wind power plants) experiences associated with hazards to health and safety. This required the users of these renewable energy (RE) power plants to be understood from within their environments and not to be measured. This position aligns with a qualitative approach that explores the experiences and opinions within the natural context in which they occur to improve levels of understanding (Denzin & Lincoln, 2018; Merriam, 2009; Salkind, 2012). Considering the emphasis on words when applying qualitative research, it was deemed an appropriate methodology to test the study's two propositions (Miles & Huberman, 1994; Salkind, 2012; van Aardt & Hirschsohn, 2021). The approach was further supported by its potential to develop richer understandings, deeper insight and possible serendipitous findings (Denzin & Lincoln, 2018; Miles & Huberman, 1994; van Aardt & Hirschsohn, 2021). The study did not intend to manipulate any independent variable to determine causal relationships, so it was considered non-experimental (Salkind, 2012). Therefore, the research approach was based on a qualitative methodology.

3.2 Research design

It was noted that several specialised qualitative methodologies exist; however, Caelli et al. (2003) refer to generic approaches as those that do not fully align with established ones. The generic approach to qualitative research dates back to the mid-1980s, as observed within Caelli et al. (2003). The established approaches were grouped into narrative research, phenomenology, grounded theory, ethnography, and case studies by Creswell (2007). These may be integrated depending on the needs of the study (Creswell, 2007). A study acknowledging the generic approach to qualitative research and the established methodologies was noted by Kahlke (2014), who also referred to discourse analysis and life history.

The generic approach to qualitative research may be defined as studies that include some qualitative characteristics that combine aspects from various established methodologies or do not claim alignment with any (Caelli et al., 2003). Attempting to force a study to fit within a specific methodology has resulted in errors of application and the oversight of significant findings while attempting to comply with reporting and space limitations (Caelli et al., 2003; Sandelowski, 1993). When considering this study's focus on RE power plants in South Africa and the low level of maturity of these sectors in the country, exploring the understanding of the users was given preference. Further to this, the study was to partly support the fulfilment of a Master of Management degree, where the generic approach was viewed as suitable. Therefore, applying the generic qualitative methodology to the study was considered appropriate.

As with any selection, the methodology for the research was accompanied by advantages and disadvantages. As illustrated above, the generic approach allowed the focus to remain on obtaining a greater understanding without attempting to force conformity to a specific methodology (Caelli et al., 2003; Sandelowski, 1993). This was considered suitable for the study on RE power plants in South Africa. However, a disadvantage was the lack of guidance on clarity and specifics in reporting that the established methodologies would have offered (Caelli et al., 2003). These negative aspects were mitigated by following qualitative guidelines from numerous authors.

Various research stages were followed to ensure the study appropriately addressed the research problem and maintained alignment with the study's objectives. These stages are illustrated in Figure 4, which sequentially represents the process followed by the study.

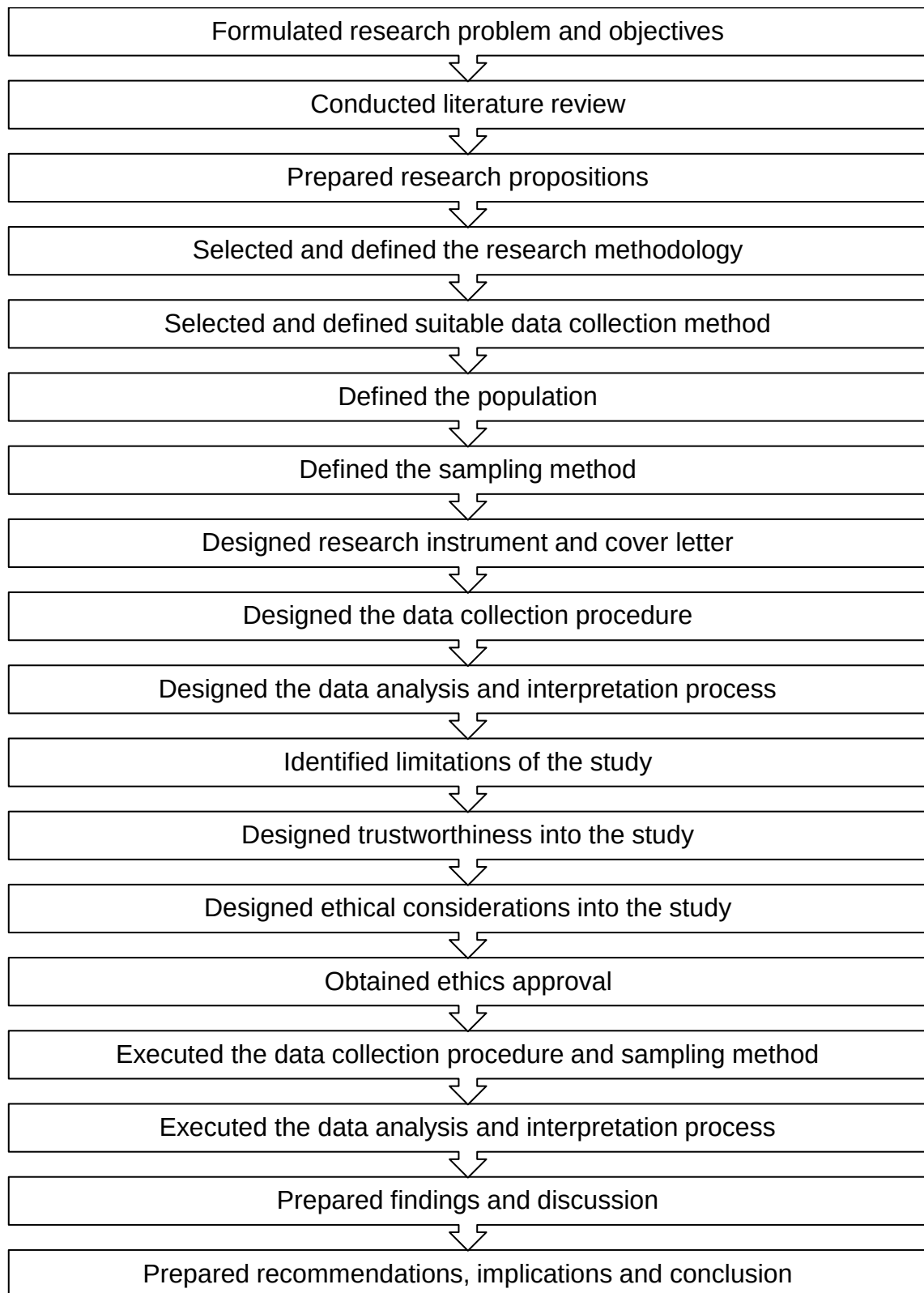


Figure 4: Research process flow chart

Figure 4 provided the blueprint for the research from start to end. Each sequential stage maintained alignment with the research objectives.

3.3 Data collection methods

The study identified a sample survey using a remote oral interview as its preferred method for data collection. This non-face-to-face method supports telephonic and online applications (dos Santos & Wagner, 2021). Considering the increased popularity of online applications since the coronavirus pandemic of 2019, it was deemed appropriate. The study, therefore, used Microsoft Teams (MS Teams) to conduct the interviews. The interview method was chosen for its suitability in examining constructs, including beliefs and opinions (Salkind, 2012). It further supported obtaining first-hand information from respondents based on their experiences, beliefs and perceptions (Salkind, 2012). This method was appropriate considering the study's objectives, which required insight into the respondents' opinions. The flexibility of the interview method was suitably applied, where probing and exploring questions were generated based on responses received (Salkind, 2012). These aspects supported the selection of the interview method; however, three leading detractors of using this method exist. These include the extensive time required where the average interview lasted 79 minutes, possible researcher biases, and reduced anonymity, which may have affected the level of honesty in responses (Salkind, 2012). The need to apply probing questions necessitated a single researcher to facilitate all interviews to avoid variation in the level of probing and limit researcher bias (Salkind, 2012).

The interviews were semi-structured as the study's objectives provided a clear focus, aligning with this type of questioning (dos Santos & Wagner, 2021). The semi-structured interview method covered various contexts, supporting knowledge-generating potential, as required by the study's objectives (Brinkmann, 2018; dos Santos & Wagner, 2021). This type of interview may be called an interview guide as it allows some latitude to expand upon responses that support deeper probing for a richer understanding (Brinkmann, 2018; dos Santos & Wagner, 2021). The interview consisted of both closed and open-ended questions. Explicit responses were required for the closed-ended questions. These were designed so that one of the response options indicated that the respondents had additional information on the matter. In these cases, open-

ended questions were followed to gain an in-depth understanding of the respondents' experiences and opinions (Salkind, 2012). Probing questions were used to follow up on the responses to these open-ended questions where further understanding was required (dos Santos & Wagner, 2021).

3.4 Population and sample

3.4.1 *Population*

The study was concerned with managing people from hazards to health and safety at in-service, grid-connected, utility-scale RE power plants. Therefore, the population could have been considered all global RE power plants to evaluate the first proposition. However, the second proposition required the evaluation of the South African Occupational Health and Safety Act, Number 85 of 1993 (OHS Act) and its Regulations in their ability to appropriately support the management of people from hazards to health and safety. This required a specifically South African perspective. It was therefore considered appropriate for the study to limit its population to all fully operational utility-scale, in-service, solar PV, CSP and wind power plants supplying electricity to the South African national grid.

The population of these RE power plants was considered as those listed on the publicly available database of the facilitators of South Africa's RE Independent Power Producers Procurement Programme (REIPPPP); the Department of Energy's (DOEs) independent power producers (IPP) Unit (Eberhard et al., 2014; Pollet et al., 2015; Republic of South Africa, 2016). It was noted that the available data only included up-to-bid window four, while bid window seven was issued in December 2023 (Independent Power Producers Office, 2023b). The database contained 83 fully operational RE power plants (Independent Power Producers Office, 2023a). As the three main types of RE technologies applied in South Africa have varied operational process requirements, these were considered different strata within the population. The population of these RE power plants is provided in separate Appendices H, I, and J. It was not intended to drill down to the various applications of these RE technologies as encountered within solar PV using a fixed panel or tracking systems or CSP applying either solar power towers (SPT),

parabolic dish collectors (PDC), parabolic trough collectors (PTC) or linear Fresnel collectors (LFR) methodologies. The primary technology types were considered sufficient. The three strata were, therefore, regarded as solar PV, CSP and wind power plants. The number of operational plants within these demographics was 44 PV, six CSP and 33 wind power plants (Independent Power Producers Office, 2023a).

3.4.2 *Sample and sampling method*

With the population being known, the study was based on probability sampling, as the likelihood of each member being selected was known (Salkind, 2012). Stratified random sampling was used to include each stratum within the population. This sampling method was considered appropriate as it accommodated the different profiles of the population, which suitably aligned with the need to include the three strata of the study (Salkind, 2012). This sampling method provided the required representation but was time-consuming (Salkind, 2012). Random sampling was conducted using sequential numbering of the list of RE power plants for each stratum as extracted from the DOEs IPP Units database (Salkind, 2012). Random numbers were generated to determine the sample of potential participants for each stratum (Salkind, 2012). This was achieved by using Microsoft Excel without duplicates. When non-participation was encountered, the random number generator steps were repeated until the appropriate sample size was achieved.

When the potential participants were identified, the project name on the database was used to conduct a Google search to locate the contact details of the potential participant or, rather, the name of the potential participant's power plant. The OHS Act and its Regulations were used to ensure an appropriate person was interviewed. This provided two options, starting with the General Machinery Regulations' prescriptive requirement for users to appoint a competent person to supervise machinery (Republic of South Africa, 1988). This competent person was the first option for interview participants and represented two of the ten respondents. The second option considered the OHS Acts cooperative approach, which prescribes the appointment of safety representatives (Republic of South

Africa, 1993). These individuals represented two of the ten respondents. A third option of interviewing participants in managerial positions with a minimum of one year of experience was included. Here, management represented seven of the ten respondents.

Various factors were considered in establishing an appropriate sample size for the study while covering each identified stratum. Firstly, the size of the population was small and even more so when split by its strata, with the lowest number being six for CSP. The population was clearly defined, including the three strata within it. Regarding the technologies, the population of RE power plants all generate electricity that feeds into the national grid. The study's three strata achieve this electrification through different energy conversion processes. Within each of the three strata, variation was further noted, such as the different types of mounting within solar PV, different focus methods in CSP, different tower construction in wind power plants, etc. However, the study was unable to address these separately. It was deemed impractical to address these within the context of the study's population. The two propositions tested by the research were clear and suitably supported by the literature. The study was qualitative and sought to provide rich insight into the objectives. This was contrasted against making inferences about populations or testing for differences between groups.

The study had a generic qualitative design that permits the integration of other approaches as required (Creswell, 2007). It was therefore considered partly appropriate to draw upon guidance from multiple case study research (Creswell, 2007). This was considered suitable as multiple case study methodologies include using a collection of clearly defined cases, which, although narrower in-depth than a single case, provide for varying in-depth perspectives (Creswell, 2007). As this was partly aligned with the study, its guidance on not exceeding a sample size of between four and five cases was noted (Caelli et al., 2003). In line with these sample numbers, it was considered appropriate to establish an absolute minimum of two participants per stratum with an overall minimum sample size of between six and eight. These numbers, albeit aligning with the supporting literature, were considered somewhat low. Therefore, the study pursued the preferred minimum sample size of three to four participants per

stratum. The final sample size achieved by the study was ten respondents, which was considered suitable. The split per stratum was similarly suitable, with three respondents on solar PV, three on CSP and four on wind. In achieving these numbers, the sampling continued until each power plant in the population was attempted to be contacted on a minimum of two occasions each.

Regarding the low level of interest experienced in participation, suitable mitigating actions were considered necessary from the onset. Firstly, the importance of RE power plants was emphasised by indicating their role in mitigating global warming and South Africa's current shortage in electricity supply. This was presented against the backdrop of the low level of maturity of these industries in South Africa and the right of each citizen to an environment that is safe and free from hazards to health and safety. The study's importance was highlighted as having the potential to inform further research and add to the current low levels of academic literature on the topic. It was indicated that participation was comparable to providing an opportunity for their voice to be heard. Data security and anonymity were guaranteed, and a summary of the concluded study's findings was offered upon completion. Finally, the researcher offered the use of their services as a consulting engineer, without charge, after completion of the research for a single day on any task where his skills may add value or be used. A cover letter addressing these matters was provided before each interview.

3.5 The research instrument

The semi-structured interviews maintained alignment with the research objectives and propositions by following an interview guide. This was prepared for the study and is provided in Appendix K. The interview guide consisted of five sections. In support of the interview guide, a cover letter was prepared and is provided in Appendix L. The cover letter was sent before conducting the interviews (dos Santos & Wagner, 2021). The cover letter justified to the respondents the rationale for them offering time to participate (dos Santos & Wagner, 2021). It further clarified what may be expected by their participation and highlighted the importance of the study and the potential value of their contribution (dos Santos & Wagner, 2021; Salkind, 2012).

The first section of the interview guide was used to establish trust and rapport with the respondents while placing them at ease (Salkind, 2012). This started with basic greetings, introductions, ice breakers, and providing the expected duration of the interview. These aspects were applied to place the respondents at ease (Salkind, 2012). The cover letter's content was confirmed as being understood and verbally explained where needed. The scope of the study was re-iterated during these discussions.

The second section of the interview guide built upon the first by further promoting rapport while characterising the respondent (Salkind, 2012). Here, neutral, face sheet-type questions were used. This approach of neutral questioning before presenting more probing questions further promoted the easing of the respondents (Salkind, 2012). These questions were necessary to provide the information required to determine the suitability of the respondents in line with the study's sampling requirements, and the contextualising of the power plant. It was experienced that one of the respondents did not meet the criteria. Although the interview was completed, the data was not included in the study.

The two sections that followed each addressed a separate proposition. The framework and approach in each of these sections were the same. The framework was based on the hazards to health and safety encountered in the literature for in-service, utility-scale RE power plants. The various studies across the three RE technologies covered within the literature review were considered (Brouwer et al., 2018; Guerin, 2017; Kamenopoulos & Tsoutsos, 2015; Karanikas et al., 2021; Olabi et al., 2021; Palmer, 2018; Webster et al., 2013). As there were no consolidated data on hazards to health and safety for CSP power plants within the literature, potential failures, failure modes and best practices that were included were considered as potential hazards (Khan et al., 2023; Papaelias et al., 2016; Price et al., 2020; Rodríguez-Sánchez et al., 2014). A consolidated list of these hazards to health and safety was created, and five main categories appeared. These categories were biological, chemical, physical and safety, ergonomic, and psychological. The physical and safety hazards category included six sub-categories: electricity, natural environmental elements, operational, mobile plant and vehicles, failures, and external human risks. These

represented a total of ten topics of questioning that formed the framework. Where the interview guide provided extensive texts and repetition, these were not re-read and were only included as a guide to use as required during the interviews.

The first proposition was tested in the third section of the interview guide. Questioning was based on the framework's ten topics. One closed-ended question was asked per topic. Each question was followed by an open-ended question depending on the initial response. First, the respondents were presented with the name of the topic and the applicable hazards to health and safety from the literature. The respondents were then asked for their opinion on whether the listed hazards suitably cover those of that topic while their power plant is under normal operating conditions. The required response was initially a simple "Yes," they do, or "No," they do not. When the response was "Yes," there was no further questioning on the topic, and the interview proceeded to the next question. When the response was "No," the respondents were then asked to provide a description based on their experience to allow for an understanding of the hazard. It was encountered where respondents did not respond negatively but provided a discussion, which was included in the study. Probing questions were used to build upon the responses. This area of questioning was also used to confirm the position of previous respondents when applicable and when possible. Here, the discussions of earlier respondent's responses were presented in hypothetical scenarios to test if similar experiences existed across the same RE technologies.

The second proposition was tested in the fourth section of the interview guide. Questioning was again based on the framework's ten topics and followed the same format as in the previous section. One closed-ended question was asked per topic. Each question was followed by an open-ended question depending on the initial response. The respondents were again presented with the name of the topic together with the same listed hazards to health and safety. The respondents were then asked for their opinion on whether the OHS Act and its Regulations appropriately supported the management of people from the listed hazards under the topic for the RE power plant they were working at while the plant was under normal operating conditions. The OHS Act and Regulations were included in the

same question as they are an integrated set of requirements that cannot be separated. They jointly and holistically guide on matters of health and safety. As the potential response to this question may have presented the respondents with some difficulty, various applicable sections from the OHS Act and Regulations, as identified in the literature review, were included together per category. These were, however, only used to assist respondents and stimulate any responses to the open-ended questions when needed. The required response to the question was initially a simple “Yes,” they are suitable, or “No,” they are not. When the response was “Yes,” there was no further questioning on the topic, and the interview proceeded to the next question. When the response was “No,” the respondents were then asked to describe their experience to allow an understanding of the shortcomings. It was encountered where respondents did not respond negatively but provided a discussion, which was included in the study. When the responses to the open-ended questions required further understanding, probing questioning was used. As in the previous section, this area of questioning was also used to confirm the position of previous respondents when applicable and possible. Here, the discussions of earlier respondent’s responses were presented in hypothetical scenarios to test if similar experiences existed across the same RE technologies.

The fifth and final section of the interview guide was where the interview was concluded. Here, the respondents were thanked for their time and their valuable contribution. The respondents were asked if they had any questions, and the offer to provide them with a summary of the concluded study’s findings was reiterated.

The average duration of the interviews was 79 minutes. This was considered acceptable as it was aligned with the findings from a study by Irvine (2011) that covered the duration of interviews. The study by Irvine (2011) found that the average duration for interviews from 28 studies was 92 minutes, with the average for telephonic interviews from 9 studies being 81 minutes.

3.6 Procedure for data collection

The data collection procedure was developed to align with the sampling method and the research instrument. Accessing the appropriate respondents at the RE power plants was a challenge in the data collection process. Therefore, emphasis was placed on detailing this in a series of progressive steps. These steps culminated in the remote interview and are provided in Figure 5.

It can be noted in Figure 5 that each step in the process towards the interview had an action and an outcome. Alternatives were provided for actions and outcomes, considering the initial level of uncertainty. The final step, consisting of the interview, followed the interview guide provided in Appendix K. Although the audio was recorded for each interview, notes were made as a backup. The audio files were used to generate a transcription into Microsoft Word using the MS Teams functionality. A consent form was sent to all respondents to obtain consent to participate in and record the interview. The form provided options for the respondents to accept, and all respondents endorsed and returned it. A copy of the consent form used is provided in Appendix M.

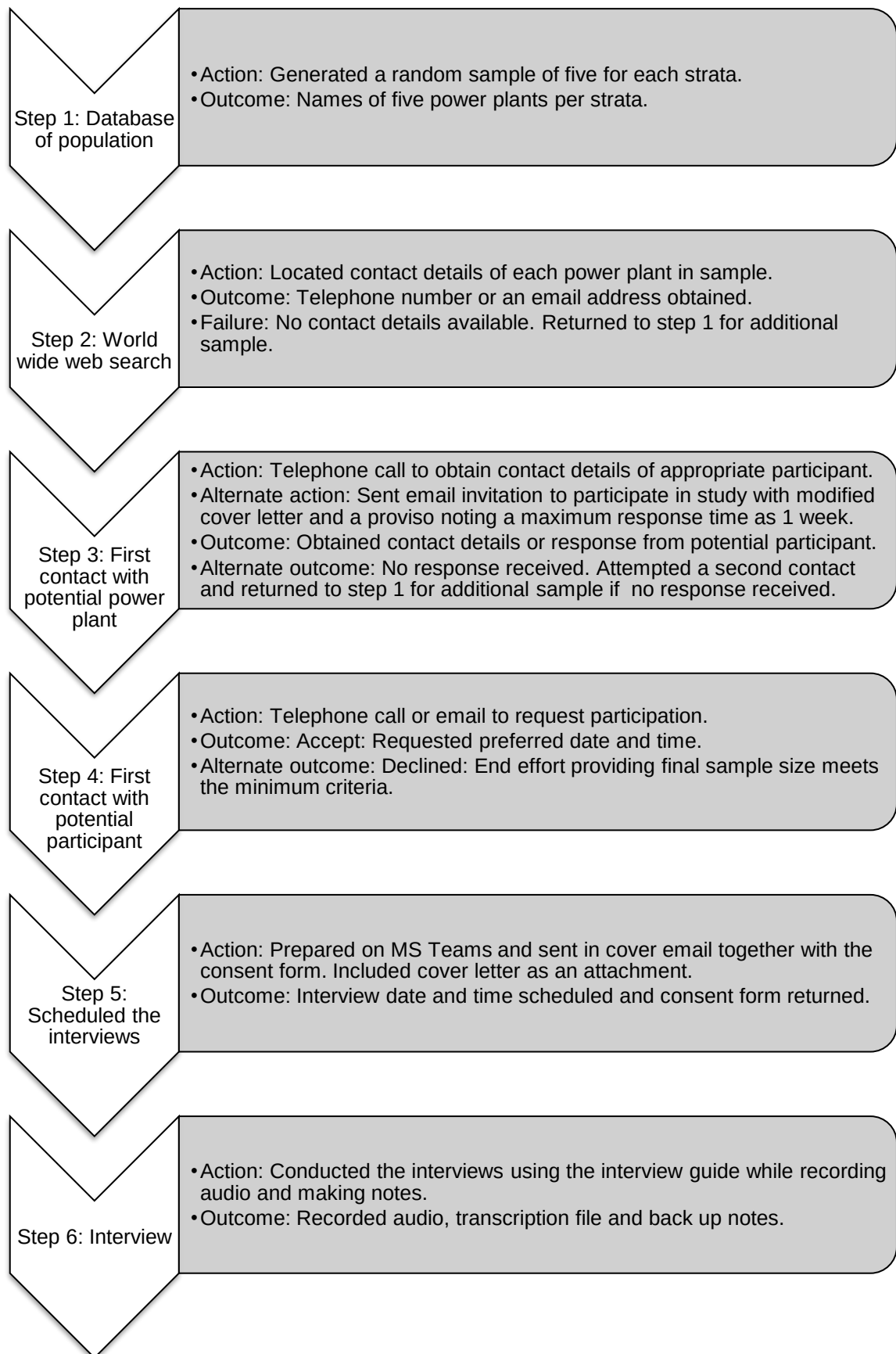


Figure 5: Data collection process

3.7 Data analysis and interpretation

The study implemented electronic data management and control from the onset. This was noted to be a fundamental aspect often overlooked (Merriam, 2009). A folder was created for each potential participant when the random samples were generated. An information sheet was created for each of these to record all communications and contact details. These information sheets and the data collected on the potential participants were stored in the same folder. The computer used was password-protected, and data storage was synchronised with Microsoft OneDrive's online platform. All data collected will be destroyed five years after concluding the report. An additional folder was created and labelled "sampling," where records of all random sampling were kept. The rationale was the possible exhaustion of potential participants within the small population (which was realised). Aligned with this approach, a log was maintained for each time random numbers were generated. The list of power plants for the population was allocated a sequential number to generate the random number from. When potential participants declined to participate or did not respond, additional potential participants were sought. In these instances, new random numbers were generated, and the reason for doing so was logged. This resulted in providing a record of all random numbers generated and the reasons for adding additional ones.

The folders where each potential participant's records were stored were labelled using the type of RE, as PV, CSP or W for wind, followed by the letters RNG for random number generator and the log number for the stratum. Therefore, the folder for the first generated sample for PV was labelled "PV_RNG01". Data associated with the interviews were similarly stored electronically within these folders with descriptive filenames.

The final element of data management and control required collating all data into a single matrix. This provided a single consolidated inventory of all the respondents' data. The matrix was populated progressively after each interview concluded. It served as a visual aid of the entire dataset and supported part of the analysis. For this purpose, a data collection matrix was designed using Microsoft Excel, and an extract of its headings is provided in Appendix N.

The analysis was preceded by contextualising each respondent and the individual power plant they represented. This provided context to the respondents and was achieved by tabulating various characteristics under three topics from the face sheet questions. The populated tables are provided in Appendix O. Firstly, the number of interviews conducted was ten, consisting of three solar PVs, three CSPs, and four wind respondents. A second table characterises the respondents, and it was observed that although only two were appointed as the competent person supervising the machinery, an additional three held the same level of competency to do so. All respondents were found to have an appropriate tenure at the power plant they represented, averaging 34.8 months. Similarly, all respondents had extensive prior experience, with an average of 15 years in various relevant industries. Ensuring the respondents met the sample requirements was essential to add validity to the responses received. Finally, the plant-specific details for each RE technology were provided. The populated tables in Appendix O can be referred to for any specific contextualisation. However, the average capacity of each stratum was 71.3, 93.3 and 138.7 megawatts (MW) for solar PV, CSP and wind, respectively.

The analysis of the interview guides closed-ended questions followed. These only required a simple “Yes” or “No” response and, as such, were considered nominal data (Tredoux, 2002/2010). The analysis consisted of simple descriptive statistics to provide an initial indication of the dataset. Considering the type of data, frequency distributions were deemed appropriate (Austin, 2002/2010). Here, percentages and bar charts were used to display the data (Austin, 2002/2010). The data collection matrix was formatted to automatically produce the various bar charts from the populated responses. The method of analysing the closed-ended questions from sections three and four of the interview guide, each dealing with a separate proposition, was identical but conducted separately.

Firstly, a bar chart indicating the extent of support for each proposition per respondent as a function of a percentage of all ten questions was provided. This was intended to provide an initial overall indication of the extent of support for the propositions per respondent. A series of bar charts followed to illustrate the extent of support per question, broken down per stratum. These charts were used to

indicate any commonalities across strata and questions. These were provided separately for each proposition, together with a descriptive discussion.

Where the propositions were not fully supported, qualitative data analysis was used. The responses and discussions provided the respondent's opinions and experiences. Thematic analysis was selected as it is suited to provide an understanding of these discussions and make such data meaningful (Merriam, 2009). It is noted to be a flexible approach suitable for those entering qualitative research (Braun & Clarke, 2012). The study initially drew insight from the respondents as a bound system and then checked for support of common themes as found in cross-case study analysis (Merriam, 2009). The way thematic analysis requires the researcher to move beyond the specific content of responses and offer potential meanings was suitably aligned with the study. An inductive, bottom-up approach driven by responses received was applied during the coding and analysis (Braun & Clarke, 2012; Merriam, 2009).

No single agreed-upon set of guidelines exists for conducting thematic analysis (Braun & Clarke, 2006). However, an approach previously identified was applied that uses six phases (Braun & Clarke, 2006). These phases consist of data familiarisation, creating the initial codes, searching for themes, reviewing the themes, defining and naming the themes and preparing the report (Braun & Clarke, 2006).

In the first data familiarisation phase, the audio file was played after each interview while reading and checking the transcribed file. Data immersion was achieved by reviewing the notes and observations while adding additional ones as required. This task was considered primary data analysis that would improve the effectiveness of the interviews that followed (Merriam, 2009). This was used to enhance the preparation and generate better-probing questions for the remaining interviews (Merriam, 2009). These questions included hypothetical scenarios to determine if similar experiences existed across the same type of RE technologies (Morse, 2015). This way, the data analysis commenced after the first interview and progressively built after each.

It was observed that an overlap existed with the second phase of generating initial codes that appeared during the initial data familiarisation. The coding process started with identifying segments within the data that were of interest in response to the propositions (Merriam, 2009). This was partly initiated during the first phase, where open coding was broadly applied (Merriam, 2009). As additional codes appeared throughout the interviews, the transcripts were re-read, and a holistic coding process was applied. The code segments were all marked up within the transcribed files. These segments were allocated descriptive code names and were referred to as the coded data (Braun & Clarke, 2012; Merriam, 2009). A list of these was maintained (Merriam, 2009). The extent of codes was not limited; instead, they were allowed to be directed by the data (Merriam, 2009).

This was followed by actively searching for patterns and commonalities across the codes within phase three (Braun & Clarke, 2012; Merriam, 2009). Potential themes were identified from these patterns and commonalities (Braun & Clarke, 2012; Merriam, 2009). This was achieved by repeatedly reviewing the coded data and grouping codes with similar attributes (Braun & Clarke, 2012). The identified potential themes were constructed from these grouped codes (Braun & Clarke, 2012; Merriam, 2009). Particular consideration was provided for commonalities across interviews as encountered in a cross-case study analysis (Merriam, 2009; Morse, 2015). Each potential theme was allocated an interpretive working title and a list of these was maintained (Braun & Clarke, 2006; Merriam, 2009). This phase was concluded by creating a tabulated list of each theme together with their supporting codes. Each code was accompanied by its respective extract from the data segment.

A quality check followed in phase four, where each potential theme was reviewed (Braun & Clarke, 2006). Within this phase, themes found ill-aligned with the proposition were discarded, and others found to be similar were merged (Braun & Clarke, 2006). This required a review of all codes followed by a refinement process of the themes (Braun & Clarke, 2006). Each theme, coded extracts previously collated, was re-read to ensure they represented coherent patterns (Braun & Clarke, 2006). Once satisfied, a thematic map was generated, and the refining process commenced (Braun & Clarke, 2006). While refining the themes,

a similar process was followed to ensure they accurately represented the data set (Braun & Clarke, 2006). This process supported the validity of the themes generated (Braun & Clarke, 2006). Achieving this, however, required another re-read of the data to consider it holistically (Braun & Clarke, 2006). This ensured accurate data representations where additional codes appeared, and themes were further refined (Braun & Clarke, 2006). This final process was repeated until the thematic map appropriately fitted with the data (Braun & Clarke, 2006).

The penultimate fifth phase ensured the themes were clearly defined by conducting intensive thematic analysis (Braun & Clarke, 2012). As experienced in previous phases, there was an overlap between the penultimate and final phases (Braun & Clarke, 2012). This phase covered the intense analysis of the themes and the selection of data extracts from the coded data to present as supporting the analysis (Braun & Clarke, 2012). Here, themes were further refined to ensure they appropriately indicated the overall essence of the theme (Braun & Clarke, 2006). The collated data extracts were further organised to ensure suitability and consistency (Braun & Clarke, 2006). A brief narrative was prepared for each data extract indicating the reason for selection and the area of interest (Braun & Clarke, 2012). From these, a written analysis of each theme was prepared using selected extracts from the data that demonstrated and supported the overall position of the theme (Braun & Clarke, 2012). The objective was to provide an interpretation of the meaning of the data (Braun & Clarke, 2012).

In the sixth and final phase, the final reporting was completed. This included organising the analysis of each theme into a logical order (Braun & Clarke, 2012). The working titles of the themes were allocated final descriptive titles (Braun & Clarke, 2006). The narrative within the analysis of the themes was refined to ensure the overall position was demonstrated and aligned with the propositions (Braun & Clarke, 2012).

3.8 Limitations of the study

The study encountered three areas that were considered limitations. These included the variation within each RE technology, the respondents, and the power plants' maturity level. These need to be considered when reviewing or interpreting the findings.

The variation within each RE technology presented itself as a weakness as different operational applications remain within each stratum. The study only encountered CSP plants with PTC-focusing technologies. As none of the other three focusing technologies were encountered, the study's context is limited to PTC. Other aspects, such as solar PV mounting on single or dual-axis tracking, were considered minor nuances within the same technology. The limitation within the CSP stratum was considered impractical to address in the current study and may be considered an area for further research.

The respondents were considered to represent a potential weakness in the validity of the data. Although the extent of this remains unknown, the study encountered instances on two occasions where respondents' responses were considered errors in judgement or misunderstandings. These may have been introduced into the data from inappropriate knowledge of the topic or the OHS Act and possibly an unacceptable level of honesty. The study attempted to mitigate the knowledge gap by ensuring that a specific respondent was interviewed. In terms of honesty, this was considered outside of the researcher's ability to control. The impact remains unknown, and the extent remains similarly unknown.

The level of maturity of RE power plants represented another potential weakness in the validity of the data. The literature revealed that the adoption of grid-connected RE power plants has a low level of maturity when compared with other established industries. The study confirmed the same, with two respondents within the wind stratum having operated for less than two years. This limited operating time has the potential to impact the extent of experience and witnessing of the effects of degradation of plant and equipment. However, the average operation for all sampled plants was just over six years. Considering the

respondents were found to participate in industry collaboration, the impact of this matter was considered to be low.

3.9 Trustworthiness

The study followed established criteria to ensure it was conducted rigorously, as provided within a framework developed in the 1980s (Guba & Lincoln, 1981). The criteria included four aspects of trustworthiness that promote rigour in a qualitative study: applicability, truth value, consistency, and neutrality (Guba & Lincoln, 1981). In response to these, the study needed to consider four matching terms: fittingness, credibility, auditability and confirmability (Guba & Lincoln, 1981). The names of two of these terms were found to change and were noted by one of the same authors as transferability, credibility, dependability and confirmability (Guba, 1981). These later names were more common and applied in the study (Lincoln & Guba, 1986; Morse, 2015; van Aardt & Hirschsohn, 2021). It was observed that Guba and Lincoln added authenticity to trustworthiness; however, current literature suggests less focus on this criterion (Shannon & Hambacher, 2014; van Aardt & Hirschsohn, 2021). Therefore, the study did not include this in establishing its level of trustworthiness.

Although the criteria dates back three decades, Morse (2015) confirmed that the framework's continued use mainly remained unchallenged. This position was supported by van Aardt and Hirschsohn (2021), who recommend its use for evaluating qualitative research. The criteria do not, however, remain without contestation, as was raised by Morse (2015). Morse (2015) recommended using alternate terminology typically associated with quantitative studies as found within the scientific paradigm. Although this recommendation was made, the strategies provided in the study mostly aligned with those presented in Guba and Lincoln's writings (Morse, 2015). It was noted by van Aardt and Hirschsohn (2021) that there is no universally agreed-upon set of criteria to evaluate qualitative research.

The study, therefore, considered the criteria and terminology of Guba and Lincoln as suitable. The four terms, transferability, credibility, dependability, and confirmability, were incorporated into the study, as illustrated below.

3.9.1 *Transferability*

Here, the study sought to ensure a suitable level of trustworthiness for its applicability was addressed (Guba & Lincoln, 1981). Applicability determines the degree to which the study's findings may be applied in other contexts (Guba & Lincoln, 1981). This required considering the transferability of the study (Guba & Lincoln, 1981). Guba and Lincoln (1981) referred to this aspect of trustworthiness as the naturalistic paradigm's equivalent to external validity or generalisability in the scientific paradigm.

According to Guba and Lincoln (1981), the study's findings may only be considered transferable to other RE power plants when the contexts are the same. As the study included questions to characterise each of the RE power plants by their type of technology, it was considered that a fair level of transferability exists (Guba & Lincoln, 1981). The extent of transferability was improved by the study's adoption of probability sampling (Guba, 1981). A matter that detracts from the study's transferability level was the extent to which the final sample represented the population (Guba & Lincoln, 1981). Here, the study sampled a fair representation of the CSP and wind strata at 50 and 15.2%, respectively. However, the Solar PV stratum was relatively low at 6.8%, which reduces the level of transferability for this stratum.

To further promote the study's level of transferability, appropriate data was collected and "thick descriptions" developed (Guba & Lincoln, 1981). These thick descriptions needed to include specific contextual aspects to allow for transferability to be considered in context (Guba & Lincoln, 1981). Applying the definition of thick description from Geertz (1973) required the study to include detailed descriptions of the RE power plant technologies and their operational characteristics. Their circumstances were considered comparable as they were all grid-connected.

3.9.2 *Credibility*

Here, the study sought to ensure a suitable level of trustworthiness for its truth value was addressed (Guba & Lincoln, 1981). Truth value promotes confidence in believing the study's findings are truthful (Guba & Lincoln, 1981). This required ensuring the credibility of the study (Guba & Lincoln, 1981). Guba and Lincoln (1981) referred to this aspect of trustworthiness as the naturalistic paradigm's equivalent to internal validity in the scientific paradigm.

The study adopted recommendations from Guba and Lincoln (1981) that improved its credibility. These included random sampling, minimising distortion during the interview by building rapport and reducing bias between data collection, coding and analysis by using a single researcher (Guba & Lincoln, 1981). The study drew insight from respondents as a bound system and then checked for support across respondents that promoted the credibility of findings (Guba & Lincoln, 1981). This aspect was called member checks that promoted the credibility of the study's findings (Guba & Lincoln, 1981; Morse, 2015).

3.9.3 *Dependability*

Here, the study sought to ensure a suitable level of trustworthiness for its consistency was addressed (Guba & Lincoln, 1981). Consistency promotes the notion that a study's findings can be replicated when applied to similar respondents within similar contexts (Guba & Lincoln, 1981). This required considering the study's dependability (Guba & Lincoln, 1981). Guba and Lincoln (1981) referred to this aspect of trustworthiness as the naturalistic paradigm's equivalent to reliability in the scientific paradigm.

Guba and Lincoln (1981) suggest that some overlap exists where enhanced credibility simultaneously results in appropriate levels of dependability. Similarly, the methods for demonstrating dependability were repeated from those applied to improve credibility (Guba & Lincoln, 1981). Additionally, Guba and Lincoln (1981) suggest that clear records of the research process and decisions in an audit trail promote dependability. Aligning with this, the study developed a detailed electronic data management and control system. Therefore, the study

was considered suitably dependable and able to be replicated. Aspects that further promoted the position of replicability of the study's findings were considered as the detailed requirements for the respondents, the detailed interview guide and the data collection matrix (Guba & Lincoln, 1981). Guba and Lincoln (1981) recommend conducting external audits after completing the research to confirm dependability. This position was not considered practical for the study and is suggested by Morse (2015) not to be standard practice.

3.9.4 ***Confirmability***

Here, the study sought to ensure a suitable level of trustworthiness for its neutrality was addressed (Guba & Lincoln, 1981). Neutrality promotes the notion that the study's findings are devoid of the researcher's biases and appropriately represent the respondents' position (Guba & Lincoln, 1981). This required considering the confirmability of the study (Guba & Lincoln, 1981). Guba and Lincoln (1981) referred to this aspect of trustworthiness as the naturalistic paradigm's equivalent to objectivity in the scientific paradigm.

Again, Guba and Lincoln (1981) suggest some overlap exists where enhanced credibility simultaneously results in appropriate levels of confirmability. Similarly, the methods for demonstrating dependability were repeated from those applied to improve credibility (Guba & Lincoln, 1981). Ensuring confirmability was challenging and required further consideration over and above the methods provided to promote credibility for the study (Guba & Lincoln, 1981). Therefore, the study aimed to produce findings that were as far as reasonably practicable, free from researcher bias, personal traits, and shortcomings (Guba & Lincoln, 1981). This was achieved by reporting the data as it emerged and not pre-empting the outcome, applying random sampling to avoid preferred context selection and using neutral questioning in the interview guide (Guba & Lincoln, 1981; Morse, 2015). Reporting the data in a manner that could be confirmed shifted the emphasis from the researcher to the data itself (Guba & Lincoln, 1981). The study was considered to contain an acceptable level of confirmability, which was supported by the repeated use of the same researcher to conduct all

interviews, coding, and analysis and as indicated by Guba and Lincoln (1981), subjectivity remains an unavoidable human trait.

3.10 Ethical considerations

The study was considered in line with the University of Witwatersrand's (WITS) Human Research Ethics Committee (HREC) (non-medical) risk categories, where the appropriate category was deemed to fall between minimal and low risk. This was because the study pursued opinions on hazards to health and safety. However, biographical questioning was used to qualify respondents. Although the category for minimal risk does not include detailed biographical information, it was considered more appropriate as there was no risk of the respondents experiencing discomfort, as included in the low-risk category. The study did not include any sensitive questions. Therefore, the appropriate risk category for the study was considered to be "minimal risk". Ethical clearance for the study was received from the WITS Business School's Ethics Committee and is provided in Appendix P.

The study was conducted per the WITS research integrity procedure and the Singapore statement of research and integrity. An approach based on universalism was adopted where it was considered morally wrong to compromise ethical principles (Hirschsohn & Faasen, 2021). The following discussions on how this was achieved illustrate where seven aspects of ethical research were considered (Hirschsohn & Faasen, 2021; Salkind, 2012).

Protection from harm: The study considered physical and psychological risks (Hirschsohn & Faasen, 2021; Salkind, 2012). The research was designed and conducted so that no physical risk to respondents or the researcher was possible (Hirschsohn & Faasen, 2021; Salkind, 2012). The remote interview platform supported this, as did the interview guide's questioning sequence. Rapport was established during the interviews, which reduced the respondent's stress levels and promoted trust before shifting to open-ended questioning of opinions (Hirschsohn & Faasen, 2021). All interview questions were related to the scope of the study; however, biographical questions about the respondents were

included. Random sampling was used, which provided an equal participation opportunity to all. The study applied stringent data management to ensure anonymity and confidentiality. This was done to avoid potential harm to the respondents regarding victimisation or employment limitations (Hirschsohn & Faasen, 2021; Salkind, 2012).

Informed consent: The study addressed this matter within the consent form contained in Appendix M. The consent form allowed the respondents to agree or disagree on aspects of the research. All respondents populated, endorsed, and returned the consent forms to the researcher. This was deemed suitable when considering the WITS, HREC (non-medical) risk categorisation as minimal (Hirschsohn & Faasen, 2021). An accompanying cover letter was provided to all respondents, that supported the ability to make informed decisions when completing the consent form (Hirschsohn & Faasen, 2021; Salkind, 2012).

Maintenance of privacy: The study was designed and conducted so that only the researcher could cross-check the results of coded data to respondents to ensure anonymity (Hirschsohn & Faasen, 2021; Salkind, 2012). The study's findings do not include the names of respondents or the power plants they represented, so there is no way of linking the findings to respondents or power plants. Qualifying the respondents was included, but there is no way of linking the respondents or power plants to the findings. Privacy and anonymity were addressed in the cover letter and reiterated at the beginning of the interviews.

Maintenance of confidentiality: The study was designed and conducted to ensure appropriate data management was applied (Hirschsohn & Faasen, 2021; Salkind, 2012). This included limiting access to the data to a single researcher and password-protecting the computer where the data was stored. The respondents were notified in the cover letter that all data collected would be destroyed five years after the report's conclusion. Consideration was provided for South Africa's Protection of Personal Information Act, Number 4 of 2013 (POPIA). The POPIA provides for various aspects that were suitably addressed by the study, such as consent, data collection for research purposes, and security measures ensuring confidentiality (Republic of South Africa, 2013). The consent forms that were endorsed and returned by all respondents appropriately meet the

intention of POPIA. This includes obtaining prior written permission to use the information for research purposes. Confidentiality was similarly addressed in the cover letter and reiterated at the beginning of the interviews.

To avoid coercion or deception: The study was designed and conducted to ensure that clear intentions of the research were provided and that participation was communicated as being entirely voluntary (Hirschsohn & Faasen, 2021; Salkind, 2012). Voluntary participation was included in the cover letter.

Conflict of interest: The study was designed and conducted in an environment free from conflict of interest (Hirschsohn & Faasen, 2021; Salkind, 2012). The researcher received no funding, which could have compromised the study. The researcher also has no affiliation with any authority that may have a vested interest in the study's outcome.

In pursuit of trust and reciprocity: All respondents were offered a summary of the concluded study's findings (Hirschsohn & Faasen, 2021; Salkind, 2012). This was to ensure that any benefits that may arise from the study were shared.

3.11 Consistency table

A consistency table has been provided below that illustrates the linkage between the research objectives, propositions, data collection and analysis.

Table 3. Consistency table: Research objectives, propositions, data collection and data analysis

Research objective number	Research objective	Proposition number	Proposition	Data collection detail	Data analysis method
-	-	-	-	Interview guide, section 2, questions 1-12	Basic descriptive analysis to characterise and qualify potential respondent
1	Identify health and safety hazards unique to in-service, grid-connected, utility-scale solar PV, CSP and wind power plants.	1	Considering the literature reviewed for in-service, grid-connected, utility-scale solar PV, CSP and wind power plants, it is proposed that these plants do not present any health and safety hazards unique to these sectors while under normal operating conditions.	Interview guide, section 3, questions 1-10.	Basic descriptive analysis of closed-ended questions and thematic analysis of open-ended questions.
2	Evaluate the suitability of the South African OHS Act and its Regulations	2	Considering the literature reviewed for in-service, grid-connected, utility-scale solar	Interview guide, section 4, questions 1-10.	Basic descriptive analysis of closed-ended questions

Research objective number	Research objective	Proposition number	Proposition	Data collection detail	Data analysis method
	to appropriately support the management of people from hazards to health and safety within utility-scale, in-service, solar PV, CSP and wind power plants supplying electricity to the South African national grid.		PV, CSP and wind power plants and the USAs position on managing hazards on these RE power plants, it is proposed that the South African OHS Act and its Regulations appropriately support the management of people from hazards to health and safety.		and thematic analysis of open-ended questions.

CHAPTER 4. FINDINGS AND DISCUSSION

4.1 Introduction

The findings from the study are presented together with the analysis within this chapter. This approach was adopted as appropriate to the method of analysis. The findings and discussion for proposition number one are presented first. This is followed by the same for proposition number two. Although both propositions are presented separately, the format will be identical.

Each proposition will first be provided with an overall indication of the findings from the closed-ended questions. This will be presented within a series of bar charts using frequency distributions. The extent of support for the propositions precedes the thematic analysis where the propositions were not fully supported. The two propositions and related themes are illustrated in a thematic map in Figure 6.

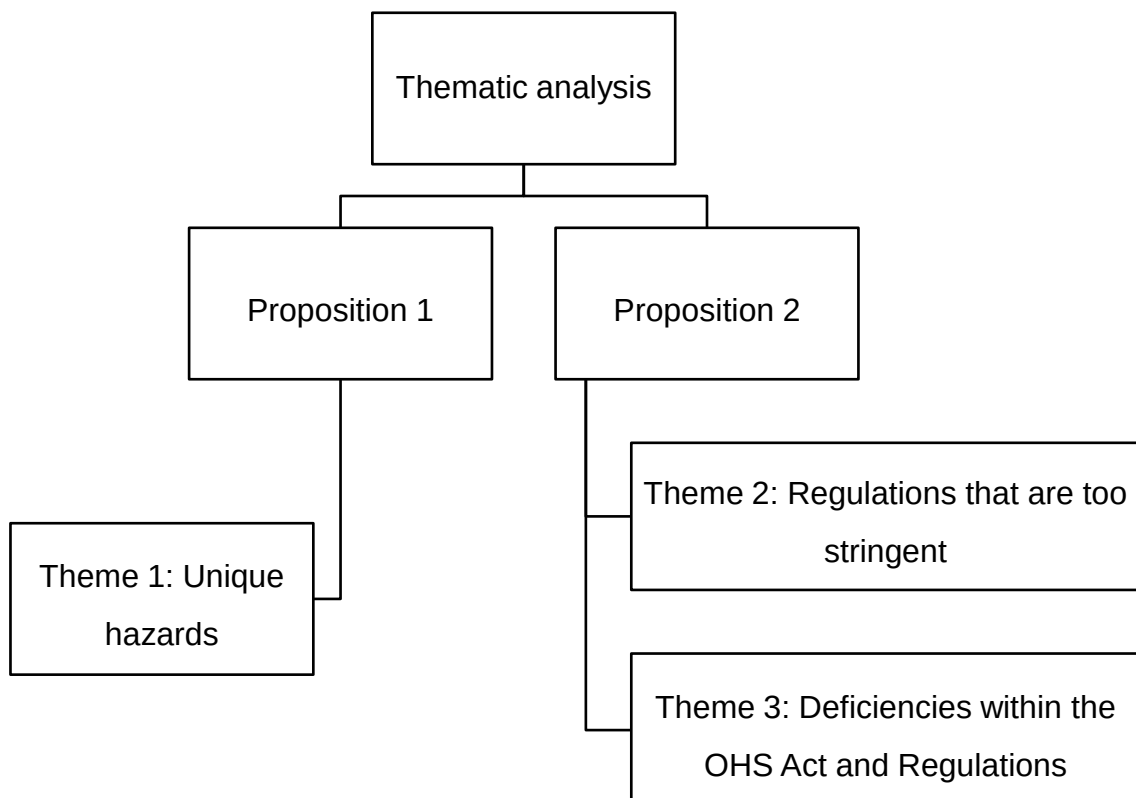


Figure 6: Thematic map

Following the bar charts and discussion of frequency distributions is the thematic analysis of the open-ended questions and discussions. The above thematic map illustrates that the first proposition has a single theme titled, "Unique hazards". The second proposition is shown with two themes titled, "Regulations that are too stringent" and "Deficiencies within the South African Occupational Health and Safety Act, Number 85 of 1993 (OHS Act) and Regulations". Within each of these themes, segments from the interviews are provided together with a discussion. Within the thematic analysis, where extracts are used, they are followed by the letter "R" and the sequential interview or respondent number. Access to more extensive data extracts is available upon request.

Following the thematic analysis for each proposition, a conclusion is provided. The chapter concludes with a summary of the findings and a table comparing the current study's findings with those from the literature.

4.2 Findings and discussion pertaining to proposition 1

This section presents the findings and discussion that tests the first proposition. Herein, it was sought to determine if the respondents considered their renewable energy (RE) power plants to present any health and safety hazards unique to these sectors while under normal operating conditions.

4.2.1 *Closed-ended questions on unique hazards*

The study's findings revealed that the respondents agreed to a large degree with proposition number one (97%). The extent of the agreement supported the position that these RE power plants do not present any health and safety hazards unique to these sectors while under normal operating conditions. Figure 7 below illustrates this position in a bar chart as a function of the percentage agreement per respondent.

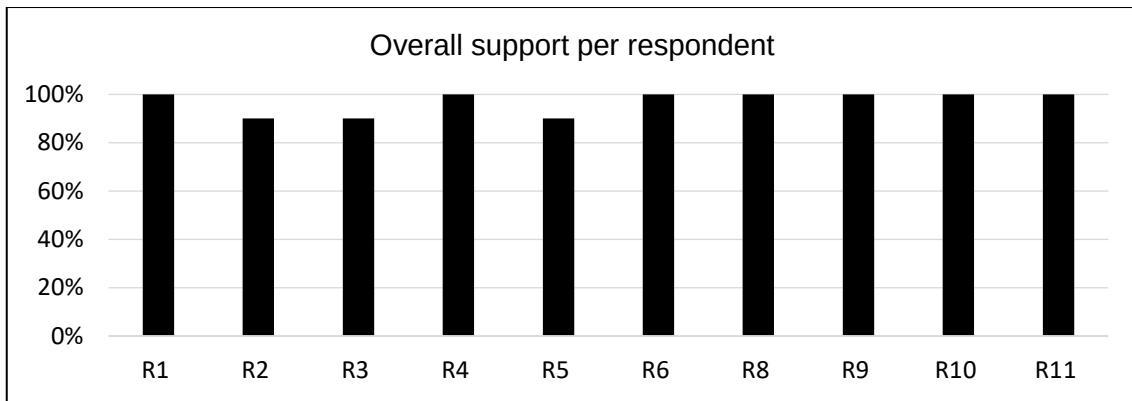


Figure 7: Overall support for proposition number 1 per respondent

Figure 7 illustrates that seven of the ten respondents fully agreed with proposition number one. With only three in agreement to some extent (90%). As ten closed-ended questions were presented to each respondent, the extent of disagreement only covered three questions. To illustrate this, Figure 8 below provides a bar chart showing the number of respondents in agreement per question.

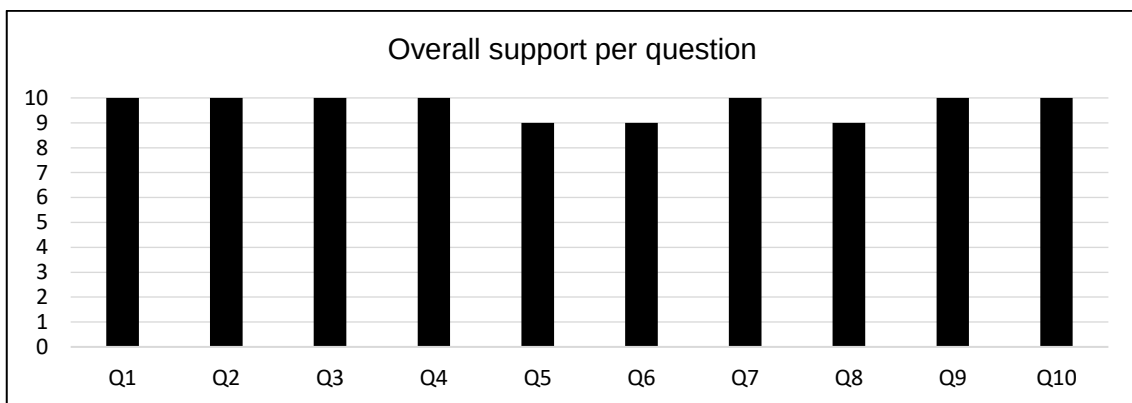


Figure 8: Overall support for proposition number 1 per question

Figure 8 illustrates the three questions where disagreement was encountered, as questions 5, 6, and 8. These were within the categories of operational hazards (Q5), mobile plant and vehicles (Q6), and external human risks (Q8). The frequency of disagreement was noted as a single respondent for each of these. In these instances, it suggests that the respondents considered their RE power plant to present unique health and safety hazards under normal operating conditions. The data was split according to the three strata within the population to explore these areas further. Figure 9 below provides three bar charts showing

the number of respondents in agreement per question for each stratum within the study.

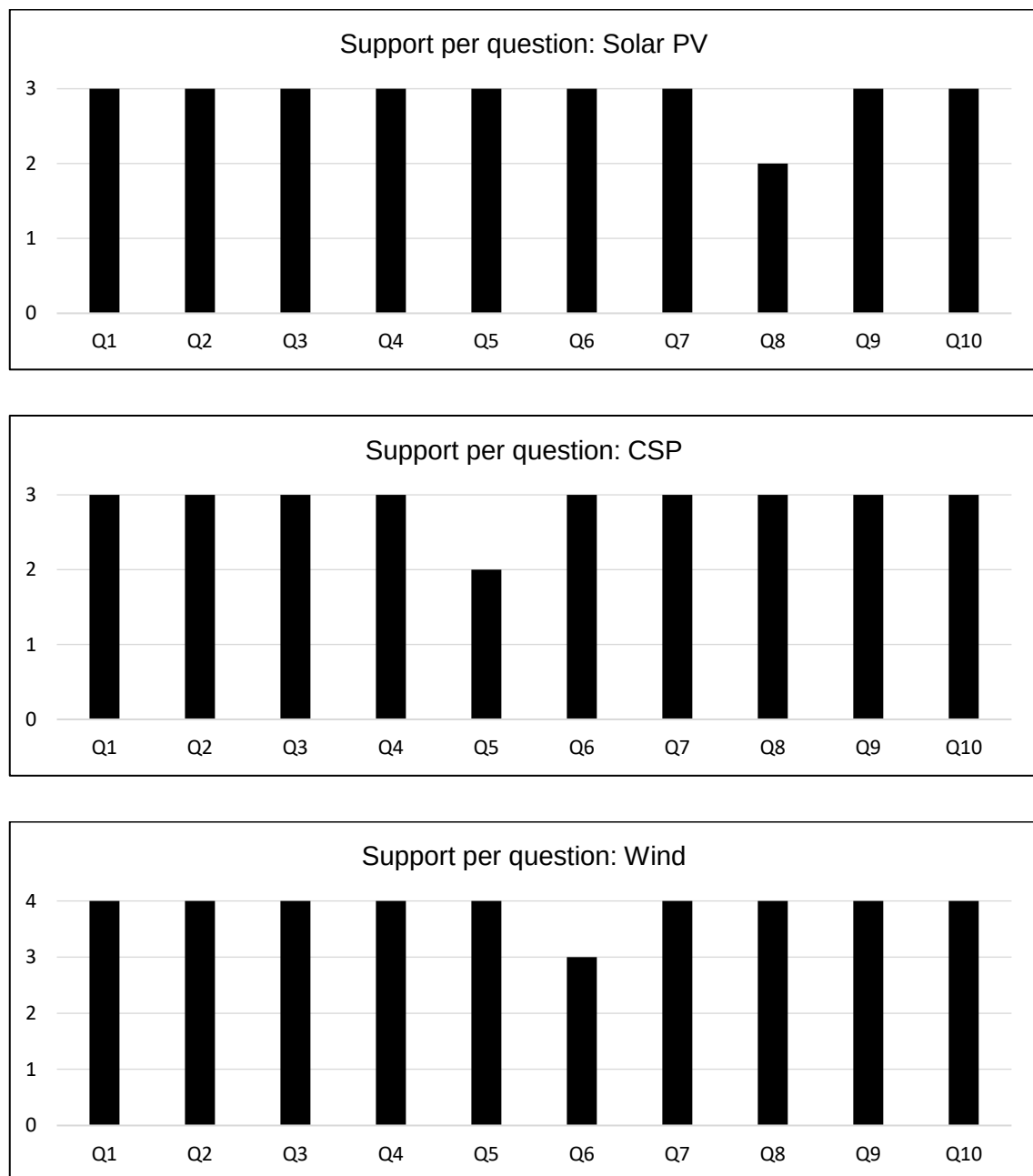


Figure 9: Support for proposition number 1 per RE technology type

Figure 9 illustrates that the single disagreement for each question was from different strata. Solar photovoltaic (PV) technology represents a single disagreement under the category of hazards associated with external human risks (Q8). Concentrated solar power technology represents the single disagreement under the category of hazards associated with operations (Q5).

The final disagreement under the category of hazards associated with mobile plant and vehicles (Q6) was from the wind technology stratum. The initial indication of the dataset illustrates the extent of support for proposition number one across all three of the RE technologies. None of the categories where disagreement was encountered was repeated.

4.2.2 *Open-ended questions on unique hazards*

As indicated above, there were only three instances where the respondents suggested that they considered their plant to present unique hazards. It was observed that these may have been errors in judgement or misunderstandings. As two of the three suggested, unique hazards were not considered unique when presenting them to respondents from the interviews that followed. The third one appears to be a typical industry hazard only recognised by the application of the new technology. These will, however, for completeness, be presented and discussed in the section below under a single theme.

4.2.2.1 *Theme 1: Unique hazards*

The first hazard that was suggested to be unique was related to the risk that a disabled person may present. The below extracts illustrate the position of the respondent:

- i. "I don't think we do cater for disabled people. So in case of an emergency, we don't have people that will assist them" (R2).
- ii. "We only cater for the toilets, but I don't think we cover adequately when it comes to disabled people in terms of inclusion to the evacuation plans" (R2).
- iii. "I think they are exposed because we are not, covering them and we don't have training on how to handle disabled person in a case of an emergency" (R2).

The risk was associated with the ability to appropriately cater for disabled persons in the event of an emergency that may require their evacuation. This hazard was

presented to seven respondents in the interviews that followed. Where all seven disagreed, and the following are examples of their responses:

- i. "No, no, no, Sir. I'm also a person with a disability. I've got an amputation. So that speaks for itself" (R4).
- ii. "it shouldn't be a problem" (R5).
- iii. "if they can't pass the GWO training, they can't work on-site" (R10). (GWO stands for Global Wind Organisation).
- iv. "need to do a recognised training for going into the turbines" (R9).
- v. "In the what we call the OEM complex, which now will be our offices and our warehouse and our ablution facilities and canteen area, no, we will be able to assist in that. The facilities is such that we have made provision for disabled people and so it shouldn't be, yeah, but going to a turbine or tower that we call them, accommodating a disabled person, there will be extremely difficult and if something if for some reason we do need to get away, to accommodate them if something seriously happens inside the nacelle, to evacuate them will be immensely difficult and immensely complex. So for turbine-wise, I wouldn't advise somebody with the disabilities to go there" (R6).

The responses to the question indicated that a person with a disability would not present a unique risk, with one respondent having a disability themselves. However, numerous respondents referred to appropriate training needs for specific plant locations. It was concluded that the initial respondent who suggested that persons with a disability present a unique hazard to have been an error or a misunderstanding.

The second hazard was suggested to be unique as it was not provided under the list of hazards within the category of mobile plant that was presented. The respondent stated that the lifts within the wind power plant towers need to be included. The below extracts illustrate the position of the respondent:

"The lifts we using going from top to bottom, bottom to top" (R3). "The lift is also a part of mobile plant. It's moving equipment" (R3).

The respondent was further asked if they consider lifts to be mobile plant, and the response was that they did. This matter was presented to three respondents from wind power plants in the interviews that followed. All three disagreed, and the following were their responses:

- i. "I won't say so, no" (R6).
- ii. "I wanted to say no. In terms of the lifts, I'm not looking at it as a plant" (R9).
- iv. "No. It's not mobile" (R10).

Mobile plant is defined in the Construction Regulations as machinery that is used to perform construction work that can move independently (Republic of South Africa, 2022a). Whereas lifts are defined in the Lift, Escalator and Passenger Conveyor Regulations as a lifting installation operating on fixed guides (Republic of South Africa, 2010a). It was concluded that the initial respondent who suggested mobile plant to include lifts to have had an error in judgement or a misunderstanding.

The third hazard that was suggested to be unique within concentrated solar power (CSP) plants applying parabolic trough collector-focusing technologies was one that could result in burns during the thermal collection process. The following extracts provide a description of the potential event:

- i. "In the collector field when, for instance, the collectors, they are tracking the sun. They're following the movement of the sun" (R5).
- ii. "So sometimes when they are a bit down if somebody is standing there on a focal point it might be a danger" (R5).
- iii. "So, it might be dangerous if the person is on a focal point for like let's say 2-3 minutes and then the thing is directed to him" (R5).

It was enquired if a person would be able to access the space between the focal point and collector while conducting a task, and the response was:

"Yes, you can do that" (R5).

It was then further enquired if this would result in the absorption of the thermal energy, where the response was:

“Yes, it will get hot” (R5).

Unfortunately, this hazard was not able to be confirmed by any further respondents as it was encountered during the final interview conducted on CSP technology. It can be noted that burns are recognised as a typical industry hazard and are included in other studies on RE power plants (Scotland Against Spin, 2023; Webster et al., 2013). The exposure to burns in this manner was through the application of the new technology. As indicated by the United States of America’s (USA’s) Department of Labor, they consider work associated with RE power plants as growing industries, but they do not consider their hazards to health and safety as unique (United States Department of Labor, n.d.-d). Instead, it is suggested that the rate of growth in employment in the RE industry may result in the hazards only being new to people with limited experience (United States Department of Labor, n.d.-d).

4.2.3 *Conclusion pertaining to proposition 1*

It was concluded that although three respondents indicated they had unique hazards at their RE power plants, the analysis found these positions inaccurate. Therefore, considering the findings from the study for in-service, grid-connected, utility-scale solar PV, CSP and wind power plants, it was deemed that these plants do not present any health and safety hazards unique to these sectors while under normal operating conditions.

4.3 Findings and discussion pertaining to proposition 2

This section presents the findings and discussion that tests the second proposition. Herein, it was sought to determine if the respondents considered the South African OHS Act and its Regulations to appropriately support the management of people from hazards to health and safety at their RE power plants while under normal operating conditions.

4.3.1 *Closed-ended questions on the appropriateness of the OHS Act*

The study's findings revealed that the respondents agreed to a large degree with proposition number two (89%). The extent of the agreement supports the position that the South African OHS Act and its Regulations appropriately support the management of people from hazards to health and safety at RE power plants. Figure 10 below illustrates this position in a bar chart as a function of the percentage agreement per respondent.

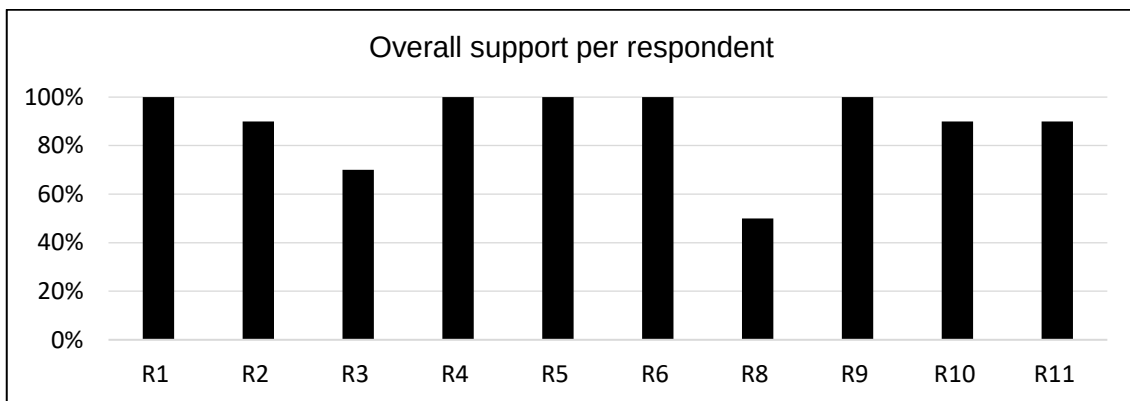


Figure 10: Overall support for proposition number 2 per respondent

Figure 10 illustrates that five of the ten respondents fully agreed with proposition number two. The other five exhibit varying levels of agreement (50-90%). Ten closed-ended questions were presented to each respondent, and disagreement was encountered on six of them. To illustrate this, Figure 11 below provides a bar chart showing the number of respondents in agreement per question.

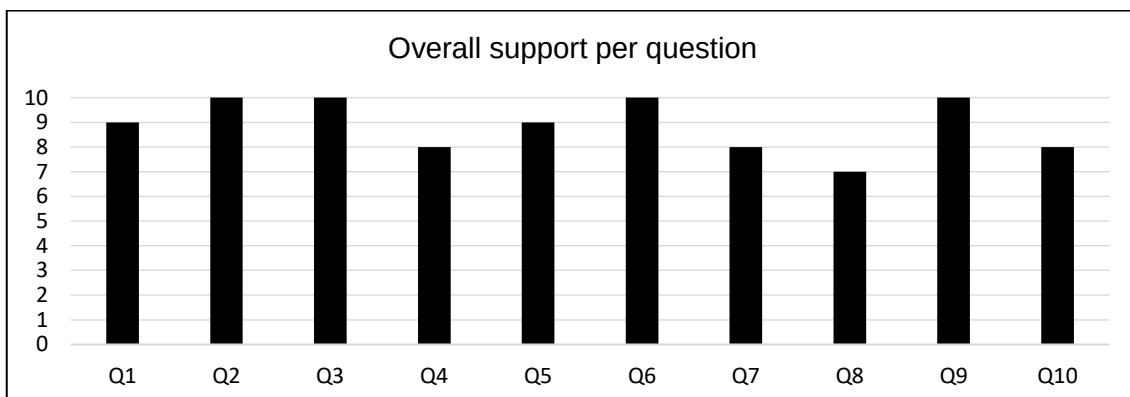


Figure 11: Overall support for proposition number 2 per question

Figure 11 illustrates the six questions where disagreement was encountered, as question numbers 1, 4, 5, 7, 8 and 10. These were within the categories of biological hazards (Q1), natural environmental elements (Q4), operational hazards (Q5), failures (Q7), external human risks (Q8), and psychological hazards (Q10). The frequency of disagreement for these questions was noted as one for questions 1 and 5, two for questions 4, 7 and 10, followed by three for question number 8. In these instances, it suggests that the respondents consider the South African OHS Act and its Regulations not to appropriately support the management of people from hazards to health and safety at their RE power plants while under normal operating conditions. The data was split according to the three strata within the population to explore these areas further. Figure 12 below provides three bar charts showing the number of respondents in agreement per question for each stratum within the study.

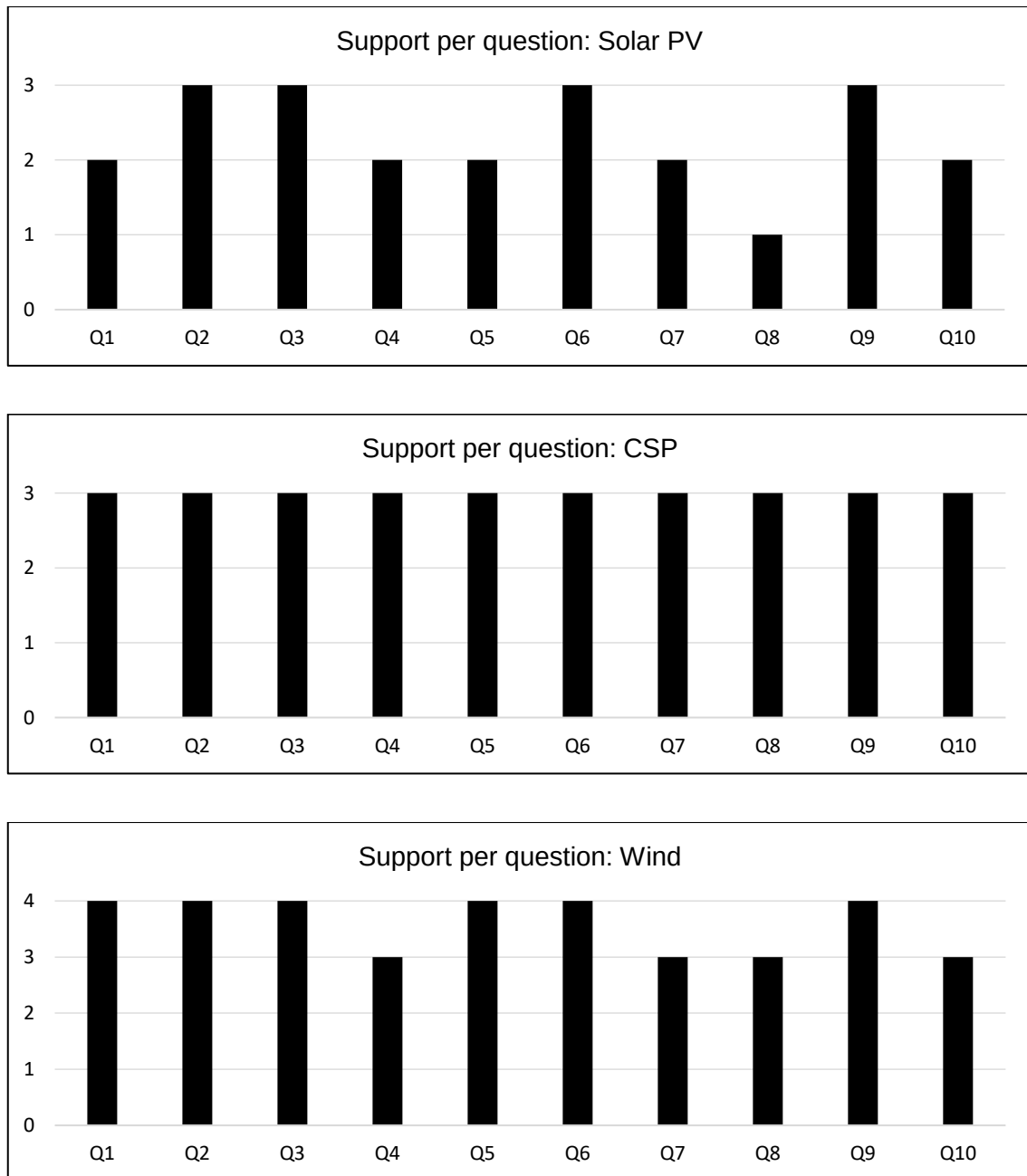


Figure 12: Support for proposition number 2 per RE technology type

Figure 12 illustrates that the solar PV technology stratum had the most disagreement (7), followed by wind technology (4), while CSP technology had none. All questions with disagreement under the wind technology stratum were similarly reported under the solar PV technology stratum. The initial indication of the dataset illustrates the extent of support for proposition number two across all three of the RE technologies.

4.3.2 ***Open-ended questions on the appropriateness of the OHS Act***

The findings from the study suggested that the appropriateness of the OHS Act and Regulations were mostly suitable, with 89% of respondents supporting this position. Certain aspects were identified where the OHS Act and Regulations were not considered entirely suitable. These aspects were grouped into two themes: "Regulations that were considered too stringent" (theme 2) and "Deficiencies within the OHS Act and Regulations" (theme 3). Each theme below uses quoted extracts from the interviews that illustrate the varied challenges.

4.3.2.1 ***Theme 2: Regulations that are too stringent***

Before exploring the Regulations that were suggested as being too stringent, it is necessary to mention the positive aspects that the respondents are applying. The reason for being included within this theme may appear conflicting. However, it provides the perspective of the respondents, grounding their challenges. The study revealed that managing health and safety was not limited to the prescribed requirements of the OHS Act. This task was supported by various aspects, such as using the OHS Act and Regulations as a broad outline and applying industry collaboration, including requirements from the original equipment manufacturer (OEM) and industry standards. This position is supported by selected extracts listed below under the same headings.

The OHS Act and Regulations as a broad outline from the study:

- i. "The OSH Act provides broad outline, and the employer must see how he can fulfil that broad outline in his environment" (R11).
- ii. "Section 8 of the Act is very clear, and it says that the employer must identify hazards and risks in the workplace" (R3).
- iii. "you can't really govern every single thing to the letter of the word" (R5).
"But you can use it as a guideline" (R5).
- iv. "they cannot make a OHS Act specific for a plant for let's say paper and pulp or chemical, petroleum or power station" (R11).
- v. "it's really difficult for the legislator to actually be exact prescript to each and every dot and question" (R3).

Industry collaboration from the study:

- i. "in the industry we collaborate" (R1).
- ii. "we belong to an industry body called SAWEA, which is a South African Wind Energy Association, and we share lessons learned" (R10).
- iii. "I am a member of SAWEA". "in terms of SHEQ". "what has been working in other areas" (R9). (SHEQ stands for safety, health, environment and quality).

Requirements from the OEMs from the study:

- i. "the supplier of blades have certain requirements from the supplier, if you go to OHSA section 10, about the manufacturing and supply of equipment" (R3).
- ii. "we work according to an OEM plan that's drawn up from all the OEM manuals" (R4).
- iii. "your OEM should give you guidelines and are often what you should look at and what you should inspect. You purchased the product from them. So, they are also legally bound to provide you with it; they don't just supply the product, and that's the end of it" (R5).

Industry standards from the study:

- i. "we still have standards. You know EN standards and engineering standards that" (R1).
- ii. "I believe GWO was actually put in place for this issue of, as far as reasonably practicable, to ensure the safety of people. So basically, it's like. It is the industry standard" (R9). (GWO stands for Global Wind Organisation).

From the above extracts, it was observed that the respondents consider the OHS Act to provide guidance on managing people from hazards to health and safety. However, it was clear that the respondents do not believe the OHS Act needs to detail every possible hazard for every industry. This illustrates a level of commitment or responsibility towards health and safety. This was further motivated by the application of industry collaboration and industry standards.

These extracts have been grouped as they collectively support (amongst others) Section 8 of the OHS Act's General duties of employers to their employees (Republic of South Africa, 1993). The OEM requirements support Section 10 of the OHS Act's General duties of manufacturers and others regarding articles and substances for use at work (Republic of South Africa, 1993). These positions align with those encountered in the USA, where the Occupational Health and Safety Act of 1970 and its framework promote collaboration, application of industry standards and reliance on the general duty clause where hazards are not explicitly covered (Occupational Safety and Health Administration, 2014; United States Department of Labor, n.d.-a; US OSH Act of 1970).

The findings of the study indicated that two Regulations were too stringent. Unfortunately, this was only mentioned by the final two respondents and, as such, could not be checked against any further interviews, as none followed. This initial extract identifies the challenge:

“There's one or two sections in the Act where we have found some difficulty where it is very difficult for us to comply, one of them being the turbine lifts, for example, the other one being the GMR 2.1 regulations, the General machinery regulations” (R10).

Considering the General Machinery Regulations, two respondents considered these too stringent for the same reason. The central aspect being challenged was associated with the person responsible for supervising machinery under Section 2.1 (Republic of South Africa, 1988). Section 2.1 of the General Machinery Regulations requires a competent person who, for these types of power plants, is an engineer possessing a Government Certificate of Competency (GCC) to be in full-time employment at the plant being supervised (Republic of South Africa, 1988). The study's findings may be grouped into general, justification, current actions and preferred solutions. Extracts are provided below under the respective category headings, and a discussion follows these.

Generally inappropriate statements from the study:

- i. "With regard to that particular regulation, which is general machinery Regulations 2.1 where they require a GCC ticketed engineer on site, it's inappropriate" (R11).
- ii. "the fact that they want a GMR 2.1 for every plant" (R11).
- iii. "full-time appointment on one plant at a time" (R10).
- iv. "Those regulations stipulate that on a power plant" (R10), "such as what we operating that you need to have a GCC permanently employed on that plant" (R10).

The above extracts clearly illustrate where the respondents suggest that the General Machinery Regulations are too stringent. The findings challenge the appropriateness of the Regulation in terms of the requirement to have an individual who holds a GCC permanently employed and based on a single power plant. The Regulations are similarly clear in that this individual is responsible for ensuring compliance with all of the requirements of the OHS Act and Regulations (Republic of South Africa, 1988). The aspects associated with this individual that are challenged, such as being employed in the "full-time capacity" and for "every premises", are included explicitly under Section 2.1 (Republic of South Africa, 1988).

Justification challenging the appropriateness of the requirements from the study:

- i. "in terms of the way the servicing and maintenance takes place on the plant, we don't" (R10), "believe that a GCC is warranted 24/7 as a full-time appointment on one plant at a time" (R10).
- ii. "too stringent based on the kind of work in the industry" (R10).
- iii. "especially a PV plant, you know it doesn't have rotating machines and you know, like a power station" (R11).
- iv. "it was written for big plants" (R11), "energy from coal and producing power or, you know, like a smelter. You know the energy conversion process there is intensive whereas in my plant, PV plants just photons to electrons man, peoples got in their house. Why would I need a GCC guy here?" (R11).
- v. "If you worked in a solar plant only, in my opinion, you got a 1% chance of passing the GCC exams" (R11), "the questions they ask you about boilers

and turbines and pumps and what? Where are you gonna see that in a solar plant?” (R11).

- vi. “in this plant, the idea of having a GRM 2.1 for every plant more than 10 MW, the industry is saying, hey, we don't have so many people anyway with GMR 2.1” (R11).
- vii. “The GCC employments and appointments come at a cost” (R10).

The above extracts include the respondent's justification for reducing the requirements of the General Machinery Regulations at RE power plants. Here, both respondents suggest that the nature of the work associated with these plants is not comparable with other plants, such as large fossil fuel power plants and smelters, thus challenging the requirement. This position may be supported by a case study at a solar PV power plant in the USA, where it was stated that the plant operates without personnel on-site (Moore & Post, 2008). Further support from the wind sector suggests that most sites are uncrewed except for periods of maintenance or repair (Webster et al., 2013). The Regulation does not allow for the removal of the requirement for the supervision of machinery; it only allows for a person with a reduced level of education however, this is based on the sum of the power generated (Republic of South Africa, 1988). The risks associated with applying these new technologies and the energy conversion processes, particularly considering solar PV, may provide adequate justification and support the need to consider exemptions. The reference to the GCC examination and the unlikely chance of an individual with purely solar PV experience being able to complete this examination successfully does hold some merit. However, the access requirements for entering the GCC examination regarding education and or experience would preclude this from being realised (Department of Labour, 2007). Finally, the cost, which is suggested as presenting a challenge to meeting the requirement, is considered incongruent with the Regulation's intention.

Current industry actions from the study:

- i. “we have formulated formal requests to the department, and we have not received feedback” (R10).

- ii. "engagement that we've been having with the Department of Labour, which has also" (R10), "been very limited in terms of a formulated response coming back from them" (R10).
- iii. "the one that we got appointed is doing a number of facilities not only my two plants but there is an application in place" (R11).
- iv. "one other industry player in terms of having received" (R10), "a concession from the Department of Labour" (R10).
- v. "I've seen an exemption letter, believe it or not, and the exemption letter is limited for a period and is limited to that person. They don't give the company that exemption they give a person" (R11).
- vi. "they are now appointing a GMR 2.1 plant manager for every site. They don't wanna fight this fight anymore" (R11).

The above extracts include the current actions of respondents associated with the suggestion that the General Machinery Regulations are too stringent. Both respondents have engaged with the Department of Employment and Labour (DEL) on this matter without success. The Regulations cater to exemptions under Section 11 (Republic of South Africa, 1988). These applications require details supporting the exemption to be provided to the Chief Inspector of the DEL (Republic of South Africa, 1988). There was evidence that both respondents applied for these exemptions. However, dissatisfaction remained about these being issued to a specific person and for a specified period. The challenges surrounding the applications themselves may have culminated in the final respondents' extract, where it is suggested that it will not continue to be pursued.

Preferred solutions from the study:

- i. "could be excluded from the rule where it says "on-site" and allow someone to be for more than one site obviously, they apply to the government and tell them this person will be GMR 2.1 for these four power plants, and he will have a 2.7 on each site, but not at 2.1 on each site" (R11).
- ii. "the industry group agrees that having a GCC appointed across a platform of plants" (R10), "would make a lot more sense" (R10).

- iii. “we've set up a working group in trying to encourage the department to come back to us to be able to apply this blanket role across the wind, well, the renewable energy sector, which has not been forthcoming” (R10).

The above extracts include the preferred solutions of respondents associated with the suggestion that the General Machinery Regulations are too stringent. Both respondents suggested that the appointment may remain, but the requirement for RE power plants be reduced. This includes removing the limitation of being on-site for a single power plant and allowing supervision by a competent person across a platform of RE power plants. One respondent suggested using a 2.7 appointment, which is included in the Regulations as a competent person who may assist the GMR 2.1 (Republic of South Africa, 1988). As the Regulations provide varying levels of competency, with the highest level required for the utility-scale power plants in the study, a reduced level of competency would still necessitate an exemption and DEL approval (Republic of South Africa, 1988). Considering the engagements with the DEL, pursuing a blanket exemption for the entire RE sector does not appear feasible or in accordance with the Regulations' application process. The varied energy conversion processes and RE plant sizes would further complicate this.

Considering the suggested deficiency in the Lift, Escalator, and Passenger Conveyor Regulations (LEPC Regulations), one respondent considered them too stringent and that compliance presented a challenge.

“we've got a big issue with the Lift Regulations because, you know, they have written the Regulations, you know, and based on a lift that is in a building, you know, that goes up and down every minute of the day and you know so there's lots of wear and tear on the lifts” (R10).

It was provided that the lifts in a wind tower are not exposed to the same level of wear and tear compared to conventional lifts in buildings. The respondent then went on to emphasise the cost associated with meeting the requirements of the Regulations.

“Now my lifts in my in our turbines our teams only go to that lift four days in a year or when there's a breakdown. So they might only go to that lift,

say, 5-6 days in a year, but we still have to comply the same Regulation. So we're over maintaining those lifts, and it's costing us a (obscenity removed) lot of money" (R10). "it's (value removed) Rand per lift and then also, you know I have to switch off the turbine, but I can't go up the turbine while it's operating. So I am losing that revenue as well" (R10).

There may be some merit in challenging the comparison of lifts in a conventional setting to those that may only be used on five or six occasions in a year. However, the challenge in meeting the requirements was primarily from a financial perspective, which frustrated the respondent. The respondent indicated that the challenge experienced on lifts was not limited to their wind farm and referred to the involvement of the DEL.

"early last year or quarter two of last year, the Department of Labour issued a Code of practice on turbine lifts, which they circulated for public comment, and as I've mentioned to you, we form part of the wind energy working group, SAWEA we got together as interested industry group, and we then came up with public commentary on this code of practice" (R10).

The code of practice (COP) was sourced and found to have been published in the Government Gazette dated September 2022 (Republic of South Africa, 2022a). This suggests that the draft COP for comment was concluded and the document published. The COP is titled "Code of practice for lifts inside wind turbine" (Republic of South Africa, 2022a). The COP states that there is an increase in these types of lifts being installed, and there are currently no published International Organisation for Standardization (ISO) standards that address these specific lifts, which is the reason for the publication (Republic of South Africa, 2022a). A search was conducted on the ISO standards website where no wind turbine-specific standards were found. When applying a search beyond ISO, a standard titled "Safety rules for the construction and installation of lifts - Special lifts for the transport of persons and goods - Part 44: Lifting appliances in wind turbines" with unique identifier "BS EN 81-44" was located; however, its status was noted as "draft for comment". In addition, an American Society of Mechanical Engineers (ASME) Standard was located titled "Standard for Wind Turbine Tower Elevators" with the unique identifier "ASME A17.8/CSA

B44.8 - 2021". It was not the intention to review these standards, as the COP stated that no standards currently address the South African wind turbine lifts. The COP was compiled through collaboration with industry and stakeholders to guide a standardised approach to managing wind turbine lifts (Republic of South Africa, 2022a). Minimum requirements for safety are included within the COP, and various cross-references to the LEPC Regulations are included (Republic of South Africa, 2022a). It is not intended to evaluate the technical content of the COP; however, the following aspects related to the in-service operations were observed; the COP has kept the statutory inspection intervals in line with the LEPC Regulations at 24 months; however, the maintenance service interval has been relaxed from monthly to 6 monthly, while the overspeed governor and safety gear have changed from 12 monthly tests to 6 monthly inspections (Republic of South Africa, 2010a, 2022a). The respondent indicated that industry collaboration was conducted, and formal communications were sent to the DEL. Here, the emphasis on finance as a barrier to compliance was reiterated.

"We then formulated a response, a formal response as SAWEA, as well as individual wind farms back to the Department of Labour, illustrating where we believe that there were shortfalls in the code of practice and where even with the code of practise it would make it very difficult either very expensive or very difficult to be able to comply with the code of practice" (R10).

The COP includes reference to industry collaboration; however, the extent of the suggested shortfalls being implemented will remain unknown.

"We then requested an engagement with the Department of Labour of, which was realised, and the chief directorate from Pretoria came down to Cape Town, and we had a full day session with them with industry leaders, with specialists from within the wind industry, both from working on the wind farm as well as our OEM suppliers, our LMI inspectors" (R10). (LMI stands for lifting machine inspector).

This illustrates the engagement with the industry, potentially supporting the statement within the COP. This collaboration is suitably aligned with the method

encountered in the USA (Occupational Safety and Health Administration, 2014; United States Department of Labor, n.d.-a). Finally, the respondent stated they had not received a response from the DEL.

“We followed up requesting feedback. We've, yeah. And like I said today, we haven't received any feedback from them” (R10).

This finding of the LEPC Regulations being too stringent was only noted by a single respondent from the four interviews conducted on wind technology. The publication of the COP suggests the extent of concern from the DEL in ensuring safety in the sector. This is considered a positive indicator and adds credence to the effectiveness of managing safety through the framework of the OHS Act. However, the publication of the COP also suggests that the DEL has recognised that the LEPC Regulations are not entirely appropriate to the wind sector.

4.3.2.2 ***Theme 3: Deficiencies within the OHS Act and Regulations***

Several areas were encountered where the OHS Act and Regulations were not considered entirely appropriate. These were grouped under four categories: psychological well-being, naturally occurring hazards, social unrest and managing structures. Several broad statements were encountered, such as the term used in the OHS Act, “reasonably practicable,” which was considered susceptible to misuse when aspects were not prescribed.

“The term which we normally use, reasonably practicable, has got some loopholes, and I think that's where it says, looking at the cost and also the availability of means. That's where people normally, especially things that has got cost implication they, tend to use that explanation to run away from the responsibility” (R2).

The OHS Act places a significant emphasis on the term “reasonably practicable” where, for example, the General duty clause requires an employer to ensure safe working environments as far as is reasonably practicable (Republic of South Africa, 1993). This also appears in the General duty of employers and self-employed persons other than their employees, where the employer shall

undertake as far as is reasonably practicable to conduct activities in such a manner so as not to expose persons outside of their employment to health and safety hazards (Republic of South Africa, 1993). The OHS Act defines the term in a way that requires certain aspects to be considered when applying it (Republic of South Africa, 1993). These may include the severity of the hazard, understanding of the hazard, measures to remove the hazard, mitigation actions and associated costs and benefits (Republic of South Africa, 1993). One respondent suggested the need for Regulations to address the management of RE power plants during the operation and maintenance phases.

"I think that is a big gap in the Act that we have" (R3). "we still gonna be involved in managing these operations and maintenance of all the different solars and windfarms, etc. So, most definitely, if we can get a set of regulations managing the operations and maintenance after completed site like that and looking at all the risks most definitely that is a big, big gap in the market that can be addressed most definitely" (R3).

When considering the approach adopted in the USA, where the General Industry Standard addresses industry hazards and includes listed industries, none specifically refers to RE power plants (United States Department of Labor, n.d.). These fall within the electric power generation subpart (United States Department of Labor, n.d.-c). This, by contrast, challenges the merit of having specific regulations. However, the study identified aspects of managing health and safety at RE power plants where the OHS Act and Regulations were considered deficient. These are discussed in the sections that follow.

Psychological well-being was the first category where the OHS Act and Regulations were suggested not to be entirely appropriate. Two respondents identified this as a deficiency when presented with the question of the appropriateness of the OHS Act and Regulations in managing people from psychological hazards that may impact human health and well-being.

- i. "No, it's not sufficient, it's not addressing that at all" (R8). "The Act is very silent on psychological affects" (R8).

- ii. "I'm saying tentatively, no, because we've taken all of those things into consideration and again, we've mitigated" (R10). "I'd say No" (R10).

It was suggested that the remoteness of the power plant resulted in most employees staying away from their families. This caused stress that negatively impacted the employee's psychological well-being, which was further compromised by the abuse of alcohol.

- i. "and mental stress also, not that the work is causing stress. They only come here, you know, to work here then they don't bring their families with them, then they miss the families" (R10).
- ii. "I'd say at least 60, 70%, you know, is males that works here and the families just either, you know in Eastern Cape wherever" (R10).
- iii. "It's just think, the remoteness of the town. The town is very remote, you know, it's a secluded" (R10).
- iv. "Boredom and then you know the start thinking the families and then they start drinking and we recently had to let someone go because he just, he didn't want to step in line" (R10).
- v. "We do have intoxication, you know, alcohol and drugs, we do have, you know, testing facilities at the gate we test for, alcohol, at every person" (R10).

Although only two respondents identified psychological stress as not being adequately addressed, seven mentioned the use of alcohol testing.

- i. "Yes, we've got alcohol testing at the gate and then yeah, drug test as you say. So, I'm like we had that previously and then some of the guys they found to have occurred to test positive, and then the some of them had to be sent to this rehab, and then some after a hearing and this and that they were no longer with us" (R5).
- ii. "I have to do this is Northern Cape" (R11). "Yes, on entry, anyone that enters on site, we do alcohol test" (R11).
- iii. "And we also do alcohol testing daily?" (R8). "Random exit in which you got regards to alcohol" (R8).

- iv. "for intoxication, we do alcohol blow testing at the gate every morning" (R9).
- v. "We do alcohol testing daily, we got a breathalyser at our main gateway, when you enter" (R6).

The extent of testing for intoxication appears to be common practice throughout the sector. The respondent who indicated that they had mitigated the shortfall in the OHS Act suggested they had implemented employee assistance programmes. These are noted to provide support to persons with "certain struggles".

"what we do have is we've got a new employee assistance wellness programme, an EAP in place, and obviously mental well-being and mental work-life balance has become a big buzz sort of word since COVID and people started working from home, so we definitely implemented a well-being programme and employee assistance programme, where employees have got access to various services to assist them with certain struggles" (R10).

This wellness programme considered the remoteness of the power plant in assisting employees with health care.

- i. "the people who work in (name removed), you know, work very far; I mean, for example, we've got some ladies who work on the plant, and there's no gynaecologist within, perhaps I don't know, (name removed), 140 kilometres of the town" (R10).
- ii. "So, they basically need to be, you know, it's unfair to ask them to take a day of leave from work to go for a gynaecologist check-up. So, you know, they are given time off without having to put in a leave form just to be able to travel so that they can go for the medical check-ups and those kinds of things" (R10).

Although two respondents suggested a shortfall, one disagreed with the need to include psychological well-being within the OHS Act and Regulations and indicated that this remains a personal matter that the individual should manage.

- i. "What do people want" (R11). "I think mental health is a individual thing, you should manage your own mental health" (R11).
- ii. "I think no, it shouldn't be there" (R11).

There is limited reference to psychological stress or well-being within the OHS Act and Regulations. The Ergonomic Regulations require human well-being to be considered and optimised as far as is reasonably practicable in connection with the design, manufacture and use of systems and machinery (Republic of South Africa, 2019b). The only other area where psychological stress is included is the Regulations on Hazardous Work by Children in South Africa (Republic of South Africa, 2010b). These Regulations prohibit a child from working when exposure to psychological abuse is reasonably foreseeable (Republic of South Africa, 2010b). The USA's OHS Act of 1970 does not include psychological stress within it (US OSH Act of 1970). However, the OSHA has published training material on workplace stress (United States Department of Labor, n.d.-e). The online publication includes loneliness and isolation as mental health challenges that are affected by stress (United States Department of Labor, n.d.-e). This supports the experience of the respondent, who referred to the remoteness of the power plants and being removed from families as causing stress. The publication provides various topics on improving the understanding and dealing with mental health and workplace stress (United States Department of Labor, n.d.-e).

Naturally occurring hazards were the second category where the OHS Act and Regulations were suggested not to be entirely appropriate. These consisted of risks associated with the weather and biological hazards associated with wildlife. Three respondents indicated that the OHS Act and Regulations were not entirely appropriate in managing people from hazards associated with the weather.

- i. "If you look at the Environmental Regulations, it's very much limited to factories, not so much construction, and specific to wind farms and solar farms, etc. I think there's a big gap to fill there in that Regulation" (R3). "Ice throw it does not do" (R3). "lightning strikes is not specified" (R3). "it's not specified in the OHS Act" (R3).
- ii. "There can be some improvements done on the, for example, high winds, I mean, currently, it's the limitation is basically set by either the turbine

- manufacturer or the client" (R6). "lightning as well, you know" (R6). "there's nothing really mentioned in the OHS Act" (R6). "I think there can be some improvement there" (R6).
- iii. "you can't allow employees too close to the area or remotely close to the area because I mean you can take a block of ice, let's say less than a kilogram falling from 90 metres or higher will fall right through the car" (R6). "I don't think there's really any cover for that in the OHS Act because that's specific to the wind turbines" (R6).
 - iv. "it's not addressed in the Act as such high winds or gust winds or what the case might be. Most definitely not" (R8). "We've had major floods that prevented us from going home" (R8).

The hazards associated with the weather included floods, wind, lightning, and ice throw due to cold temperatures. These hazards were all identified in previous studies (Brouwer et al., 2018; Palmer, 2018; Scotland Against Spin, 2023; Webster et al., 2013). The combination of hazards and extreme weather was suggested to present unique challenges to managing people appropriately (Karanikas et al., 2021; Webster et al., 2013). The respondents indicated that the OHS Act and Regulations do not address these weather-related hazards. The study confirmed the suggested uniqueness of combining hazards and extreme weather conditions. Other respondents confirmed these hazards but did not consider the OHS Act and Regulations inappropriate. The total number of respondents experiencing these hazards was three on ice throw, two on lightning strikes, three on strong winds and three on floods.

- i. "We do have that, we do because specifically (name removed) is close to (name removed), 74 kilometres to be exact, and we have snow and ice on (name removed) every year" (R3). "Legitimate, that's a good, identified hazard; I don't normally apply my mind to this in that detail because it's very secluded in a specific time frame of the year" (R3).
- ii. "We had three blade tips broken by excessive winds" (R3).
- iii. "You know if there would be any ice, you know, ice packing up on the blades" (R6).

- iv. "another risk we have in the plant is rain. That rain can cause erosion to the point where the integrity of structures are being impacted" (R11). "in these dry areas, when you get a severe storm, the water is running" (R11).
- v. "So, when it comes to rain, obviously that is because you don't know what to prepare for, you can only do your stormwater management up to certain level, but you don't know what rain to expect, but when it comes to stormwater management, we have the approved designs that cater for unplanned events" (R2).
- vi. "So, we had severe flooding on site but not physically affecting the towers itself, but the roads, coming to site driving on site, so that was one of our biggest issues as well this year was the flooding there the severe rain" (R6).

From the varied consequences of the hazards being realised, careful consideration is required to mitigate them appropriately. The wind is suggested to be the cause of blade failures. Flooding can compromise the integrity of foundations and safe road travel, with ice throw potentially resulting in an uncontrolled projectile release.

Remaining under the second category of naturally occurring hazards. One respondent indicated that the OHS Act and Regulations were not entirely appropriate for managing people from wildlife-related biological hazards. The following negative response was received when presented with the question of the appropriateness of the OHS Act and Regulations in managing people from natural environmental hazards.

- i. "Not in total with regards to vermin and insects and stuff like that" (R8).
- ii. "Not fully from" (R8). "From vermin, insect bites, snake bites and stuff like that, most definitely not" (R8). "Scorpions, Yeah" (R8).

Numerous other respondents confirmed the risks associated with wildlife-related biological hazards. Seven respondents reported that snakes, scorpions and bees presented risks.

- i. "insects, vermin and snakes" (R11). "You can put bees as well. So yeah, bees is a big case. Bees is a serious case" (R11).

- ii. "Yes, that's it, yah, because our biggest hazards are like snakes and insects and stuff like that" (R4).
- iii. "There's a possibility of having snakes around here" (R5).
- iv. "rodents or snakes or anything like that" (R3).
- v. "Bees are very big factors; well, they tend to make nests anywhere they can find a spot. So that's also a major risk, yeah" (R6).
- vi. "So like venom, snakes and scorpions, we do have it and do snake training, you know" (R10).

The natural environmental hazards encountered in the study combined with standard hazards confirm the same position of prior studies on wind power plants (Karanikas et al., 2021; Webster et al., 2013). It was noted that hazards are comparable to those in other industrial sectors; however, when combined with extreme working conditions, they may present unique challenges (Karanikas et al., 2021; Webster et al., 2013). These combinations require consideration in managing or mitigating people exposed to them.

The third category, in which the OHS Act and Regulations were suggested not to be entirely appropriate, was social unrest. The questioning initially included external human risks, such as community violence, intimidation, and unauthorised site access. The responses from the respondents included strikes, riots, social chaos, intimidation, damaging property, etc. The question may have been flawed as conflicting responses were received. Three respondents indicated that the OHS Act and Regulations were not entirely appropriate for managing people from hazards associated with external human risks (R2, R3 and R8). However, the same three respondents also stated that these hazards are outside the scope of the OHS Act and Regulations.

- i. "It becomes difficult to control with the OSH Act and Regulations" (R2). "I don't think the OHS Act or any of its Regulations will be able to deal with that effectively" (R2).
- ii. "I don't think OSH Act covers that element because it's just outside its footprint in terms of the applicability because this chaos and riots" (R2). "It's something that is just outside the reach of the OSH Act and its

Regulations" (R2). "So OHS Act and its Regulations, cannot be used in that area" (R2).

- iii. "So, you can't really plan or have 100% plan to deal with avoiding the riots" (R2).
- iv. "from a community violence perspective, I don't think the OHSA is drilling down into that detail because if you have a community violence, you can have more than one person standing in front of you guys and to manage that, it's going to be very difficult" (R3).
- v. "from an OHSA position, there's no reason to define that in the OHSA" (R3).
- vi. "the Act doesn't cover any other parts of social unrest or anything like that" (R8).
- vii. "I think the responsibility must remain with the SAP" (R8). "but the Act doesn't give the employee a right can only close up its place, but it doesn't give the employer the right to actually control a civil unrest and stuff like that. That's more of a police control from a social perspective" (R8).

The inability of the OHS Act to effectively address social unrest was indicated and suggested to fall outside of its scope. Considering the context provided as civil unrest, the respondents suitably identified the South African Police Services (SAPS) as responsible custodians. Three other respondents (R4, R6 and R9) all agreed that hazards associated with external human risks are outside the scope of the OHS Act and Regulations. In contrast, one respondent referred to the OHS Act General duty clause of employers to employees (Section 8) and the General duty clause of employers to persons other than their employees (Section 9). It was suggested that these two sections appropriately address the hazard.

- i. "a difficult one because if you go back to the beginning of the occupational health and Safety Act, I think under Section 8 is the duty of employer to ensure that, you know the duties of the employer and in the duties of the employers to non-employees and interested and affected parties. It's a very broad outline and a very broad definition, but an all-encompassing Regulation and section on its own as it is. So that's why I say I don't want to say it's within or without" (R10).

- ii. "Those two sections of the Act, I think, covers it that the duties of the employer and of the organisation is to ensure that interested and affected parties are either informed and or protected where they can be and the duties of the employer to protect its employees" (R10).

Interestingly, the same respondent referred to having access to the police in terms of access control.

- i. "I've got security, you know, at both gates with a vehicle and everything to detain someone you know and call the police to come and take them away in the OPS phase" (R10).

Suggesting the police will be contacted to remove external persons somewhat supports the other six respondent's interpretation that social unrest is outside the ability of an employer to control. However, identifying responsibilities to employees and non-employees under Sections eight and nine of the OHS Act is applicable, within the limits of their responsibility.

The fourth and final category, where the OHS Act and Regulations were suggested not to be entirely appropriate, was associated with structures. Two respondents (R3 and R8) stated that the OHS Act and Regulations were not entirely appropriate when considering structural failures. One respondent (R9) suggested that no specific part of the OHS Act addressed the management of structures.

- i. "No, I don't, the reason therefore is, you only have Section 24 that you actually has got to notify the department of a machine running out of control or what the case might be" (R3). "if you see how far the portions of the blade was from the tower up to 300 meters away from the tower" (R3).
- ii. "there's no guidance in South African law giving you that guidance, except the Construction Regulation under Construction Regulation 11" (R3).
- iii. "No, that's where the Act doesn't totally suffice. Only under the Construction Regulation for structures it actually try to give you a bit of a guidance with regards to inspections to be done" (R8).
- iv. "the use of the Construction Regulations and we out of construction then at that point in time" (R8).

- v. "No, there isn't anywhere" (R9). (In response to a question: "Is there anywhere in the Act that tells you that you shall do inspections on these structures?")

The two respondents stated that structural inspection requirements were contained within the Construction Regulations. They correctly identified that Section 11 of the Construction Regulations includes these requirements for inspecting structures (Republic of South Africa, 2014). Amongst other aspects, it places the responsibility for ensuring a structure is maintained in a manner that supports its continued safe operation solely upon its owner (Republic of South Africa, 2014). It includes prescribed requirements for conducting biannual inspections for the first two years and, after that, annually by a competent person (Republic of South Africa, 2014).

The position of applying the Construction Regulations to operational power plants presented itself as an area of conflict among an additional two respondents (R6 and R10) and confirmed by one already cited (R3).

- i. 'Yes, that's the issue we are sitting with, 100% correct" (R3). (In response to a question: "You did say it's a bit of a grey area and you could look at the Construction Regulations, but not directly)
- ii. "that's quite fascinating for me at this stage; we apply a lot of the Construction Regulations in the operational phase" (R6).
- iii. "that's an open argument; I mean, we are in operational phase, so why would you apply Construction Regulations to operational phase?" (R6).
- iv. "There's so much grey areas, it's easier to jump back to the construction phase and say, let's use that until maybe one day in the near future somebody decides, all right, we're gonna write something, exactly or specifically for the operational phase of running generating plant, you know" (R6).
- v. "The only other I would say challenge that I have is that there is a massive misunderstanding between the definitions in the Construction Regulations and operations" (R10). "then a further debate ensues as well: we are in operations, we are not in construction" (R10).

The initial three respondents and the additional ones above questioned the application of the Construction Regulations to their operational power plants. This was supported to a large degree when considering the scope of the Construction Regulations, which limits their applicability to construction work (Republic of South Africa, 2014). The definition of construction work needs to be considered. Construction work includes activities associated with the construction, erection or demolition, etc., of a building or similar structure (Republic of South Africa, 2014). The definition of a structure includes any structure constructed of steel or reinforced concrete that is not a building and includes various examples of which a mast and a tower are explicitly mentioned (Republic of South Africa, 2014). The definition of construction work continues to mention work associated with the repair of a building or similar structure (Republic of South Africa, 2014). Finally, the definition also includes work associated with the maintenance of various types of civil engineering types of works (Republic of South Africa, 2014). These final two aspects of the definition, where construction work includes "repair" and "maintenance", likely contribute to the uncertainty observed.

The application of this uncertainty was noted when one respondent was unsure, and another applied different approaches to structural towers on the same site.

- i. "it means after construction, it needs to be inspected, isn't that so?" (R5).
- ii. "Yeah, there's another one also which raised its head lately, the thing about the yearly inspection of a tower, so we've got met masts and understand that needs to be inspected every year because it's not being maintained like the towers with (Name of OEM removed), but now the question has been raised, must we get the towers inspected by a third party every year like we're doing on the met masts" (R10). (Met mast is a meteorological mast or structure of lattice-type construction).
- iii. "the met mast is like a lattice tower that we've got where we mount wind speed metres, rain sensors and whatever, and they're also 100 metres. But we need to maintain them; the OHS Act also states that we need to maintain them, but now. What about our turbine towers now? Do they fall in the same principle, or are they now plant? What now?" (R10).

The level of uncertainty from the first respondent's response (R5) was clearly illustrated by them asking if their interpretation was correct. The following respondent's extracts further support the same uncertainty. Here, they stated that the OHS Act requires the meteorological masts to be inspected annually, which would align with the requirements of the Construction Regulations. However, they were uncertain if the tubular steel towers for their wind turbines required the same. When this respondent was asked if the Construction Regulations and the annual inspection of structures applied to their operational plant, the response was as follows:

- i. "And you see, that's a question that we've posed to the turbine supplier as well. Because it becomes, it's a very in terms of the definition under Construction Regulation 11 it's very specific in terms of what a structure is" (R10).
- ii. "Yes, so where there is nowhere else in the Act" (R10).

The respondent's enquiry with their turbine supplier further indicated the uncertainty in applying the Construction Regulations. The respondent finally indicated that the Construction Regulations were applicable when no other Regulation provided guidance. Contrary to the level of uncertainty illustrated by the nine respondents, one clearly stated that the Construction Regulations did not apply to normal operations.

- i. "I feel Construction Regulations are appropriate in general for construction work" (R11).
- ii. "If you look at the Construction Regulations, for me, it was more about you are hiring a contractor, and you need to manage this contractor in terms of that Regulation for construction work, and the law says whenever you do construction work, you must inform the Department of Labour and get some (obscenity removed) number" (R11).
- iii. "So in operations, we don't, only if we did construction work" (R11).
- iv. "That's why I said no, this Regulation don't apply to me in operations" (R11).

Here, the respondent indicated that the Construction Regulations only apply when they are involved in construction work. They correctly identified the need to notify the DEL to obtain a construction work permit (Republic of South Africa, 2014). This application may be dispensed with as prescribed under Section 3(1) of the Construction Regulations for smaller construction work projects (Republic of South Africa, 2014). This exclusion only applies to work that does not exceed 180 days or 1800 person-days or is of a monetary value of less than thirteen million Rand (Republic of South Africa, 2014).

The varied interpretations of the OHS Act were found to have a reduced level of variance in terms of what was being done with the structures, particularly on wind power plants. These differences mainly pertain to the method of inspection being applied.

- i. "We do use drones" (R3). (In response to a question: Do you use drones to do inspections of the blades and towers). "doing it with a high-quality camera on the drone" (R3). "its done annually" (R3).
- ii. "on the structures, you have to do the tower and the foundations, including the blades" (R3). "And obviously the internals of the tower" (R3). "and also, the stress bolts keeping the tower in place" (R3).
- iii. "once a year, they come and do the drone inspections and provide a report for each turbine, for each blade" (R6). "Currently only focusing on blades" (R6).
- iv. "Foundations, we basically check ourselves visually" (R6). "bolts, for example, the foundation pad on top and the structure itself as well, the tower structure up to the nacelle, even the nacelle as well. We do visual inspections ourselves as well" (R6).
- v. "That will be the manufacturer of the turbines, his own technician" (R6). (In response to a question: Who does the tower).
- vi. "inspections are done much more visual" (R9). "We cover the Blades, the tower itself, in terms of the train, those are done by the site team, the visual inspections are done by the site team" (R9). "Yes, the gearbox as well as the generator" (R9).
- vii. "there is also a visual inspection that is done on the concrete" (R9).

- viii. "So on structural, we've got the bolt torque and tensioning inspections" (R10).
- ix. "they do it with a camera; they inspect the tower on the outside, so that's for the structure, you know, for the whole tower" (R10). "The camera, yes, binoculars that they use" (R10).
- x. "We use a drone to inspect the blades" (R10).

The dominant structural components covered by the inspections were the foundations, turbine tower, blades and tension bolts. These components aligned with those from previous studies that suggested health monitoring of the static load-bearing components was required (Civera & Surace, 2022; Kuntiyawichai & Limkatanyu, 2006; Olabi et al., 2021; Yang et al., 2016). All wind technology respondents inspected these same structural components. It was observed that three of the four wind power plant respondents use drone technologies for inspections. Two specifically stated that inspections were limited to the blades. One respondent (R9) conducted all inspections visually, and another (R10) stated they used binoculars to inspect the towers. This study did not intend to evaluate the appropriateness of an inspection method's ability to detect in-service degradation. This may include general material degradation due to time in service and environmental conditions, as well as original manufacturing imperfections that may further deteriorate during service (Brouwer et al., 2018; Kuntiyawichai & Limkatanyu, 2006; Palmer, 2018; Yang et al., 2016). The probability of detecting these abnormalities by visual means or when using binoculars is dependent upon the skill of the inspector (Civera & Surace, 2022).

All four wind technology respondents agreed on the purpose of conducting these inspections.

- i. "the main purpose is to avoid failures and to inspect the blades with regards to cracks" (R3).
- ii. "So, they will be looking for cracks or any bad spot showing" (R6).
- iii. "yearly is a way of monitoring and would help us not to have a premature failures" (R9). "just so that we are able to build upon condition monitoring and also not lose track of anything that can fail us all of a sudden" (R9).

- iv. "cracks you know any abnormalities" (R9). (In response to the question: What would they look for in these inspections?).
- v. "there's definitely blades that we need to do maintenance on" (R10). "So, the drone is external party; they do that, they give us a report. It's a Swedish company that gives us that report on that, their findings that they've got" (R10).

The commonality among all four respondents was detecting abnormalities to avoid premature failures. This supported the literature's position for the need to identify components that may be subject to degradation over time in service (Civera & Surace, 2022; Kuntiyawichai & Limkatanyu, 2006; Olabi et al., 2021; Yang et al., 2016)

4.3.3 ***Conclusion pertaining to proposition 2***

It was concluded that, in general, the study found the OHS Act and its Regulations to be mostly appropriate in managing people from hazards to health and safety at in-service, grid-connected, utility-scale solar PV, CSP and wind power plants. It was revealed that the industry applied various mitigating aspects that supported health and safety management beyond the OHS Act's prescriptive requirements. These included using the OHS Act as a minimum guide while considering other resources such as industry collaboration, OEM requirements and engagement, and applying industry standards.

It must, however, be noted that not all respondents fully supported this position. The study identified several areas where the OHS Act and Regulations were not considered entirely suitable. These consisted of Regulations that were considered overly stringent as well as specific deficiencies within the OHS Act.

The first of these was the General Machinery Regulations, which were considered too stringent regarding the requirements associated with supervising machinery. It was suggested that the requirement for a GCC-ticketed engineer to be appointed to a single site was inappropriate. This was based on the position that the energy conversion process differed from other fossil fuel power plants that incorporate steam generators and extensive pressure and rotating equipment.

This suggested that the associated hazards were significantly less at RE power plants. The study revealed that the industry had engaged with the DEL but failed to find suitable closure. It was considered that this position may contain merit, particularly for the solar PV technology stratum. However, as the position only appeared in the penultimate and final interviews, it was not considered conclusive but rather appropriate to recommend the matter for further research and consideration by the DEL under recommendations. This position must consider that two studies have suggested that solar PV and wind power plants remain mostly uncrewed. In closing, as the General Machinery Regulations in their current format include an exemption application option, it was therefore concluded that they were found to be mostly appropriate.

The LEPC Regulations were also considered too stringent regarding the inspection and maintenance requirements for lifts inside the vertical towers at wind power plants. Initially, the comparison to meeting the same requirements imposed upon conventional lifts was considered inappropriate. However, the study found that interaction between the DEL and industry stakeholders (such as the SAWEA) had culminated in the DEL publishing a COP specifically for these lifts. This finding was, however, only noted by a single respondent in the final interview conducted on the wind stratum. The publication of the COP illustrated the extent of concern from the DEL in ensuring safety in the sector. This was considered a positive indicator and added credence to the effectiveness of managing safety through the framework of the OHS Act. However, the publication of the COP further indicated that the DEL has recognised that the LEPC Regulations were not entirely suitable when applied to the lifts at wind power plants. It was, therefore, concluded that the LEPC Regulations were not considered entirely appropriate for managing health and safety in the wind sector.

The study highlighted four areas where the OHS Act and Regulations were suggested to be deficient. These included psychological well-being, naturally occurring hazards, social unrest, and the management of structures.

Regarding employees' psychological well-being, the requirements contained within the Ergonomic Regulations were not considered entirely appropriate. The study highlighted the possibility of its requirement of ensuring human well-being

as far as is reasonably practicable being abused. The study suggested that the remoteness of the RE power plants presented adverse psychological effects on employee well-being. It was therefore concluded that the OHS Act may not be considered entirely appropriate for managing the psychological well-being of employees in remotely located RE power plants.

The OHS Act and Regulations were not considered entirely appropriate regarding naturally occurring hazards. This included hazards associated with the weather and biologically related hazards from wildlife. Although the hazards associated with the weather, such as floods, wind, lightning and ice throw, were all included in the literature, the study suggested that improvements could be made to the OHS Act. The same was observed with biologically related hazards from wildlife such as vermin, snakes, scorpions, insects such as bees, etc. Combining these commonly understood hazards with extreme working conditions presented challenges for managing people exposed to them. Therefore, it was concluded that the OHS Act may not be considered entirely appropriate for managing people from natural hazards within RE power plants.

Regarding the matter of social unrest where the OHS Act and Regulations were suggested not to be considered entirely appropriate. This initially included external human risks, such as community violence, intimidation, and unauthorised site access. However, this was expanded to include strikes, riots, social chaos, intimidation, damaging property, etc. It was considered that the topic of discussion was fundamentally flawed as the findings from the study were contradictory. Although the OHS Act was deemed inappropriate to address such hazards, the findings also unanimously revealed that such hazards were outside the ambit of the OHS Act. It was therefore concluded that the OHS Act and Regulations were considered appropriate in managing people from external risks as appropriate to the scope of the OHS Act.

The final aspect where the study found the OHS Act and Regulations not entirely appropriate was associated with structures. The study found considerable uncertainty associated with managing structures across all three technologies. As the Construction Regulations contain requirements for periodic structural inspections, a similar level of uncertainty was highlighted in their applicability

during normal operations. Considering the extent of structural components found within a wind power plant, this deficiency was particularly prominent within this stratum. The consequence of failure was noted as severe, while the requirements of the OHS Act in the event of such were similarly considered inadequate. Here, general agreement was found on what constituted structural items. These included the foundations, turbine tower, blades and tension bolts. All of these were found to be subject to periodic inspections, although not prescribed by the OHS Act or Regulations. It was therefore concluded that the OHS Act was not considered entirely appropriate for managing structures.

4.4 Summary of the findings

The study tested two propositions associated with health and safety at in-service, grid-connected, utility-scale solar PV, CSP, and wind power plants. A semi-structured interview was used where respondents were asked ten questions on each research objective. The extent of positive responses indicated agreement with the propositions and provided an overall indication of the support for each. A thematic analysis was conducted on the negative responses and areas where only partial agreement was observed.

The study found that the respondents agreed to a large degree with proposition number one (97%). The extent of the agreement supported the position that these RE power plants do not present any health and safety hazards unique to these sectors while under normal operating conditions. A single theme grouped three areas that were identified as having unique hazards. However, these were refuted when tested against interviews that followed. These were ultimately considered errors in judgement or misunderstandings. It was therefore concluded that these RE power plants do not present any health and safety hazards unique to these sectors while under normal operating conditions.

Similarly, the study found the second proposition to be supported by the respondents to a large degree (89%). The extent of the agreement supported the position that the South African OHS Act and its Regulations were considered to be mostly appropriate in managing people from hazards to health and safety at

RE power plants. Several areas were, however, identified as not being entirely appropriate. These areas of disagreement were grouped under two themes, namely, “Regulations that were considered too stringent” and “Deficiencies within the OHS Act and Regulations”.

The Regulations considered too stringent consisted of the General Machinery Regulations and the LEPC Regulations. In both instances, engagement with the DEL was noted to have occurred. The General Machinery Regulations were considered unnecessarily stringent regarding the requirements for the supervision of machinery. A respondent from a PV power plant highlighted the difference between the energy conversion process and associated equipment found in conventional methods of electricity generation. This position was considered to hold merit; however, it was only mentioned in the final interview and, as such, could not be verified against others. As such, it was considered appropriate for the OHS Acts Advisory Council to investigate the matter. Engagement with the DEL had suggested not to yield any variation to the Regulations while exemptions were entertained in certain instances. As the Regulations in their current format include an exemption option, it was therefore concluded that they were found to be mostly appropriate. The LEPC Regulations were also considered too stringent regarding the inspection and maintenance requirements for the lifts inside the vertical towers at wind power plants. It was found that the interactions with the DEL had resulted in the publication of a COP specifically for these lifts. This was considered a positive indicator and added credence to the effectiveness of managing safety through the framework of the OHS Act. However, the publication of the COP further indicated that the DEL had recognised that the LEPC Regulations were not entirely suitable for wind power plants. It was, therefore, concluded that the LEPC Regulations were not considered entirely appropriate for managing health and safety in the wind sector.

The final theme where the study highlighted the OHS Act and Regulations as deficient. These included four areas covering psychological well-being, naturally occurring hazards, social unrest, and managing structures. All were found to be valid, except for external risks from social unrest, which was refuted when tested against interviews that followed. These were ultimately considered errors in

judgement or misunderstandings. It was therefore concluded that the OHS Act and Regulations are appropriate in managing people from external risks as appropriate to the scope of the OHS Act.

Considering the remaining three areas where the OHS Act and Regulations were not considered entirely appropriate. Firstly, concerning employees' psychological well-being, the study suggested that the remoteness of the RE power plants presented adverse psychological effects on employee well-being. The OHS Act and Regulations were found to have a limited focus on psychological well-being. It was therefore concluded that the OHS Act may not be considered entirely appropriate for managing the psychological well-being of employees in remotely located RE power plants.

Naturally occurring hazards included hazards associated with the weather and biologically related hazards from wildlife. The OHS Act and Regulations were not considered entirely appropriate in addressing these. Although common and known, the hazards associated with the weather, including floods, wind, lightning, and ice throw, were not considered adequately addressed. Similarly, the biologically related hazards from wildlife, such as vermin, snakes, scorpions, insects such as bees, etc., were also highlighted as a deficiency where the OHS Act can be improved. The findings supported previous studies that suggested the combination of commonly understood hazards with extreme working conditions presented challenges for managing people exposed to them. Therefore, it was concluded that the OHS Act may not be considered entirely appropriate for managing people from natural hazards within RE power plants.

The final aspect where the study found the OHS Act and Regulations not entirely appropriate was associated with managing structures. The study found a considerable level of uncertainty across all three of the technologies included. The Construction Regulations were noted as containing requirements for periodic structural inspections, and a similar level of uncertainty was highlighted in their applicability during normal operations. The deficiency was found particularly prominent within the wind stratum. The consequence of failure was noted as severe, while the requirements of the OHS Act in the event of such were similarly considered inadequate. Here, general agreement was found on what constituted

structural items. These included the foundations, turbine tower, blades and tension bolts. All of these were found to be subject to periodic inspections, although not prescribed by the OHS Act or Regulations. It was therefore concluded that the OHS Act was not considered entirely appropriate for managing structures.

It was revealed, however, that the industry applied various mitigating aspects that supported health and safety management beyond the OHS Act's prescriptive requirements. These include using the OHS Act as a minimum guide while considering other resources such as industry collaboration, OEM requirements and engagement, and applying industry standards.

It was finally concluded that the South African OHS Act and its Regulations were mostly appropriate in managing people from hazards to health and safety within these RE power plants. This was with the exception of the LEPC Regulations, which were found not to be entirely appropriate. Hazards not considered appropriately addressed by the OHS Act and Regulations were the psychological well-being of employees, naturally occurring hazards and the management of structures.

4.5 Comparison of literature review and own findings

The consistency table below illustrates the comparison between the research objectives and propositions with the findings from the current study.

Table 4. Consistency table: Research questions, propositions and findings

Research objective number	Research objective	Proposition number	Proposition	Findings from the current study
1	Identify health and safety hazards unique to in-service, grid-connected, utility-scale solar PV, CSP and wind power plants.	1	Considering the literature reviewed for in-service, grid-connected, utility-scale solar PV, CSP and wind power plants, it is proposed that these plants do not present any health and safety hazards unique to these sectors while under normal operating conditions.	The study found that these RE power plants do not present any health and safety hazards unique to these sectors while under normal operating conditions.
2	Evaluate the suitability of the South African OHS Act and its Regulations to appropriately support the management of people from hazards to health and safety within utility-scale, in-service,	2	Considering the literature reviewed for in-service, grid-connected, utility-scale solar PV, CSP and wind power plants and the USAs position on managing hazards on these RE power plants, it is proposed that the South African OHS Act and its Regulations appropriately support	The study found that the South African OHS Act and its Regulations were mostly appropriate in managing people from hazards to health and safety within these RE power plants. This was with the exception of the LEPC Regulations, which were found not entirely appropriate. Hazards that were not considered appropriately addressed by the OHS Act

Research objective number	Research objective	Proposition number	Proposition	Findings from the current study
	solar PV, CSP and wind power plants supplying electricity to the South African national grid.		the management of people from hazards to health and safety.	and Regulations were the psychological well-being of employees, naturally occurring hazards and the management of structures.

CHAPTER 5. CONCLUSIONS & RECOMMENDATIONS

5.1 Introduction

The objectives initially identified in response to the study's research problem are addressed in this final chapter. It commences with a conclusion regarding research objective number one, followed by the same for objective number two. Within each of the conclusions, the findings from the study are summarised and used to illustrate how the objectives were achieved. The contributions from the study are illustrated in a table following the conclusions. These lead to recommendations being provided for the stakeholders who have the potential to be positively impacted by the study. Finally, the chapter and study are concluded by offering suggestions for areas that may be considered for further research.

5.2 Conclusions regarding research objective 1

For the appropriateness of the South African Occupational Health and Safety Act, Number 85 of 1993 (OHS Act) to be explored regarding the management of people from hazards to health and safety at in-service, grid-connected, utility-scale solar photovoltaic (PV), concentrated solar power (CSP) and wind power plants, it was first necessary to identify hazards at these plants. Therefore, the first research objective was to identify hazards unique to health and safety at these renewable energy (RE) power plants. Although found to be notably limited, the literature on this topic included several studies that addressed these and provided potential failures. These were combined to represent a set of potential hazards at RE power plants. The study confirmed that these potential hazards from the literature suitably addressed those at in-service RE power plants. It was noted that several studies suggest hazards at RE power plants are simply comparable to those in other mature industrial operations. It can, therefore, be concluded that these RE power plants do not introduce additional unique hazards to health and safety while under normal operating conditions.

5.3 Conclusions regarding research objective 2

With the first objective achieved, the second was able to build upon this and respond directly to the purpose of the study. Here, the suitability of the OHS Act and its Regulations in their ability to appropriately support the management of people from hazards to health and safety was evaluated. This was performed within the scope of the study, which included utility-scale, in-service, solar PV, CSP, and wind power plants supplying electricity to the South African national grid. These RE technologies have only recently been introduced to South Africa's electricity generation, some 20 years after the enactment of the OHS Act. The study, in part, responds to the position of the White Paper on the Energy Policy of the Republic of South Africa (WPEP) and the White Paper on the RE Policy of the Republic of South Africa (WPREP) by exploring the health and safety associated with the operation of these RE power plants.

The study considers the OHS Act and its Regulations to be mostly appropriate in managing people from hazards to health and safety at RE power plants. However, some aspects are not entirely appropriate. These consist of Regulations that are too stringent and areas where the OHS Act and Regulations are deficient.

The Lift, Escalator, and Passenger Conveyor Regulations (LEPC Regulations) are considered too stringent regarding the inspection and maintenance requirements for the lifts inside the vertical towers at wind power plants. Interactions with the Department of Employment and Labour (DEL) and industry resulted in the DEL publishing a code of practice (COP) specifically for these lifts. This is a positive indicator that adds credence to the effectiveness of managing safety through the framework of the OHS Act. It also aligns with the positions of the WPEP and WPREP that applying these RE technologies requires establishing standards, guidelines, and COPs for their appropriate use. However, the publication further indicates that the DEL recognised that the LEPC Regulations were not entirely suitable for wind power plants. It is, therefore, concluded that the LEPC Regulations are not entirely appropriate for managing health and safety in the wind sector.

The OHS Act and Regulations are considered deficient in three areas: psychological well-being, naturally occurring hazards, and managing structures. These represent areas where the OHS Act and Regulations are not entirely appropriate.

Employees' psychological well-being is not appropriately addressed by the OHS Act. Here, the remoteness of the RE power plants presents adverse psychological effects on employee well-being, where the OHS Act and Regulations only have a limited focus. It is therefore concluded that the OHS Act is not entirely appropriate for managing the psychological well-being of employees in remotely located RE power plants.

Following this is the aspect of naturally occurring hazards associated with the weather and biologically related hazards from wildlife. The OHS Act and Regulations are not entirely appropriate in addressing these. Although common and known, the hazards associated with the weather, including floods, wind, lightning, and ice throw, are not adequately addressed. Similarly, the biologically related hazards from wildlife, such as vermin, snakes, scorpions, insects such as bees, etc, are also highlighted as a deficiency where the OHS Act can be improved. The findings support previous studies that suggest combining commonly understood hazards with extreme working conditions on RE power plants presents challenges for managing people exposed to them. Therefore, it is concluded that the OHS Act is not entirely appropriate for managing people from natural hazards within RE power plants.

Managing structures is the final aspect where the OHS Act and Regulations are not entirely appropriate. There was considerable uncertainty regarding managing structures across all three strata. The Construction Regulations contain requirements for periodic structural inspections. However, the study highlights the uncertainty in their applicability during normal in-service operations. The deficiency is particularly prominent within the wind stratum. The consequence of structural failure was found to be severe, while the requirements of the OHS Act in the event of such are inadequate. Here, general agreement on structural items includes the foundations, turbine towers, blades and tension bolts. All of these were found to be subject to periodic inspections, although the OHS Act or

Regulations do not prescribe them. Therefore, the OHS Act is not entirely appropriate for managing structures.

It is noted, however, that the industry applies various mitigating aspects that support health and safety management beyond the OHS Act's prescriptive requirements. These include using the OHS Act as a minimum guide while considering other resources such as industry collaboration, OEM requirements and engagement, and applying industry standards.

In closing, it can be noted that the South African OHS Act and its Regulations are mostly appropriate for managing people from hazards to health and safety within these RE power plants. This is true except for the LEPC Regulations, which are not entirely appropriate. A further exclusion is the three areas not considered appropriately addressed by the OHS Act and Regulations. These include the psychological well-being of employees, naturally occurring hazards and the management of structures. It is, therefore, ultimately concluded that the South African OHS Act and its Regulations are not entirely appropriate in managing people from hazards to health and safety within these RE power plants.

The final consistency table below illustrates the differences between the initial propositions and the conclusions of the current study.

Table 5. Consistency table: Research questions, conclusions and contribution to knowledge

Research objective number	Research objective	Literature-based proposition	Conclusion based on findings from the current study	Key differences between the initial proposition and the findings from the current study
1	Identify health and safety hazards unique to in-service, grid-connected, utility-scale solar PV, CSP and wind power plants.	Considering the literature reviewed for in-service, grid-connected, utility-scale solar PV, CSP and wind power plants, it is proposed that these plants do not present any health and safety hazards unique to these sectors while under normal operating conditions.	It was concluded that these RE power plants do not present any health and safety hazards unique to these sectors while under normal operating conditions.	The current study confirmed the position of the initial proposition.
2	Evaluate the suitability of the South African OHS Act and its Regulations to	Considering the literature reviewed for in-service, grid-connected, utility-scale solar PV, CSP and wind	It was concluded that the South African OHS Act and its Regulations were not entirely appropriate in managing people from	The LEPC Regulations are not entirely appropriate in addressing lifts inside the vertical towers at wind power plants. Hazards that are not appropriately addressed by the OHS Act and

Research objective number	Research objective	Literature-based proposition	Conclusion based on findings from the current study	Key differences between the initial proposition and the findings from the current study
	appropriately support the management of people from hazards to health and safety within utility-scale, in-service, solar PV, CSP and wind power plants supplying electricity to the South African national grid.	power plants and the USAs position on managing hazards on these RE power plants, it is proposed that the South African OHS Act and its Regulations appropriately support the management of people from hazards to health and safety.	hazards to health and safety within these RE power plants.	Regulations include the psychological well-being of employees, naturally occurring hazards and the management of structures.

5.4 Recommendations

At the beginning of the study, various potential stakeholders who may have benefited from its outcome were identified. Upon concluding the study, its findings may now provide them with an improved understanding of the hazards to health and safety encountered at RE power plants. The study also provides them with confirmation that the South African OHS Act and its Regulations in their current format are mostly suitable for mitigating hazards to health and safety at these power plants. In addition to these two general benefits that apply to all stakeholders, particular mention is provided below where specific recommendations are provided.

5.4.1 *OHS Act's Advisory Council*

In addition to the above, the OHS Acts Advisory Council are recommended to consider the areas identified by the study where the OHS Act and Regulations were not found to be entirely appropriate. Therefore, it is recommended that the OHS Acts Advisory Council consider these as summarised under the following four points.

- i. The LEPC Regulations and the published COP for lifts inside wind turbine towers: The study found these not to be entirely appropriate in addressing the lifts at wind power plants. They were considered too stringent regarding the maintenance requirements. It is recommended that the OHS Acts Advisory Council continue with the stakeholder engagement as included within the COP. The progress on the referenced ISO Standard in the COP, currently in draft format for comment, should be monitored. When published, its application and content should be considered. Finally, it is recommended that the COP be referenced within the LEPC Regulations.
- ii. Hazards not appropriately addressed by the OHS Act and Regulations: The study found these to include the psychological well-being of employees and naturally occurring hazards. The study highlights the challenges when commonly encountered hazards are combined with

extreme working environments. It is recommended that the OHS Acts Advisory Council consider the effect of these combinations from introducing RE power plants.

- iii. Structures: These were similarly not considered to be appropriately addressed by the OHS Act and Regulations. The study highlights the considerable uncertainty regarding the management of structures. This was prominent within the wind sector with its extensive structures, such as turbine towers and meteorological masts. The Construction Regulations, which include periodic inspection requirements for structures, further complicate the matter. Where the uncertainty exists in their applicability post-construction. It is, therefore, recommended that the OHS Acts Advisory Council investigate the matter. This may include determining the intention of the OHS Act for in-service structures. This needs to be followed by clear communication, including the applicability of the Construction Regulations post-construction.
- iv. The General Machinery Regulations: Although the study concluded that these were appropriate, mentioning one of the challenges encountered is necessary. This was regarding the requirement for a full-time Government Certificate of Competency (GCC) ticketed engineer to be appointed to a single site. The study highlights the differences in the energy conversion process and workforce requirements of RE power plants compared to conventional electricity-generating plants. It is therefore recommended that the OHS Acts Advisory Council investigate this matter. This may include ensuring that the Regulations' intention is met while considering the type of machinery and its operational characteristics.

5.4.2 *Users, owners, leaders, and management*

In addition to the two general benefits, the users, owners, leaders, and management are recommended to consider the areas identified by the study where the OHS Act and Regulations were not found to be entirely appropriate. In these areas, additional mitigating actions may be necessary to manage people from hazards effectively. Therefore, it is recommended that they consider these to be summarised under the same four points. (Texts within this section were not

repeated or elaborated as they were under the section for the OHS Acts Advisory Council.)

- i. The General Machinery Regulations: Regarding the supervision of RE power plants, it is recommended that engagement with the DEL be continued.
- ii. The LEPC Regulations and the published COP for lifts inside wind turbine towers: Regarding the maintenance requirements for lifts inside wind turbines, it is recommended that engagement with the DEL is continued
- iii. Various hazards that were not considered appropriately addressed by the OHS Act and Regulations: It is recommended that the psychological well-being of employees and naturally occurring hazards be evaluated and appropriate measures implemented.
- iv. Structures: Regarding the management of structural integrity, it is recommended that engagement with the DEL be continued with industry collaboration.

5.4.3 *Investors and insurance companies*

There were no additional benefits to the investors and insurance companies besides the two general benefits mentioned above.

5.4.4 *General citizens*

There were no additional benefits to South Africa's general citizens besides the two general benefits mentioned above.

5.5 Suggestions for further research

The study is concluded by providing suggestions for further research. This includes two aspects that were related to the current study and one that was unrelated.

The variation within each RE technology was considered a potential weakness in the study. The impact of the different operational applications within the strata

remained unknown. Some aspects, such as solar PV mounting on single or dual-axis tracking, were considered minor nuances. However, within CSP plants, the operational differences in the focusing technologies between parabolic trough collectors (PTC) and solar power towers (SPT) may be more significant. The current study only encountered power plants with PTC-focusing technologies within the CSP stratum. Therefore, further research is suggested to consider CSP plants with SPT-focusing technologies.

The vertical towers in wind power plants and the methods applied in managing their structural integrity were considered areas with limited understanding. The current study encountered structures that were of concrete and tubular steel construction. There did not appear to be differences in the methods applied. As managing structures also presented itself with a certain level of uncertainty, it is suggested that further research on them be conducted. This is suggested to be beyond the current study's delimitation of South Africa and include global best practices. The value that such a study could have would also aid South Africa's OHS Acts Advisory Council on the matter.

A matter outside the scope of the current study was that of animals and reptiles. The impact that these RE power plants have on them was a topic of discussion raised by most respondents. This ranged from the electrocution of animals and reptiles across the strata to the measures taken in the wind sector to protect and monitor bird and bat life. The methods applied to address these matters varied, and it is suggested that further research on this topic be conducted.

REFERENCES

- Aman, M., Solangi, K., Hossain, M., Badarudin, A., Jasmon, G., Mokhlis, H., Bakar, A., & Kazi, S. N. (2015). A review of Safety, Health and Environmental (SHE) issues of solar energy system. *Renewable and Sustainable Energy Reviews*, 41, 1190-1204.
<https://doi.org/10.1016/j.rser.2014.08.086>
- Austin, J. (2002). Displaying data. In C. Tredoux & K. Durrheim (Eds.), *Number, hypotheses & conclusions: A course in statistics for the social sciences*. University of Cape Town Press.
- Awan, A. B., Khan, M., Zubair, M., & Bellos, E. (2020). Commercial parabolic trough CSP plants: Research trends and technological advancements. *Solar Energy*, 211, 1422-1458.
<https://doi.org/10.1016/j.solener.2020.09.072>
- Bezdek, R. H. (1993). The environmental, health, and safety implications of solar energy in central station power production. *Energy*, 18(6), 681-685.
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2), 77-101.
<https://doi.org/10.1191/1478088706qp063oa>
- Braun, V., & Clarke, V. (2012). *Thematic analysis*. American Psychological Association. <https://doi.org/10.1037/13620-004>
- Brinkmann, S. (2018). The Interview. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (5th ed.). Sage Publications.
- Brouwer, S. R., Al-Jibouri, S. H., Cárdenas, I. C., & Halman, J. I. (2018). Towards analysing risks to public safety from wind turbines. *Reliability Engineering & System Safety*, 180, 77-87.
<https://doi.org/10.1016/j.ress.2018.07.010>
- Caelli, K., Ray, L., & Mill, J. (2003). 'Clear as mud': Toward greater clarity in generic qualitative research. *International journal of qualitative methods*, 2(2), 1-13. <https://doi.org/10.1177/160940690300200201>
- Chan, D., & Mo, J. (2017). Life cycle reliability and maintenance analyses of wind turbines. *ScienceDirect*, 110, 328-333.
<https://doi.org/10.1016/j.egypro.2017.03.148>
- Chen, X., & Xu, J. Z. (2016). Structural failure analysis of wind turbines impacted by super typhoon Usagi. *Engineering failure analysis*, 60, 391-404. <https://doi.org/10.1016/j.engfailanal.2015.11.028>
- Chou, J.-S., Chiu, C.-K., Huang, I.-K., & Chi, K.-N. (2013). Failure analysis of wind turbine blade under critical wind loads. *Engineering failure analysis*, 27, 99-118. <https://doi.org/10.1016/j.engfailanal.2012.08.002>

- Civera, M., & Surace, C. (2022). Non-Destructive techniques for the condition and structural health monitoring of wind turbines: A literature review of the last 20 years. *Sensors*, 22(4), 1627. <https://doi.org/10.3390/s2204162>
- Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five approaches* (2nd ed.). Sage publications.
- Del Río, P., Peñasco, C., & Mir-Artigues, P. (2018). An overview of drivers and barriers to concentrated solar power in the European Union. *Renewable and Sustainable Energy Reviews*, 81, 1019-1029. <https://doi.org/10.1016/j.rser.2017.06.038>
- Denzin, N. K., & Lincoln, Y. S. (Eds.). (2018). *The Sage handbook of qualitative research* (5th ed.). Sage Publications.
- Department of Labour. (2007). *Occupational health and safety Act, 1993 examinations for the mechanical and electrical engineers certificates of competency (factories): Information brochure*. (OHS 3/1/4/6). Online Retrieved from <https://www.labour.gov.za/DocumentCenter/Forms/Occupational%20Health%20and%20Safety/ohsexambrochure.pdf>
- dos Santos, A., & Wagner, C. (2021). Interviews and focus groups. In A. Bryman, E. Bell, & P. Hirschsohn (Eds.), *Research methodology: Business and management contexts* (2nd ed.). Oxford university press.
- Eberhard, A., Kolker, J., & Leigland, J. (2014). *South Africa's renewable energy IPP procurement Program: Success factors and lessons* (ACS8826). The World Bank. <https://openknowledge.worldbank.org/server/api/core/bitstreams/74a79bb1-6b50-5058-a614-7154f6df73df/content>
- Erten, B., Oral, B., & Yakut, M. Z. (2022). The role of virtual and augmented reality in occupational health and safety training of employees in PV power systems and evaluation with a sustainability perspective. *Journal of Cleaner Production*, 379, 134499. <https://doi.org/10.1016/j.jclepro.2022.134499>
- Eskom. (2021). *Transmission and distribution of electricity* (Fact sheet, Issue TD 0003 Revision 1). Eskom Generation Communication. <https://www.eskom.co.za/wp-content/uploads/2021/08/TD-0003-Transmission-and-Distribution-of-electricity-Rev-11.pdf>
- Eskom. (2023). *Company information*. Eskom Holdings SOC Ltd. Retrieved 12 January from <https://www.eskom.co.za/about-eskom/company-information/>
- Federal Aviation Administration. (2018). *Technical guidance for evaluating selected solar technologies on airports* (FAA-ARP-TR-10-1). Federal Aviation Administration.

<https://www.faa.gov/sites/faa.gov/files/airports/environmental/FAA-Airport-Solar-Guide-2018.pdf>

Fernández, A. G., Gomez-Vidal, J., Oró, E., Kruizenga, A., Solé, A., & Cabeza, L. F. (2019). Mainstreaming commercial CSP systems: A technology review. *Renewable energy*, 140, 152-176.

<https://doi.org/10.1016/j.renene.2019.03.049>

Freris, L., & Infield, D. (2008). *Renewable energy in power systems*. John Wiley & Sons.

Geertz, C. (1973). *The interpretation of cultures*. Basic books.

Guba, E. G. (1981). Criteria for assessing the trustworthiness of naturalistic inquiries. *Educational Communication and Technology*, 29(2), 75-91.

https://0-www-jstor-org.innopac.wits.ac.za/stable/pdf/30219811.pdf?refregid=fastly-default%3Ae60223d603b73729b4c7bc91e01b9c5f&ab_segments=0%2Fbasic_search_gsv2%2Fcontrol&origin=&initiator=search-results&acceptTC=1

Guba, E. G., & Lincoln, Y. S. (1981). *Effective evaluation: Improving the usefulness of evaluation results through responsive and naturalistic approaches*. Jossey-Bass.

Guerin, T. (2017). A case study identifying and mitigating the environmental and community impacts from construction of a utility-scale solar photovoltaic power plant in eastern Australia. *Solar Energy*, 146, 94-104.

<https://doi.org/10.1016/j.solener.2017.02.020>

Hernandez, R. R., Easter, S., Murphy-Mariscal, M. L., Maestre, F. T., Tavassoli, M., Allen, E. B., Barrows, C. W., Belnap, J., Ochoa-Hueso, R., & Ravi, S. (2014). Environmental impacts of utility-scale solar energy. *Renewable and Sustainable Energy Reviews*, 29, 766-779.

<https://doi.org/10.1016/j.rser.2013.08.041>

Hirschsohn, P., & Faasen, N. (2021). Ethics in business research. In A. Bryman, E. Bell, & P. Hirschsohn (Eds.), *Research methodology: Business and management contexts* (2nd ed.). Oxford university press.

Hussain, W., Khan, S., & Mover, A. H. (2022). Development of quality, environment, health, and safety (QEHS) management system and its integration in operation and maintenance (O&M) of onshore wind energy industries. *Renewable energy*, 196, 220-233.

<https://doi.org/10.1016/j.renene.2022.06.138>

Independent Power Producers Office. (2023a). *IPP Projects: Project database*.

Retrieved 15 January from <https://www.ipp-projects.co.za/ProjectDatabase>

- Independent Power Producers Office. (2023b). *IPP Renewables: Independent power producer procurement programme*. Retrieved 15 January from <https://www.ipp-renewables.co.za/>
- International Energy Agency. (2022). *Renewables*. International Energy Agency. Retrieved 4 March from <https://www.iea.org/fuels-and-technologies/renewables>
- International Energy Agency. (2023). *Electricity generation by source: South Africa 1990-2020*. International Energy Agency. Retrieved 15 January from <https://www.iea.org/countries/south-africa>
- International Renewable Energy Agency. (2022). *Energy profile: South Africa*. International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Statistics/Statistical_Profiles/Africa/South%20Africa_Africa_RE_SP.pdf
- Irvine, A. (2011). Duration, dominance and depth in telephone and face-to-face interviews: A comparative exploration. *International journal of qualitative methods*, 10(3), 202-220. <https://journals.sagepub.com/doi/pdf/10.1177/160940691101000302>
- Ishihara, T., Yamaguchi, A., Takahara, K., Mekaru, T., & Matsuura, S. (2005). *An analysis of damaged wind turbines by typhoon Maemi in 2003*. Wind Engineering (APCWE-VI), Seoul, Korea. http://windeng.t.u-tokyo.ac.jp/ishihara/e/proceedings/2005-7_paper.pdf
- Islam, M. T., Huda, N., Abdullah, A., & Saidur, R. (2018). A comprehensive review of state-of-the-art concentrating solar power (CSP) technologies: Current status and research trends. *Renewable and Sustainable Energy Reviews*, 91, 987-1018. <https://doi.org/10.1016/j.rser.2018.04.097>
- Jeong, Y.-J., Park, M.-S., Song, S.-H., & Kim, J. (2020). Numerical evaluation of structural safety for aged onshore wind foundation to extend service life. *Applied Sciences*, 10(13), 4561. <https://doi.org/10.3390/app10134561>
- Kahlke, R. M. (2014). Generic qualitative approaches: Pitfalls and benefits of methodological mixology. *International journal of qualitative methods*, 13(1), 37-52. <https://doi.org/10.1177/160940691401300119>
- Kaldellis, J. K., & Zafirakis, D. (2011). The wind energy (r) evolution: A short review of a long history. *Renewable energy*, 36(7), 1887-1901. <https://doi.org/10.1016/j.renene.2011.01.002>
- Kamenopoulos, S. N., & Tsoutsos, T. (2015). Assessment of the safe operation and maintenance of photovoltaic systems. *Energy*, 93, 1633-1638. <https://doi.org/10.1016/j.energy.2015.10.037>
- Karanikas, N., Steele, S., Bruschi, K., Robertson, C., Kass, J., Popovich, A., & MacFadyen, C. (2021). Occupational health hazards and risks in the wind industry. *Energy reports*, 7, 3750-3759. <https://doi.org/10.1016/j.eqyr.2021.06.066>

- Khan, M. I., Asfand, F., & Al-Ghamdi, S. G. (2023). Progress in research and technological advancements of commercial concentrated solar thermal power plants. *Solar Energy*, 249, 183-226. <https://doi.org/10.1016/j.solener.2022.10.041>
- Kumar, B. S., & Sudhakar, K. (2015). Performance evaluation of 10 MW grid connected solar photovoltaic power plant in India. *Energy reports*, 1, 184-192. <https://doi.org/10.1016/j.egyr.2015.10.001>
- Kuntiyawichai, K., & Limkatanyu, S. (2006). State of the art in quality assurance issues of structures with particular emphasis on strength degradation. *Songklanakarin Journal of Science and Technology (SJST)*, 28(6), 1289-1304.
- Larson, A. (2016). *Fire is latest hurdle for Ivanpah concentrating solar power plant*. POWER Magazine. Retrieved 16 March from <https://www.powermag.com/fire-is-latest-hurdle-for-ivanpah-concentrating-solar-power-plant/>
- LexisNexis (Ed.). (2022). *Occupational Health and Safety Act No. 85 of 1993 and Regulations* (24th ed.). LexisNexis South Africa.
- Lincoln, Y. S., & Guba, E. G. (1986). But is it rigorous? Trustworthiness and authenticity in naturalistic evaluation. *New directions for program evaluation*, 1986(30), 73-84. <https://doi.org/https://0-onlinelibrary-wiley-com.innopac.wits.ac.za/doi/epdf/10.1002/ev.1427>
- Luque, A., & Hegedus, S. (2003). *Handbook of photovoltaic science and engineering*. John Wiley & Sons.
- Manwell, J. F., McGowan, J. G., & Rogers, A. L. (2009). *Wind energy explained: Theory, design and application* (2nd ed.). John Wiley & Sons.
- Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. Wiley.
- Mertens, K. (2014). *Photovoltaics: Fundamentals, technology and practice* (1st ed.). John Wiley & Sons.
- Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Sage Publications.
- Moore, L. M., & Post, H. N. (2008). Five years of operating experience at a large, utility-scale photovoltaic generating plant. *Progress in Photovoltaics: Research and Applications*, 16(3), 249-259. <https://doi.org/10.1002/pip.800>
- Morse, J. M. (2015). Critical analysis of strategies for determining rigor in qualitative inquiry. *Qualitative health research*, 25(9), 1212-1222.
- Mulloy, K. B., Sumner, S. A., Rose, C., Conway, G. A., Reynolds, S. J., Davidson, M. E., Heidel, D. S., & Layde, P. M. (2013). Renewable energy

- and occupational health and safety research directions: A white paper from the Energy Summit, Denver Colorado, April 11–13, 2011. *American journal of industrial medicine*, 56(11), 1359-1370.
<https://doi.org/10.1002/ajim.22184>
- Occupational Safety and Health Administration. (2014). *At a glance: OSHA* (OSHA 3439-B-12R 2014).
<https://www.osha.gov/sites/default/files/publications/3439at-a-glance.pdf>
- Olabi, A. G., Wilberforce, T., Elsaid, K., Sayed, E. T., Salameh, T., Abdelkareem, M. A., & Baroutaji, A. (2021). A review on failure modes of wind turbine components. *Energies*, 14(17), 5241.
<https://doi.org/10.3390/en14175241>
- Palmer, W. K. (2018). Wind turbine public safety risk, direct and indirect health impacts. *Journal of Energy Conservation*, 1(1), 41.
<https://doi.org/10.14302/issn.2642-3146.jec-18-2416>
- Papaelias, M., Cheng, L., Kogia, M., Mohimi, A., Kappatos, V., Selcuk, C., Constantinou, L., Muñoz, C. Q. G., Marquez, F. P. G., & Gan, T.-H. (2016). Inspection and structural health monitoring techniques for concentrated solar power plants. *Renewable energy*, 85, 1178-1191.
<https://doi.org/10.1016/j.renene.2015.07.090>
- Parida, B., Iniyar, S., & Goic, R. (2011). A review of solar photovoltaic technologies. *Renewable and Sustainable Energy Reviews*, 15(3), 1625-1636. <https://doi.org/10.1016/j.rser.2010.11.032>
- Peppas, G. D., Bekas, K. I., Naxakis, I. A., Pyrgioti, E. C., & Charalampakos, V. P. (2012). Analysis of lightning impacts in Greece. *2012 International Conference on Lightning Protection (ICLP)*.
<https://doi.org/10.1109/ICLP.2012.6344347>
- Pollet, B. G., Staffell, I., & Adamson, K.-A. (2015). Current energy landscape in the Republic of South Africa. *International Journal of Hydrogen Energy*, 40(46), 16685-16701. <https://doi.org/10.1016/j.ijhydene.2015.09.141>
- Price, H., Mehos, M. S., Cable, R., Kearney, D., Kelly, B., Kolb, G., & Morse, F. (2020). CSP plant construction, start-up, and O&M best practices study. *AIP Conference Proceedings* 2303, 040002.
<https://doi.org/10.1063/5.0028859>
- Republic of South Africa. (1988). *General Machinery Regulations*. Government Gazette Number 11443. Government Printer.
- Republic of South Africa. (1993). *Occupational Health and Safety Act, Number 85*. Government Gazette Number 14918. Cape Town, Government Printer.
- Republic of South Africa. (1998). *Department of Minerals and Energy: White paper on the energy policy of the Republic of South Africa*.

https://www.energy.gov.za/files/policies/whitepaper_energypolicy_1998.pdf

Republic of South Africa. (2003a). *Environmental Regulations for Workplaces. Government Gazette Number 24967*. Pretoria, Government Printer.

Republic of South Africa. (2003b). *General Safety Regulations. Government Gazette Number 25207*. Government Printer.

Republic of South Africa. (2003c). *Noise Induced Hearing Loss Regulations. Government Gazette Number 24967*. Pretoria, Government Printer.

Republic of South Africa. (2004a). *Department of Minerals and Energy: White paper on the renewable energy policy of the Republic of South Africa. Government Gazette Number 26169*. Pretoria, Government Printer

Republic of South Africa. (2004b). *Facilities Regulations. Government Gazette Number 26636*. Pretoria, Government Printer.

Republic of South Africa. (2009a). *Constitution of the Republic of South Africa, 1996. Government Gazette Number 32065*. Cape Town, Government Printer.

Republic of South Africa. (2009b). *Electrical Installation Regulations. Government Gazette Number 31975*. Government Printer.

Republic of South Africa. (2010a). *Lift, Escalator and Passenger Conveyor Regulations. Government Gazette Number 33561*. Government Printer.

Republic of South Africa. (2010b). *Regulations on hazardous work by children in South Africa. Government Gazette Number 32862*. Government Printer.

Republic of South Africa. (2011). *Electrical Machinery Regulations. Government Gazette Number 34154*. Government Printer.

Republic of South Africa. (2013). *Protection of Personal Information Act, Number 4. Government Gazette Number 37067*. Cape Town, Government Printer.

Republic of South Africa. (2014). *Construction Regulations. Government Gazette Number 37305*. Government Printer.

Republic of South Africa. (2015). *Driven Machinery Regulations. Government Gazette Number 38887*. Government Printer.

Republic of South Africa. (2016). *Department of Energy: Integrated energy plan. <http://www.energy.gov.za/files/IEP/2016/Integrated-Energy-Plan-Report.pdf>*

- Republic of South Africa. (2017). *Guidance notes to the Pressure Equipment Regulations July 2009*. Government Gazette Number 41256. Government Printer.
- Republic of South Africa. (2019a). *Department of Energy: Integrated resource plan 2019*. Government Gazette Number 42784. Government Printer.
- Republic of South Africa. (2019b). *Ergonomics Regulations*. Government Gazette Number 42894. Government Printer.
- Republic of South Africa. (2019c). *National Planning Commission. Department of Planning, Monitoring and Evaluation: NPC Economy series: Energy*. [https://www.nationalplanningcommission.org.za/assets/Documents/Energy%20Position%20Paper .pdf](https://www.nationalplanningcommission.org.za/assets/Documents/Energy%20Position%20Paper.pdf)
- Republic of South Africa. (2021). *Regulations for Hazardous Chemical Agents*. Government Gazette Number 44348. Government Printer.
- Republic of South Africa. (2022a). *Code of practice for lifts inside wind turbine*. Government Gazette Number 46917. Government Printer.
- Republic of South Africa. (2022b). *Department of Public Works and Infrastructure: South Africa's National infrastructure plan 2050*. Government Gazette Number 46033. Government Printer.
- Rodríguez-Sánchez, M. R., Soria-Verdugo, A., Almendros-Ibáñez, J. A., Acosta-Iborra, A., & Santana, D. (2014). Thermal design guidelines of solar power towers. *Applied Thermal Engineering*, 63(1), 428-438. <https://doi.org/10.1016/j.applthermaleng.2013.11.014>
- Sahu, A., Yadav, N., & Sudhakar, K. (2016). Floating photovoltaic power plant: A review. *Renewable and Sustainable Energy Reviews*, 66, 815-824. <https://doi.org/10.1016/j.rser.2016.08.051>
- Salkind, N. (2012). Exploring research. In C. Van Zyl, L (Comps.), *Research methodology for the economic and management sciences* [Custom textbook]. In: Capetown: Pearson.
- Sandelowski, M. (1993). Rigor or rigor mortis: The problem of rigor in qualitative research revisited. *Advances in nursing science*, 16(2), 1-8. https://doi.org/https://journals.lww.com/advancesinnursingscience/abstract/1993/12000/rigor_or_rigor_mortis_the_problem_of_rigor_in.2.aspx
- Scotland Against Spin. (2021). *Caithness Windfarm Information Forum (CWIF): Accident statistics*. Scotland Against Spin. Retrieved 19 March from <https://scotlandagainstspin.org/2021/07/caithness-windfarm-information-forum-cwif-accident-statistics/>
- Scotland Against Spin. (2023). *Summary of wind turbine accident data to 31 December 2022*. Scotland Against Spin. Retrieved 20 March from <https://scotlandagainstspin.org/wp-content/uploads/2023/01/Turbine-Accident-Summary-to-31-Dec-2022.pdf>

- Semano, M., & Dicks, C. (2019). *Annual administrative statistics of the department of labour* (RP276/2020). Department of Employment and Labour.
<https://www.labour.gov.za/DocumentCenter/Reports/Annual%20Reports/Annual%20Administrative%20Statistics%20of%20the%20Department%20of%20Labour/2019/Annual%20Administrative%20Statistics%20Report%202019.pdf>
- Shannon, P., & Hambacher, E. (2014). Authenticity in constructivist inquiry: Assessing an elusive construct. *The Qualitative Report*.
<http://nsuworks.nova.edu/tqr/vol19/iss52/3>
- Shumake, S. A., Sterner, R. T., & Gaddis, S. E. (2000). Repellents to reduce cable gnawing by wild Norway rats. *Journal of wildlife management*, 64(4), 1009-1013.
https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1834&context=icwdm_usdanwrc
- The National Institute for Occupational Safety and Health. (2023). *About NIOSH*. Retrieved 16 April from
<https://www.cdc.gov/niosh/about/default.html>
- The Presidency of the Republic of South Africa. (2012). *National Planning commission: National development plan 2030: Our future - make it work*.
https://www.gov.za/sites/default/files/gcis_document/201409/ndp-2030-our-future-make-it-workr.pdf
- Tredoux, C. (2002). Numbers, variables, and measures. In C. Tredoux & K. Durrheim (Eds.), *Number, hypotheses & conclusions: A course in statistics for the social sciences*. University of Cape Town Press.
- United States Department of Labor. (2022). *2023 Annual adjustments to OSHA civil penalties* (OSHA Memo, Dec. 20, 2022).
<https://www.osha.gov/memos/2022-12-20/2023-annual-adjustments-osh-civil-penalties>
- United States Department of Labor. (n.d.-a). *About Occupational Safety & Health Administration (OSHA)*. United States Department of Labor. Retrieved 13 April from <https://www.osha.gov/aboutosha>
- United States Department of Labor. (n.d.-b). *Occupational Safety and Health Administration (OSHA): Enforcement*. United States Department of Labor. Retrieved 22 April from <https://www.osha.gov/enforcement/2021-enforcement-summary>
- United States Department of Labor. (n.d.-c). *OSHA Laws & Regulations: 1910*. United States Department of Labor. Retrieved 13 April from <https://www.osha.gov/laws-regs/regulations/standardnumber/1910>

- United States Department of Labor. (n.d.-d). *Safety and health topics: Green job hazards*. United States Department of Labor. Retrieved 03 March from <https://www.osha.gov/green-jobs>
- United States Department of Labor. (n.d.-e). *Safety and health topics: Workplace Stress*. United States Department of Labor. Retrieved 24 December from <https://www.osha.gov/workplace-stress/employer-guidance>
- United States Occupational Safety and Health Act of 1970, Pub. L. No. 91-596, 29 U.S.C., United States Department of Labor. <https://www.osha.gov/laws-regs/oshact/toc>
- van Aardt, I., & Hirschsohn, P. (2021). The nature of quantitative and qualitative research. In A. Bryman, E. Bell, & P. Hirschsohn (Eds.), *Research methodology: Business and management contexts* (2nd ed.). Oxford university press.
- Wagner, H.-J. (2020). Introduction to wind energy systems. *EPJ Web of Conferences* 246, 00004 (2020), 246, 00004. <https://doi.org/10.1051/epjconf/202024600004>
- Webster, J., Cabeças, J. M. M., Kuhl, K., Liddle, M., Ellwood, P., Smith, P., Gervais, R., Bradbrook, S. D., & Väänänen, V. (2013). Occupational safety and health in the wind energy sector: European risk observatory report. <https://doi.org/10.2802/86555>
- Yang, R., He, Y., & Zhang, H. (2016). Progress and trends in nondestructive testing and evaluation for wind turbine composite blade. *Renewable and Sustainable Energy Reviews*, 60, 1225-1250. <https://doi.org/10.1016/j.rser.2016.02.026>
- Zhang, H., Baeyens, J., Degreè, J., & Cacères, G. (2013). Concentrated solar power plants: Review and design methodology. *Renewable and Sustainable Energy Reviews*, 22, 466-481. <https://doi.org/10.1016/j.rser.2013.01.032>

APPENDIX A: Probable hazards at a solar PV power plant

The probable hazards to health and safety for operational solar PV plants were extracted from a European study (Kamenopoulos & Tsoutsos, 2015). A baseline of probable hazards to health and safety was compiled in the study from prior literature (Kamenopoulos & Tsoutsos, 2015). The hazards identified were divided by their source as technological, natural or human (Kamenopoulos & Tsoutsos, 2015). The listed hazards presented within the study have been summarised in the table below, including the corresponding primary source referenced. After reviewing the primary sources for each hazard, applicability and deserved inclusion or exclusion from this study were indicated in the table below.

Item number	Hazard	Primary source	Comments on applicability to this study	Applicable to this study
Technological hazards				
1	Electrocution	Located one of the referenced sources: United States Department of Labor (n.d.-d).	The source was found to be a guide to the United States Occupational Safety and Health Act (OSH Act).	Yes
2	Fire	Located one of the referenced sources: United States	The source was found to be a guide to the United States Occupational Safety and Health Act (OSH Act).	Yes

Item number	Hazard	Primary source	Comments on applicability to this study	Applicable to this study
		Department of Labor (n.d.-d).		
3	Contact with sharp surface	Not located	The primary source was a website for Allianz and an industry product catalogue. Source to hazard unable to be located and, as such, was not considered reasonable to include at this stage.	No
4	Contact with hot surface	Not located	The primary source was a website for Allianz and an industry product catalogue. Source to hazard unable to be located and, as such, was not considered reasonable to include at this stage.	No
5	Fall from heights	Located one of the referenced sources: United States Department of Labor (n.d.-d).	The source was found to be a guide to the United States Occupational Safety and Health Act (OSH Act).	Yes
6	Non-ionizing radiation	Not located	The primary source was a website for the State of Oregon`, titled Oregon's department	No

Item number	Hazard	Primary source	Comments on applicability to this study	Applicable to this study
			of transportation. Source to hazard unable to be located and, as such, was not considered reasonable to include at this stage.	
7	Aviation system interference	Federal Aviation Administration (2018)	The 2010 version of the primary source could not be located; however, a later version was sourced. Document written to provide technical guidance on evaluating solar technology at airports.	No
8	Aviation reflection or glare for pilot	Federal Aviation Administration (2018)	The 2010 version of the primary source could not be located; however, a later version was sourced. Document written to provide technical guidance on evaluating solar technology at airports.	No
9	Airspace penetration	Federal Aviation Administration (2018)	The 2010 version of the primary source could not be located; however, a later version was sourced. Document written to provide technical guidance on evaluating solar technology at airports.	No

Item number	Hazard	Primary source	Comments on applicability to this study	Applicable to this study
10	Aircraft strikes debris on the airfield	Federal Aviation Administration (2018)	The 2010 version of the primary source could not be located; however, a later version was sourced. Document written to provide technical guidance on evaluating solar technology at airports.	No
11	Aircraft evacuation difficulties	Federal Aviation Administration (2018)	The 2010 version of the primary source could not be located; however, a later version was sourced. Document written to provide technical guidance on evaluating solar technology at airports.	No
12	Aircraft rescuing difficulty	Federal Aviation Administration (2018)	The 2010 version of the primary source could not be located; however, a later version was sourced. Document written to provide technical guidance on evaluating solar technology at airports.	No
Natural hazards				
13	Lightning	The referenced source was for a thesis which was unable to be	The source located included the impact of lightning strikes in general and was considered reasonable to include	Yes

Item number	Hazard	Primary source	Comments on applicability to this study	Applicable to this study
		located. A conference paper with the same author included lightning studies with similar title: Peppas et al. (2012)		
14	Strong winds	Not located	The primary source was a website for Allianz and an industry product catalogue. Source to hazard unable to be located and, as such, was not considered reasonable to include at this stage.	No
15	Dust	Not located	The primary source was a website for Allianz and an industry product catalogue. Source to hazard unable to be located and, as such, was not considered reasonable to include at this stage.	No
16	Heat	Located one of the referenced sources: United States Department of Labor (n.d.-d).	The source was found to be a guide to the United States Occupational Safety and Health Act (OSH Act).	Yes

Item number	Hazard	Primary source	Comments on applicability to this study	Applicable to this study
17	Hail	Not located	The primary source was a website for Allianz and an industry product catalogue. Source to hazard unable to be located and, as such, was not considered reasonable to include at this stage.	No
18	Moisture	Not located	The primary source was a website for Allianz and an industry product catalogue. Source to hazard unable to be located and, as such, was not considered reasonable to include at this stage.	No
19	Rodents	Shumake et al. (2000)	The source located included the impact of rodents gnawing on power cables in general and was considered reasonable to include	Yes
20	Birds in aircraft engines	Not located	The primary source was a website for Allianz and an industry product catalogue. Source to hazard unable to be located.	No
21	Flora and allergies	Not located	The primary source was a website for Allianz and an industry product catalogue. Source to hazard unable to be located and, as such,	No

Item number	Hazard	Primary source	Comments on applicability to this study	Applicable to this study
			was not considered reasonable to include at this stage.	
22	Venomous bites and stings	Not located	The primary source was a website for Allianz and an industry product catalogue. Source to hazard unable to be located and, as such, was not considered reasonable to include at this stage.	No
Human-made hazards				
23	Vandalism, damage, sabotage, and theft	The referenced source was for a thesis which was unable to be located. A conference paper with the same author included lightning studies with similar title: Peppas et al. (2012)	The source located included the impact of lightning strikes in general and nil on the noted hazard and, as such, was not considered reasonable to include at this stage.	No

APPENDIX B: Risk assessment of a solar PV power plant

A health, safety, environmental, and community (HSEC) risk assessment was compiled in a case study of a 100 MW grid-connected utility-scale solar PV power plant in Australia by Guerin (2017). The assessment covered the construction and operational stages of the power plant (Guerin, 2017). The in-service operational risks to health and safety have been extracted from the HSEC risk assessment and summarised below.

1. Lightning strike
2. Static discharge of electricity
3. Electricity from general electrical tooling
4. Electricity from supply systems
5. Electricity from underground cables
6. Fire
7. Dangerous flora and fauna
8. Psychological stress
9. Hazardous manual tasks
10. Hazardous chemicals
11. Non-ionising radiation
12. Hot work
13. Heat stress
14. Community violence or intimidation
15. Cuts and pinches from hand tools
16. Poor quality drinking water
17. Herbicides
18. Moving parts of vehicle, plant or equipment
19. Falling from heights
20. Slip, trips and falls
21. Struck by mobile plant
22. Dust or airborne particulate (inhalation)
23. Uncontrolled release of projectiles or materials

- 24. Worker fatigue and fitness to work
- 25. Working under the influence of intoxicating drugs or alcohol
- 26. Unauthorised site access
- 27. Collision between any mobile plant or vehicles on site
- 28. Collision between any fixed structure and mobile plant or vehicles on site
- 29. Collapse of excavation works

APPENDIX C: Hazards at wind power plants

Summary of hazards to health and safety emanating from in-service wind power plants (Brouwer et al., 2018; Karanikas et al., 2021; Olabi et al., 2021; Palmer, 2018; Scotland Against Spin, 2023; Webster et al., 2013).

Item	Hazard	Impact on public		Impact on worker		Source literature					
		Health	Safety	Health	Safety	(Webster et al., 2013)	(Karanikas et al., 2021)	(Brouwer et al., 2018)	(Palmer, 2018)	(Olabi et al., 2021)	Within Scotland Against Spin (2023)
1	Blade failure		✓		✓	✓		✓	✓	✓	✓
2	Tower failure or collapse		✓		✓	✓		✓	✓	✓	✓
3	Nacelle failure				✓			✓			
4	Nacelle fire		✓		✓	✓			✓		✓
5	Tower strike					✓					
6	Lightning strike				✓	✓		✓			✓
7	Ice throw					✓			✓		✓
8	Working at heights: Falls				✓	✓					✓
9	Working with electricity: Electrocution				✓	✓					✓

Item	Hazard	Impact on public		Impact on worker		Source literature					
		Health	Safety	Health	Safety	(Webster et al., 2013)	(Karanikas et al., 2021)	(Brouwer et al., 2018)	(Palmer, 2018)	(Olabi et al., 2021)	Within Scotland Against Spin (2023)
10	Working in confined spaces				✓	✓					
11	Working with moving/ rotating equipment				✓	✓					✓
12	Working with hot parts: Burns				✓	✓					✓
13	Extreme weather			✓	✓	✓	✓				
14	Fatigue: Musculoskeletal disorders			✓	✓	✓	✓				✓
15	Inhalation hazards: Chemicals/ gases			✓	✓	✓	✓				✓
16	Noise			✓		✓	✓				✓
17	Vibration			✓			✓				✓
18	Electromagnetic fields			✓		✓	✓				
19	Biological hazards			✓			✓				

Item	Hazard	Impact on public		Impact on worker		Source literature					
		Health	Safety	Health	Safety	(Webster et al., 2013)	(Karanikas et al., 2021)	(Brouwer et al., 2018)	(Palmer, 2018)	(Olabi et al., 2021)	Within Scotland Against Spin (2023)
20	Envenomation hazards			✓			✓				
21	Shadow flicker	✓		✓		✓	✓				✓

APPENDIX D: Sections of the USA OHS Act of 1970

Listed summary of the 34 section titles from the USA's "Occupational Health, and Safety Act of 1970" (US OSH Act of 1970).

Section	Title
1	Introduction
2	Congressional findings and purpose
3	Definitions
4	Applicability of this Act
5	Duties
6	Occupational safety and health standards
7	Advisory committees; administration
8	Inspections, investigation, and recordkeeping
9	Citations
10	Procedure for enforcement
11	Judicial review
12	The occupational safety and health review commission
13	Procedures to counteract imminent dangers
14	Representation in civil litigation
15	Confidentiality of trade secrets
16	Variations, tolerances, and exemptions
17	Penalties
18	State jurisdiction and state plans
19	Federal agency safety programs and responsibilities

Section	Title
20	Research and related activities
21	Training and employee education
22	National Institute for occupational safety and health
23	Grants to the state
24	Statistics
25	Audits
26	Annual report
27	National Commission on State workmen's compensation laws
28	Economic assistance to small businesses
29	Additional assistant secretary of labor
30	Additional positions
31	Emergency locator beacons
32	Separability
33	Appropriations
34	Effective date

APPENDIX E: Sections of the General Industry Standard

Listed summary from the USA's, OSHA's General Industry Standard, number 1910 with its 26 subparts listed A to Z (United States Department of Labor, n.d.-c).

Subpart	Title
A	General
B	Adoption and extension of established federal standards
C	Reserved
D	Walking, working surfaces
E	Exit routes and emergency planning
F	Powered platforms, manlifts, and vehicle-mounted work platforms
G	Occupational health and environmental control
H	Hazardous materials
I	Personal protective equipment
J	General environmental controls
K	Medical and first aid
L	Fire protection
M	Compressed gas and compressed air equipment
N	Materials handling and storage
O	Machinery and machine guarding
P	Hand and portable powered tools and other hand-held equipment
Q	Welding, cutting and brazing
R	Special industries:

Subpart	Title
	1910.261: Pulp, paper, and paperboard mills 1910.262: Textiles 1910.263: Bakery equipment 1910.264: Laundry machinery and operations 1910.265: Sawmills 1910.266: Logging operations 1910.268: Telecommunications 1910.269: Electric power generation, transmission, and distribution 1910.272: Grain handling facilities
S	Electrical
T	Commercial diving operations
U	COVID-19
V-Y	Reserved
Z	Toxic and hazardous substances

APPENDIX F: Sections of the South African OHS Act

Listed summary of the 50 sections within South Africa's Occupational Health and Safety Act Number 85 of 1993 (Republic of South Africa, 1993).

Section	Title
1	Definitions
2	Establishment of advisory council for occupational health and safety
3	Functions of council
4	Constitution of council
5	Period of office and remuneration of members of council
6	Establishment of technical committees of council
7	Health and safety policy
8	General duties of employers to their employees
9	General duties of employers and self-employed persons to persons other than their employees
10	General duties of manufacturers and others regarding articles and substances for use at work
11	Listed work
12	General duties of employers regarding listed work
13	Duty to inform
14	General duties of employees at work
15	Duty not to interfere with, damage or misuse things
16	Chief executive officer charged with certain duties
17	Health and safety representatives
18	Functions of health and safety representatives

Section	Title
19	Health and safety committees
20	Functions of health and safety committees
21	General prohibitions
22	Sale of certain articles prohibited
23	Certain deductions prohibited
24	Report to inspector regarding certain incidents
25	Report to chief inspector regarding occupational disease
26	Victimization forbidden
27	Designation and functions of chief inspector
28	Designation of inspectors by Minister
29	Functions of inspectors
30	Special powers of inspectors
31	Investigations
32	Formal inquiries
33	Joint inquiries
34	Obstruction of investigation or inquiry or presiding inspector or failure to render assistance
35	Appeal against decision of inspector
36	Disclosure of information
37	Acts or omissions by employees or mandataries
38	Offences, penalties and special orders of court
39	Proof of certain facts
40	Exemptions

Section	Title
41	This Act not affected by agreements
42	Delegation and assignment of functions
43	Regulations
44	Incorporation of health and safety standards in regulations
45	Serving of notices
46	Jurisdiction of magistrates' courts
47	State bound
48	Conflict of provisions
49	Repeal of laws
50	Short title and commencement

APPENDIX G: Regulations supporting the OHS Act

Listed summary of the 23 Regulations that support the intention of the South African Occupational Health and Safety Act Number 85 of 1993 and an indication of the Regulations that are applicable to in-service, grid connected, utility-scale solar PV, CSP and wind power plants (Republic of South Africa, 1993).

Category	Title	Applicability to RE power plants
General	General administrative Regulations	Yes
	General safety Regulations	Yes
	Major hazard installation Regulations	No
	Regulations for hazardous biological agents	No
	Explosives Regulations	No
	Construction Regulations	No
	Regulations on hazardous work by children in South Africa	No
Health	Asbestos Regulations	No
	Diving Regulations	No
	Environmental Regulations for workplaces	Yes
	Facilities Regulations	Yes
	Regulations for hazardous chemical agents	Yes
	Lead Regulations	No
	Noise-induced hearing loss Regulations	Yes
	Incorporation of health and safety standard in terms of section 44 (1) of the Act: Driven machinery Regulations 18 (11)	No
	Ergonomics Regulations, 2018	Yes

Category	Title	Applicability to RE power plants
Mechanical	Driven machinery Regulations, 2015	Yes
	General machinery Regulations	Yes
	Lift, escalator and passenger conveyor Regulations	Yes
	Regulations concerning the certificate of competency	No
	Pressure equipment Regulations	Yes
Electrical	Electrical installation Regulations	Yes
	Electrical machinery Regulations	Yes

APPENDIX H: Solar PV power plants in South Africa

The listed summary of South Africa's operational solar PV power plants has been extracted from the DOEs IPP Unit's database (Independent Power Producers Office, 2023a).

Sequential Number	Technology	Project name	Bid window	Province	Project status
1	PV: Crystalline Fixed	-	3	Northern Cape	Operational
2	PV: Crystalline, single axis	-	4	Northern Cape	Operational
3	PV: Crystalline Fixed	-	1	Northern Cape	Operational
4	PV: Crystalline Fixed	-	2	Western Cape	Operational
5	PV: Crystalline, single axis	-	4	Northern Cape	Operational
6	PV: Crystalline, single axis	-	4	North West	Operational
7	PV: Crystalline, single axis	-	2	Free State	Operational
8	PV: Crystalline, fixed	-	1	Northern Cape	Operational
9	PV: Crystalline, single axis	-	4	North West	Operational
10	PV: Crystalline, single axis	-	2	Eastern Cape	Operational

Sequential Number	Technology	Project name	Bid window	Province	Project status
11	PV: Crystalline, single axis	-	4	Northern Cape	Operational
12	PV: Crystalline, single axis	-	4	Northern Cape	Operational
13	PV: Crystalline, single axis	-	1	Northern Cape	Operational
14	PV: Crystalline, single axis	-	1	Northern Cape	Operational
15	PV: Crystalline, fixed	-	2	Northern Cape	Operational
16	PV: Crystalline, fixed	-	1	Northern Cape	Operational
17	PV: Crystalline, single axis	-	4	Northern Cape	Operational
18	PV: Crystalline, fixed	-	1	Northern Cape	Operational
19	PV: Crystalline, fixed	-	1	Northern Cape	Operational
20	PV: Crystalline, fixed	-	1	Free State	Operational
21	PV: Crystalline, single axis	-	2	Northern Cape	Operational
22	PV: Crystalline, single axis	-	4	Northern Cape	Operational
23	PV: Crystalline, single axis	-	3	Northern Cape	Operational

Sequential Number	Technology	Project name	Bid window	Province	Project status
24	PV: Crystalline, fixed	-	1	Northern Cape	Operational
25	PV: Crystalline, fixed	-	1	Northern Cape	Operational
26	PV: Crystalline, fixed	-	3	Northern Cape	Operational
27	PV: Crystalline, fixed	-	3	Western Cape	Operational
28	PV: Thin film, fixed	-	3	Free State	Operational
29	PV: Crystalline, single axis	-	1	Northern Cape	Operational
30	PV: Crystalline, fixed	-	1	North West	Operational
31	PV: Crystalline, fixed	-	1	Northern Cape	Operational
32	PV: Crystalline, single axis	-	4	Northern Cape	Operational
33	PV: Crystalline, single axis	-	2	Northern Cape	Operational
34	PV: Crystalline, fixed	-	1	Western Cape	Operational
35	PV: Thin film, fixed	-	1	Northern Cape	Operational
36	PV: Thin film, fixed	-	2	Northern Cape	Operational
37	PV: Crystalline, single axis	-	1	Limpopo	Operational

Sequential Number	Technology	Project name	Bid window	Province	Project status
38	PV: Thin film, fixed	-	3	Limpopo	Operational
39	PV: Crystalline, dual axis	-	1	Western Cape	Operational
40	PV: Thin film, fixed	-	2	Northern Cape	Operational
41	PV: Crystalline, fixed	-	2	Western Cape	Operational
42	PV: Crystalline, single axis	-	4	North West	Operational
43	PV: Crystalline, single axis	-	1	Limpopo	Operational
44	PV: Crystalline, single axis	-	4	North West	Operational

APPENDIX I: Solar CSP plants in South Africa

The listed summary of South Africa's operational solar CSP power plants has been extracted from the DOE's IPP Unit's database (Independent Power Producers Office, 2023a).

Sequential Number	Technology	Project name	Bid window	Province	Project status
1	CSP	-	3	Northern Cape	Operational
2	CSP	-	2	Northern Cape	Operational
3	CSP	-	3	Northern Cape	Operational
4	CSP	-	3.5	Northern Cape	Operational
5	CSP	-	1	Northern Cape	Operational
6	CSP	-	1	Northern Cape	Operational

APPENDIX J: Wind power plants in South Africa

The listed summary of South Africa's operational wind power plants has been extracted from the DOE's IPP Unit's database (Independent Power Producers Office, 2023a).

Sequential Number	Technology	Project name	Bid window	Province	Project status
1	Wind	-	2	Eastern Cape	Operational
2	Wind	-	2	Western Cape	Operational
3	Wind	-	2	Eastern Cape	Operational
4	Wind	-	1	Eastern Cape	Operational
5	Wind	-	4	Northern Cape	Operational
6	Wind	-	1	Western Cape	Operational
7	Wind	-	1	Eastern Cape	Operational
8	Wind	-	4	Western Cape	Operational
9	Wind	-	4	Northern Cape	Operational
10	Wind	-	4	Eastern Cape	Operational
11	Wind	-	2	Western Cape	Operational
12	Wind	-	2	Eastern Cape	Operational
13	Wind	-	1	Eastern Cape	Operational
14	Wind	-	4	Northern Cape	Operational
15	Wind	-	3	Northern Cape	Operational

Sequential Number	Technology	Project name	Bid window	Province	Project status
16	Wind	-	1	Eastern Cape	Operational
17	Wind	-	3	Northern Cape	Operational
18	Wind	-	3	Northern Cape	Operational
19	Wind	-	3	Northern Cape	Operational
20	Wind	-	1	Eastern Cape	Operational
21	Wind	-	1	Northern Cape	Operational
22	Wind	-	3	Eastern Cape	Operational
23	Wind	-	3	Northern Cape	Operational
24	Wind	-	4	Eastern Cape	Operational
25	Wind	-	4	Eastern Cape	Operational
26	Wind	-	4	Western Cape	Operational
27	Wind	-	3	Eastern Cape	Operational
28	Wind	-	4	Northern Cape	Operational
29	Wind	-	4	Northern Cape	Operational
30	Wind	-	2	Eastern Cape	Operational
31	Wind	-	1	Western Cape	Operational
32	Wind	-	2	Eastern Cape	Operational
33	Wind	-	4	Eastern Cape	Operational

APPENDIX K: Interview guide

Interview guide to be used in the semi-structured interviews. Where extensive texts and repetition are provided, these were not re-read and were only included as a guide to use as required during the interviews.

INTERVIEW GUIDE CONTENTS PAGE

Section 1: Opening and formalities

- 1.1 Greeting.
- 1.2 Complete brief introductions.
- 1.3 Build rapport / break the ice.
- 1.4 Confirmation of cover letter received and understood.
- 1.5 Items to be reiterated from the cover letter.
- 1.6 Confirm receipt of the endorsed consent form

Section 2: Face sheet information

Consisting of 12 questions

Section 3: Addressing the first proposition

This section consists of ten questions addressing research objective number 1.

Section 4: Addressing the second proposition:

This section consists of ten questions addressing research objective number 2.

Section 5: Final closure and thanks

Section 1

Opening and formalities

1.1 Greeting

Good morning/afternoon.

1.2 Complete some brief introductions

My name is Mark Sloan, and I am a master's student studying at the University of the Witwatersrand.

1.3 Build rapport / break the ice

Discuss possible current items such as the news, weather, load-shedding, touch on the cover letter to ensure clarity of understanding, casual discussion as appropriate, etc.

Thank them for taking the call and for agreeing to be interviewed.

1.4 Confirm cover letter received and understood

Confirm that the cover letter was received and understood.

Ask if there are any questions or read if it was not received.

1.5 Items to be reiterated from the cover letter

Reiterate that privacy will be respected and ensured through anonymity.

Reiterate that confidentiality of all data collected will be ensured through storage on a password-protected computer and will not be disclosed to any third party. All information will be destroyed five years after the conclusion of the report.

Reiterate the scope as per the table below.

Included within the study	Excluded from the study
Utility-scale RE power plants	Design and manufacturing
RE Technologies covering solar PV, CSP and wind	Construction, erection, and commissioning
RE Power plants supplying electricity to the South African national grid	Offshore technologies
In-service RE power plants operating under normal conditions covering routine maintenance and inspection activities	Other legislation not directly linked to the scope
OHS Act and its Regulations	Boundary limit: Supply point to the national grid's substation

1.6 Confirm receipt of the consent form and respect for the options selected

Section 2

Face sheet information

1. Name and Surname.
2. Appointment (Position / Title): GMR2.1 / Health and Safety Representative / Management:
 - ❖ GMR 2.1 competent person:
 - Type a: Served an apprenticeship and five years of experience.
 - Type b: Engineering diploma and two years of experience.
 - Type c: A graduate engineer who passed the OHS Act and Regulations exam and has two years of experience.
 - Type d: Certificated engineer.
 - ❖ Health and safety representative:
 - Nil drill down necessary
 - ❖ Management/supervision:
 - Minimum one year in the position.
3. Highest qualification (Diploma, degree, GCC).
4. Duration of employment at the current power plant (Years and months).
5. Previous experience:
 - ❖ Industry: Include to determine relevance.
 - ❖ Position: Include to determine relevance.
 - ❖ Duration: Years and months.
6. Name of employer.
7. Name of power plant.
8. Location of power plant.
9. Year of power plant commissioning.
10. Location of your regular employment.
11. Capacity of power plant.
12. Technology type: Solar PV, CSP or Wind (Refer below for options):
 - ❖ Solar PV options:
 - PV Mounting: Fixed or tracking and single-axis or dual-axis.
 - PV technology: crystalline or thin film.

- Number of panels used.
- Spatial footprint.
- Other: Anything of interest to volunteer.

❖ CSP options:

- Differentiate based on the method of focusing the concentrated solar radiation on a central receiver or linear absorber tubes:
- Point-focusing systems consist of solar power towers (SPT) and parabolic dish collectors (PDC).
- Linear focusing systems consist of parabolic trough collectors (PTC) and linear Fresnel collectors (LFR).
- Heat transfer fluid: synthetic thermal oils, organic oils, molten salts, water, air, and gases.
- Thermal energy storage: “Yes” or “No” and duration.
- Number of reflectors used.
- Spatial footprint.
- Other: Anything of interest to volunteer.

❖ Wind options:

- Number of towers/turbines.
- Turbine capacity.
- Tower construction: concrete or steel (tubular or lattice).
- Hub height.
- Number of blades.
- Blade length.
- Spatial footprint.
- Other: Anything of interest to volunteer.

Section 3

The final two sections of the interview each address one of the study's objectives. The framework for each of these sections is the same and is based on the hazards to health and safety as encountered in the literature. As there was no consolidated data on hazards to health and safety for CSP power plants within the literature, potential failures, failure modes and best practices included, have been considered potential hazards. A consolidated list of these hazards to health and safety was created, and five main categories appeared. These categories are biological, chemical, physical and safety, ergonomic, and psychological. The physical and safety hazards category includes six sub-categories: electricity, natural environmental elements, operational, mobile plant and vehicles, failures, and external human risks. These represent a total of ten topics of questioning that form the framework of ten questions. So, there will be ten questions for the first and another ten for the second objective. One closed-ended question will be asked per topic. Each question will be followed by open-ended questioning when negative responses are received, or further information is volunteered.

Now, let us proceed with the ten questions for the first objective.

Objective number 1: Identify health and safety hazards unique to in-service, grid-connected, utility-scale solar PV, CSP and wind power plants.

Question 1

Topic: Biological hazards that may negatively impact health.

Listed hazards identified within the literature:

1. Dangerous flora (plants)
2. Dangerous fauna (animals)
3. Dangerous insects
4. Envenomation
5. Vermin
6. Mould
7. Sewage
8. Dust or airborne particulate

Question 1: In your opinion and experience (within the scope of the study):

Does the above list cover the topic of biological hazards encountered at your RE power plant? (“Yes” or “No”).

When the response is “No,” then request the respondent to describe their experience for me to understand the hazard.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Conclude by asking if the hazard is unique to their plant or the technology type and not encountered in other industries while the plant is under normal operating conditions.

.

Question 2

Topic: Chemical hazards that may negatively impact health, corrode materials, and react violently.

Listed hazards identified within the literature:

1. Hazardous chemicals
2. Inhalation hazards: Chemicals/gases
3. Harmful gases (E.g., nitrous oxides from molten salt used as a TES medium)
4. Herbicides

Question 2: In your opinion and experience (within the scope of the study):

Does the above list cover the topic of chemical hazards encountered at your RE power plant? (“Yes” or “No”).

When the response is “No,” then request the respondent to describe their experience for me to understand the hazard.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Conclude by asking if the hazard is unique to their plant or the technology type and not encountered in other industries while the plant is under normal operating conditions.

Question 3

Topic: Physical and safety hazards, sub-category: Electricity

The physical and safety hazards have been grouped as they were considered to have some commonality. Typically, physical hazards represent those that may negatively impact a person without any direct connection, such as noise. Safety hazards result in an unsafe environment, such as poor housekeeping, which may result in trips or falls. This category included many hazards, which were divided into six sub-categories for ease of understanding. Each sub-category will represent a topic for questioning and consist of electricity, natural environmental elements, operational, mobile plant and vehicles, failures, and external human risks.

Listed hazards identified within the literature:

1. Electrocution
2. Working with electricity
3. Static discharge of electricity
4. Electric shock from general electrical tooling
5. Electric shock/electrocution from systems
6. Electric shock/electrocution from underground cables

Question 3: In your opinion and experience (within the scope of the study):

Does the above list cover the hazards to people's health and safety from electricity within your RE power plant's physical and safety category? ("Yes" or "No").

When the response is "No," then request the respondent to describe their experience for me to understand the hazard.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Conclude by asking if the hazard is unique to their plant or the technology type and not encountered in other industries while the plant is under normal operating conditions.

Question 4

Topic: Physical and safety hazards, sub-category: Natural environmental elements

Listed hazards identified within the literature:

1. Lightning
2. Extreme weather events
3. High winds
4. Heat and heat stress
5. Dangerous flora and fauna
6. Tower strike
7. Poor quality drinking water
8. Ice throw

Question 4: In your opinion and experience (within the scope of the study):

Does the above list cover the hazards to people's health and safety from natural environmental elements within your RE power plant's physical and safety category? ("Yes" or "No").

When the response is "No," then request the respondent to describe their experience for me to understand the hazard.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Conclude by asking if the hazard is unique to their plant or the technology type and not encountered in other industries while the plant is under normal operating conditions.

Question 5

Topic: Physical and safety hazards, sub-category: Operational

Listed hazards identified within the literature:

1. Working at heights: Falls
2. Slip, trips and falls
3. Cuts and pinches from hand tools
4. Hot work: Burns
5. Working in confined spaces
6. Working with moving/rotating equipment
7. Noise
8. Vibration
9. Electromagnetic fields
10. Fire
11. Harmful gases
12. High-temperature exposures
13. Non-ionising radiation
14. Shadow flicker
15. Working under the influence of intoxicating drugs or alcohol

Question 5: In your opinion and experience (within the scope of the study):

Does the above list cover the operational hazards to people's health and safety within your RE power plant's physical and safety category? (Yes or "No").

When the response is "No," then request the respondent to describe their experience for me to understand the hazard.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Conclude by asking if the hazard is unique to their plant or the technology type and not encountered in other industries while the plant is under normal operating conditions.

Question 6

Topic: Physical and safety hazards, sub-category: Mobile plant and vehicles

Listed hazards identified within the literature:

1. Moving parts of vehicle, plant or equipment
2. Struck by mobile plant
3. Collision between any mobile plant or vehicles on site
4. Collision between any fixed structure and mobile plant or vehicles on site

Question 6: In your opinion and experience (within the scope of the study):

Does the above list cover the hazards to people's health and safety from mobile plant and vehicles within the physical and safety category at your RE power plant? ("Yes" or "No").

When the response is "No," then request the respondent to describe their experience for me to understand the hazard.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Conclude by asking if the hazard is unique to their plant or the technology type and not encountered in other industries while the plant is under normal operating conditions.

Question 7

Topic: Physical and safety hazards, sub-category: Failures

Listed hazards identified within the literature:

1. Uncontrolled release of projectiles or materials or media under pressure
2. Blade failure
3. Tower failure or collapse
4. Nacelle failure (fire)
5. Tower strike
6. Equipment degradation due to high-temperature exposure (resulting in thermomechanical fatigue, creep, corrosion, stress corrosion cracking, cracking, fatigue, overheating, etc.)
7. Failure of mechanical equipment: Heat exchangers, steam generators, pumps, valves, pump seals, piping, piping supports, collector ball/rotary joints, flexible hoses, structural failures, etc.
8. Failure of CSP equipment: Absorber tubes, receivers, central tower structures, piping, Hot salt tank leaks, Salt freezing, HTF degradation, etc
9. Material loss due to the corrosive nature of molten salts at elevated temperatures
10. Heliostat misalignment
11. Collapse of excavation works

Question 7: In your opinion and experience (within the scope of the study):

Does the above list cover the hazards to people's health and safety from failures within your RE power plant's physical and safety category? ("Yes" or "No").

When the response is "No," then request the respondent to describe their experience for me to understand the hazard.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Conclude by asking if the hazard is unique to their plant or the technology type and not encountered in other industries while the plant is under normal operating conditions.

Question 8

Topic: Physical and safety hazards, sub-category: External human risks

Listed hazards identified within the literature:

1. Community violence or intimidation
2. Unauthorised site access

Question 8: In your opinion and experience (within the scope of the study):

Does the above list cover the hazards to people's health and safety from external human risks within your RE power plant's physical and safety category? ("Yes" or "No").

When the response is "No," then request the respondent to describe their experience for me to understand the hazard.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Conclude by asking if the hazard is unique to their plant or the technology type and not encountered in other industries while the plant is under normal operating conditions.

Question 9

Topic: Ergonomic hazards that may negatively impact human health and well-being by causing injury to the musculoskeletal system.

Listed hazards identified within the literature:

1. Hazardous manual tasks
2. Worker fatigue and fitness to work
3. Fatigue: Musculoskeletal disorders

Question 9: In your opinion and experience (within the scope of the study):

Does the above list cover the topic of ergonomic hazards to people's health and safety at your RE power plant? ("Yes" or "No").

When the response is "No," then request the respondent to describe their experience for me to understand the hazard.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Conclude by asking if the hazard is unique to their plant or the technology type and not encountered in other industries while the plant is under normal operating conditions.

Question 10

Topic: Psychological hazards that may negatively impact human health and well-being.

Listed hazards identified within the literature:

1. Psychological stress
2. Heat stress
3. Worker fatigue and fitness to work
4. Working under the influence of intoxicating drugs or alcohol
5. Shadow flicker

Question 10: In your opinion and experience (within the scope of the study):

Does the above list cover the topic of psychological hazards to people's health and safety at your RE power plant? ("Yes" or "No").

When the response is "No," then request the respondent to describe their experience for me to understand the hazard.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Conclude by asking if the hazard is unique to their plant or the technology type and not encountered in other industries while the plant is under normal operating conditions.

Section 4

We have only ten questions remaining, so let us proceed with these that address the second and final objective.

Objective number 2: Evaluate the suitability of the South African OHS Act and its Regulations to appropriately support the management of people from hazards to health and safety within utility-scale, in-service, solar PV, CSP and wind power plants supplying electricity to the South African national grid.

Question 1

Topic: Biological hazards that may negatively impact health.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
<p>Listed hazards identified within the literature:</p> <ol style="list-style-type: none">1. Dangerous flora (plants)2. Dangerous fauna (animals)3. Dangerous insects4. Envenomation5. Vermin6. Mould7. Sewage8. Dust or airborne particulate	<p>The OHS Act:</p> <ul style="list-style-type: none">❖ Sections 2, 3, 4 and 6: Establishment of an advisory council for occupational health and safety, functions, and constitution and technical committees.❖ Section 8: General duties of employers to their employees.❖ Section 9: General duties of employers and self-employed persons to persons other than their employees.❖ Section 13: Duty to inform.❖ Section 14: General duties of employees at work.❖ Section 16: Chief executive officer charged with certain duties.❖ Sections 17, 18, 19, and 20: Health and safety representatives and committees and their functions.❖ Section 24: Report to inspector regarding certain incidents.❖ Sections 29, 30, 31 and 32: Inspectors, functions, powers, investigations and formal inquiries.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<ul style="list-style-type: none"> ❖ Section 38: Offences, penalties, and special orders of court. ❖ Section 43: Regulations. ❖ Section 44: Incorporation of health and safety standards in Regulations. <p>Regulations for Hazardous Biological Agents</p> <ul style="list-style-type: none"> ❖ Section 4: Information and training. ❖ Section 6: Risk assessment by employer. ❖ Sections 7, 8, 11, and 14: Monitoring exposure, medical surveillance, PPE, labelling etc. <p>General Administrative Regulations:</p> <ul style="list-style-type: none"> ❖ Section 8: Reporting of incidents and occupational diseases. <p>General Safety Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Personal safety equipment and facilities. ❖ Section 3: First aid, emergency equipment and procedures. ❖ Section 5: Work in confined spaces. <p>Environmental Regulations:</p> <ul style="list-style-type: none"> ❖ Section 5: Ventilation. <p>Facilities Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Sanitation.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	General Machinery Regulations: ❖ Section 2: Supervision of machinery.

Question 1: In your opinion and experience (within the scope of the study):

Does the OHS Act and its Regulations appropriately support the management of people from hazards to health and safety at the RE power plant at which you are employed, for the said topic, while the plant is under normal operating conditions? Consider the listed hazards and potentially applicable OHS Act sections and Regulations identified above. (“Yes” or “No”).

When the response is “No,” then request the respondent to describe their experience for me to understand the shortcomings.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Question 2

Topic: Chemical hazards that may negatively impact health, corrode materials, and react violently.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
<p>Listed hazards identified within the literature:</p> <ol style="list-style-type: none">1. Hazardous chemicals2. Inhalation hazards: Chemicals/gases3. Harmful gases (E.g., nitrous oxides from molten salt used as a TES medium)4. Herbicides	<p>The OHS Act:</p> <ul style="list-style-type: none">❖ Sections 2, 3, 4, and 6: Establishment of advisory council for occupational health and safety, functions, and constitution and technical committees.❖ Section 8: General duties of employers to their employees.❖ Section 9: General duties of employers and self-employed persons to persons other than their employees.❖ Section 13: Duty to inform.❖ Section 14: General duties of employees at work.❖ Section 16: Chief executive officer charged with certain duties.❖ Sections 17, 18, 19, and 20: Health and safety representatives and committees and their functions.❖ Section 24: Report to inspector regarding certain incidents.❖ Sections 29, 30, 31, and 32: Inspectors, functions, powers, investigations and formal inquiries.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<ul style="list-style-type: none"> ❖ Section 38: Offences, penalties, and special orders of court. ❖ Section 43: Regulations. ❖ Section 44: Incorporation of health and safety standards in Regulations. <p>General Administrative Regulations:</p> <ul style="list-style-type: none"> ❖ Section 8: Reporting of incidents and occupational diseases. <p>General Safety Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Personal safety equipment and facilities. ❖ Section 3: First aid, emergency equipment and procedures. ❖ Section 4: Use and storage of flammable liquids. ❖ Section 5: Work in confined spaces. <p>Environmental Regulations:</p> <ul style="list-style-type: none"> ❖ Section 5: Ventilation. <p>Regulations for Hazardous Chemical Agents (HCA):</p> <ul style="list-style-type: none"> ❖ Section 3: Information and training. ❖ Section 4: Duties of persons who may be exposed to HCA. ❖ Section 5: Assessment of potential exposure. ❖ Section 6: Air monitoring. ❖ Section 8: Respirator zone.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<ul style="list-style-type: none"> ❖ Section 9: Records and handling of HCA. ❖ Section 10: Control of exposure to HCA. ❖ Section 11: Personal protective equipment and facilities. ❖ Section 12: Maintenance of control measures. ❖ Section 14: Labelling, packaging, transportation and storage. ❖ Section 15: Disposal of HCA ❖ Annex 1: HCA Guidelines. ❖ Table 1 and 2: Occupational exposure limits, control and recommended limits for HCA. <p>General Machinery Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Supervision of machinery.

Question 2: In your opinion and experience (within the scope of the study):

Does the OHS Act and its Regulations appropriately support the management of people from hazards to health and safety at the RE power plant at which you are employed, for the said topic, while the plant is under normal operating conditions? Consider the listed hazards and potentially applicable OHS Act sections and Regulations identified above. (“Yes” or “No”).

When the response is “No,” then request the respondent to describe their experience for me to understand the shortcomings.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Question 3

Topic: Physical and safety hazards, sub-category: Electricity

The physical and safety hazards have been grouped as they were considered to have some commonality. Typically, physical hazards represent those that may negatively impact a person without any direct connection, such as noise. Safety hazards result in an unsafe environment, such as poor housekeeping, which may result in trips or falls. This category included many hazards, which were divided into six sub-categories for ease of understanding. Each sub-category will represent a topic for questioning and consist of electricity, natural environmental elements, operational, mobile plant and vehicles, failures, and external human risks.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
<p>Listed hazards identified within the literature:</p> <ol style="list-style-type: none">1. Electrocution2. Working with electricity3. Static discharge of electricity4. Electric shock from general electrical tooling5. Electric shock/electrocution from systems6. Electric shock/electrocution from underground cables	<p>The OHS Act:</p> <ul style="list-style-type: none">❖ Sections 2, 3, 4, and 6: Establishment of advisory council for occupational health and safety, functions, and constitution and technical committees.❖ Section 8: General duties of employers to their employees.❖ Section 9: General duties of employers and self-employed persons to persons other than their employees.❖ Section 13: Duty to inform.❖ Section 14: General duties of employees at work.❖ Section 16: Chief executive officer charged with certain duties.❖ Sections 17, 18, 19, and 20: Health and safety

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<p>representatives and committees and their functions.</p> <ul style="list-style-type: none"> ❖ Section 24: Report to inspector regarding certain incidents. ❖ Sections 29, 30, 31, and 32: Inspectors, functions, powers, investigations and formal inquiries. ❖ Section 38: Offences, penalties, and special orders of court. ❖ Section 43: Regulations. ❖ Section 44: Incorporation of health and safety standards in Regulations. <p>General Administrative Regulations:</p> <ul style="list-style-type: none"> ❖ Section 8: Reporting of incidents and occupational diseases. <p>General Safety Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Personal safety equipment and facilities. ❖ Sections 2A, 2B, 2C: Intoxication, display of substituted notices and signs, and admittance of persons. <p>General Machinery Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Supervision of machinery. ❖ Section 3: Safeguarding of machinery.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<ul style="list-style-type: none"> ❖ Section 4: Operation of machinery. <p>Electrical Installation Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Responsibility for electrical installations. ❖ Section 5: Design and construction. ❖ Sections 7 and 9: Certificate of compliance and their issuing. <p>Electrical Machinery Regulations:</p> <ul style="list-style-type: none"> ❖ Section 3: Personal protective equipment. ❖ Section 4: Work on disconnected electrical machinery. ❖ Section 5: Notice (to be displayed) ❖ Section 6: Switchgear and transformer premises. ❖ Section 7: Electrical control gear. ❖ Section 8: Switchboards. ❖ Section 10: Portable electric tools. ❖ Section 11: Portable electric lights. ❖ Sections 12 and 13: Electric fences and system certificates. ❖ Section 18: Earthing. ❖ Section 19: Overhead power lines. ❖ Section 20: Service connections.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<ul style="list-style-type: none"> ❖ Section 21: Overhead line crossings. ❖ Section 22: Bare conductors on premises.

Question 3: In your opinion and experience (within the scope of the study):

Does the OHS Act and its Regulations appropriately support the management of people from hazards to health and safety at the RE power plant at which you are employed, for the said topic, while the plant is under normal operating conditions? Consider the listed hazards and potentially applicable OHS Act sections and Regulations identified above. (“Yes” or “No”).

When the response is “No,” then request the respondent to describe their experience for me to understand the shortcomings.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Question 4

Topic: Physical and safety hazards, sub-category: Natural environmental elements

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
<p>Listed hazards identified within the literature:</p> <ol style="list-style-type: none">1. Lightning2. Extreme weather events3. High winds4. Heat and heat stress5. Dangerous flora and fauna6. Tower strike7. Poor quality drinking water8. Ice throw	<p>The OHS Act:</p> <ul style="list-style-type: none">❖ Sections 2, 3, 4, and 6: Establishment of advisory council for occupational health and safety, functions, and constitution and technical committees.❖ Section 8: General duties of employers to their employees.❖ Section 9: General duties of employers and self-employed persons to persons other than their employees.❖ Section 10: General duties of manufacturers and others regarding articles and substances for use at work.❖ Section 13: Duty to inform.❖ Section 14: General duties of employees at work.❖ Section 16: Chief executive officer charged with certain duties.❖ Sections 17, 18, 19, and 20: Health and safety representatives and committees and their functions.❖ Section 24: Report to inspector regarding certain incidents.❖ Section 29, 30, 31 and 32: Inspectors, functions, powers,

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<p>investigations and formal inquiries.</p> <ul style="list-style-type: none"> ❖ Section 38: Offences, penalties, and special orders of court. ❖ Section 43: Regulations. ❖ Section 44: Incorporation of health and safety standards in Regulations. <p>General Administrative Regulations:</p> <ul style="list-style-type: none"> ❖ Section 8: Reporting of incidents and occupational diseases. <p>General Safety Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Personal safety equipment and facilities. ❖ Section 3: First aid, emergency equipment and procedures. <p>Environmental Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Thermal requirements. ❖ Section 5: Ventilation. <p>Facilities Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Sanitation. ❖ Section 7: Drinking water. <p>General Machinery Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Supervision of machinery. ❖ Section 3: Safeguarding of machinery. ❖ Section 7: Reporting of incidents in connection with machinery.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<p>Electrical Installation Regulations:</p> <ol style="list-style-type: none"> 1. Section 2: Responsibility for electrical installations. 2. Section 5: Design and construction. <p>Electrical Machinery Regulations:</p> <ul style="list-style-type: none"> ❖ Section 18: Earthing. ❖ Section 22: Bare conductors on premises.

Question 4: In your opinion and experience (within the scope of the study):

Does the OHS Act and its Regulations appropriately support the management of people from hazards to health and safety at the RE power plant at which you are employed, for the said topic, while the plant is under normal operating conditions? Consider the listed hazards and potentially applicable OHS Act sections and Regulations identified above. (“Yes” or “No”).

When the response is “No,” then request the respondent to describe their experience for me to understand the shortcomings.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Question 5

Topic: Physical and safety hazards, sub-category: Operational

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
<p>Listed hazards identified within the literature:</p> <ol style="list-style-type: none"> 1. Working at heights: Falls 2. Slip, trips and falls 3. Cuts and pinches from hand tools 4. Hot work: Burns 5. Working in confined spaces 6. Working with moving/rotating equipment 7. Noise 8. Vibration 9. Electromagnetic fields 10. Fire 11. Harmful gases 12. High-temperature exposures 13. Non-ionising radiation 14. Shadow flicker 15. Working under the influence of intoxicating drugs or alcohol 	<p>The OHS Act:</p> <ul style="list-style-type: none"> ❖ Sections 2, 3, 4, and 6: Establishment of advisory council for occupational health and safety, functions, and constitution and technical committees. ❖ Section 8: General duties of employers to their employees. ❖ Section 9: General duties of employers and self-employed persons to persons other than their employees. ❖ Section 10: General duties of manufacturers and others regarding articles and substances for use at work. ❖ Section 13: Duty to inform. ❖ Section 14: General duties of employees at work. ❖ Section 16: Chief executive officer charged with certain duties. ❖ Sections 17, 18, 19, and 20: Health and safety representatives and committees and their functions. ❖ Section 24: Report to inspector regarding certain incidents. ❖ Section 29, 30, 31 and 32: Inspectors, functions, powers,

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<p>investigations and formal inquiries.</p> <ul style="list-style-type: none"> ❖ Section 38: Offences, penalties, and special orders of court. ❖ Section 43: Regulations. ❖ Section 44: Incorporation of health and safety standards in Regulations. <p>General Administrative Regulations:</p> <ul style="list-style-type: none"> ❖ Section 8: Reporting of incidents and occupational diseases. <p>General Safety Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Personal safety equipment and facilities. ❖ Sections 2A, 2B, 2C: Intoxication, display of substituted notices and signs, and admittance of persons. ❖ Section 3: First aid, emergency equipment and procedures. ❖ Section 4: Use and storage of flammable liquids. ❖ Section 5: Work in confined spaces. ❖ Section 6: Work in elevated positions. ❖ Section 7: Working in danger of engulfment. ❖ Section 8: Stacking of articles. ❖ Section 9: Welding, flame-cutting, soldering and similar operations.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<ul style="list-style-type: none"> ❖ Section 13A and B: Ladders and ramps. <p>Noise-induced hearing loss Regulations:</p> <ul style="list-style-type: none"> ❖ Section 3: Exposure to noise. ❖ Section 4: Information and training. ❖ Section 5: Duties of persons who may be exposed to noise. ❖ Section 6: Assessment of potential noise exposure. ❖ Section 7: Noise monitoring. ❖ Section 9: Noise zone. ❖ Section 10: Control of noise exposure. ❖ Section 12: Hearing protective equipment <p>Driven Machinery Regulations:</p> <ul style="list-style-type: none"> ❖ Section 3: Revolving machinery. ❖ Sections 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15: Various types of driven machinery. ❖ Section 18: Lifting machines, hand-powered lifting devices and lifting tackle. <p>General Machinery Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Supervision of machinery. ❖ Section 3: Safeguarding of machinery. ❖ Section 4: Operation of machinery.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<ul style="list-style-type: none"> ❖ Section 5: Working on moving or electrically alive machinery. <p>Lift, Escalator and Passenger Conveyor Regulations:</p> <ul style="list-style-type: none"> ❖ Section 6: Inspection and test. ❖ Section 7: Maintenance.

Question 5: In your opinion and experience (within the scope of the study):

Does the OHS Act and its Regulations appropriately support the management of people from hazards to health and safety at the RE power plant at which you are employed, for the said topic, while the plant is under normal operating conditions? Consider the listed hazards and potentially applicable OHS Act sections and Regulations identified above. (“Yes” or “No”).

When the response is “No,” then request the respondent to describe their experience for me to understand the shortcomings.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Question 6

Topic: Physical and safety hazards, sub-category: Mobile plant and vehicles

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
<p>Listed hazards identified within the literature:</p> <ol style="list-style-type: none"> 1. Moving parts of vehicle, plant or equipment 2. Struck by mobile plant 3. Collision between any mobile plant or vehicles on site 4. Collision between any fixed structure and mobile plant or vehicles on site 	<p>The OHS Act:</p> <ul style="list-style-type: none"> ❖ Sections 2, 3, 4, and 6: Establishment of advisory council for occupational health and safety, functions, and constitution and technical committees. ❖ Section 8: General duties of employers to their employees. ❖ Section 9: General duties of employers and self-employed persons to persons other than their employees. ❖ Section 10: General duties of manufacturers and others regarding articles and substances for use at work. ❖ Section 13: Duty to inform. ❖ Section 14: General duties of employees at work. ❖ Section 16: Chief executive officer charged with certain duties. ❖ Sections 17, 18, 19, and 20: Health and safety representatives and committees and their functions. ❖ Section 24: Report to inspector regarding certain incidents. ❖ Section 29, 30, 31 and 32: Inspectors, functions, powers,

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<p>investigations and formal inquiries.</p> <ul style="list-style-type: none"> ❖ Section 38: Offences, penalties, and special orders of court. ❖ Section 43: Regulations. ❖ Section 44: Incorporation of health and safety standards in Regulations. <p>General Administrative Regulations:</p> <ul style="list-style-type: none"> ❖ Section 8: Reporting of incidents and occupational diseases. <p>General Safety Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Personal safety equipment and facilities. ❖ Sections 2A, 2B, 2C: Intoxication, display of substituted notices and signs, and admittance of persons. ❖ Section 3: First aid, emergency equipment and procedures. ❖ Section 13 B: Ladders and ramps.

Question 6: In your opinion and experience (within the scope of the study):

Does the OHS Act and its Regulations appropriately support the management of people from hazards to health and safety at the RE power plant at which you are employed, for the said topic, while the plant is under normal operating conditions? Consider the listed hazards and potentially applicable OHS Act sections and Regulations identified above. (“Yes” or “No”).

When the response is “No,” then request the respondent to describe their experience for me to understand the shortcomings.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Question 7

Topic: Physical and safety hazards, sub-category: Failures

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
<p>Listed hazards identified within the literature:</p> <ol style="list-style-type: none"> 1. Uncontrolled release of projectiles or materials or media under pressure 2. Blade failure 3. Tower failure or collapse 4. Nacelle failure (fire) 5. Tower strike 6. Equipment degradation due to high-temperature exposure (resulting in thermomechanical fatigue, creep, corrosion, stress corrosion cracking, cracking, fatigue, overheating, etc.) 7. Failure of mechanical equipment: Heat exchangers, steam generators, pumps, valves, pump seals, piping, piping supports, collector ball/rotary joints, flexible hoses, structural failures, etc. 8. Failure of CSP equipment: Absorber tubes, receivers, central tower structures, piping, Hot salt tank leaks, Salt freezing, HTF degradation, etc 9. Material loss due to the corrosive nature of molten salts at elevated temperatures 10. Heliostat misalignment 	<p>The OHS Act:</p> <ul style="list-style-type: none"> ❖ Sections 2, 3, 4, and 6: Establishment of advisory council for occupational health and safety, functions, and constitution and technical committees. ❖ Section 8: General duties of employers to their employees. ❖ Section 9: General duties of employers and self-employed persons to persons other than their employees. ❖ Section 13: Duty to inform. ❖ Section 14: General duties of employees at work. ❖ Section 16: Chief executive officer charged with certain duties. ❖ Sections 17, 18, 19, and 20: Health and safety representatives and committees and their functions. ❖ Section 24: Report to inspector regarding certain incidents. ❖ Sections 29, 30, 31, and 32: Inspectors, functions, powers, investigations and formal inquiries.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
11. Collapse of excavation works	<ul style="list-style-type: none"> ❖ Section 38: Offences, penalties, and special orders of court. ❖ Section 43: Regulations. ❖ Section 44: Incorporation of health and safety standards in Regulations. <p>General Administrative Regulations:</p> <ul style="list-style-type: none"> ❖ Section 8: Reporting of incidents and occupational diseases. <p>General Safety Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Personal safety equipment and facilities. ❖ Section 3: First aid, emergency equipment and procedures. ❖ Section 4: Use and storage of flammable liquids. ❖ <p>Driven Machinery Regulations:</p> <ul style="list-style-type: none"> ❖ Section 3: Revolving machinery. <p>General Machinery Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Supervision of machinery. ❖ Section 7: Reporting of incidents in connection with machinery. <p>Pressure Equipment Regulations:</p> <ul style="list-style-type: none"> ❖ Section 4: Duties of manufacturers.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<ul style="list-style-type: none"> ❖ Section 5: Duties of importers and suppliers. ❖ Section 6: Duties of users. ❖ Section 8: Registration of a steam generator. ❖ Section 10: Pressure equipment safety accessories. ❖ Section 11: Inspection and test.

Question 7: In your opinion and experience (within the scope of the study):

Does the OHS Act and its Regulations appropriately support the management of people from hazards to health and safety at the RE power plant at which you are employed, for the said topic, while the plant is under normal operating conditions? Consider the listed hazards and potentially applicable OHS Act sections and Regulations identified above. (“Yes” or “No”).

When the response is “No,” then request the respondent to describe their experience for me to understand the shortcomings.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Question 8

Topic: Physical and safety hazards, sub-category: External human risks

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
<p>Listed hazards identified within the literature:</p> <ol style="list-style-type: none">1. Community violence or intimidation2. Unauthorised site access	<p>The OHS Act:</p> <ul style="list-style-type: none">❖ Sections 2, 3, 4, and 6: Establishment of advisory council for occupational health and safety, functions, and constitution and technical committees.❖ Section 8: General duties of employers to their employees.❖ Section 9: General duties of employers and self-employed persons to persons other than their employees.❖ Section 13: Duty to inform.❖ Section 14: General duties of employees at work.❖ Section 16: Chief executive officer charged with certain duties.❖ Sections 17, 18, 19, and 20: Health and safety representatives and committees and their functions.❖ Section 24: Report to inspector regarding certain incidents.❖ Sections 29, 30, 31, and 32: Inspectors, functions, powers, investigations and formal inquiries.❖ Section 38: Offences, penalties, and special orders of court.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<ul style="list-style-type: none"> ❖ Section 43: Regulations. ❖ Section 44: Incorporation of health and safety standards in Regulations. <p>General Administrative Regulations:</p> <ul style="list-style-type: none"> ❖ Section 8: Reporting of incidents and occupational diseases. <p>General Machinery Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Supervision of machinery.

Question 8: In your opinion and experience (within the scope of the study):

Does the OHS Act and its Regulations appropriately support the management of people from hazards to health and safety at the RE power plant at which you are employed, for the said topic, while the plant is under normal operating conditions? Consider the listed hazards and potentially applicable OHS Act sections and Regulations identified above. (“Yes” or “No”).

When the response is “No,” then request the respondent to describe their experience for me to understand the shortcomings.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Question 9

Topic: Ergonomic hazards that may negatively impact human health and well-being by causing injury to the musculoskeletal system.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
<p>Listed hazards identified within the literature:</p> <ol style="list-style-type: none"> 1. Hazardous manual tasks 2. Worker fatigue and fitness to work 3. Fatigue: Musculoskeletal disorders 	<p>The OHS Act:</p> <ul style="list-style-type: none"> ❖ Sections 2, 3, 4, and 6: Establishment of advisory council for occupational health and safety, functions, and constitution and technical committees. ❖ Section 8: General duties of employers to their employees. ❖ Section 9: General duties of employers and self-employed persons to persons other than their employees. ❖ Section 13: Duty to inform. ❖ Section 14: General duties of employees at work. ❖ Section 16: Chief executive officer charged with certain duties. ❖ Sections 17, 18, 19, and 20: Health and safety representatives and committees and their functions. ❖ Section 24: Report to inspector regarding certain incidents. ❖ Section 29, 30, 31 and 32: Inspectors, functions, powers, investigations and formal inquiries.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<ul style="list-style-type: none"> ❖ Section 38: Offences, penalties, and special orders of court. ❖ Section 43: Regulations. ❖ Section 44: Incorporation of health and safety standards in Regulations. <p>Ergonomics Regulations:</p> <ul style="list-style-type: none"> ❖ Section 3: Information, instruction and training. ❖ Section 4: Duties of persons who may be at risk of exposure to ergonomic risks. ❖ Section 5: Duties of designers, manufacturers, importers and suppliers. ❖ Section 6: Ergonomics risk assessment. ❖ Section 7: Risk control. ❖ Section 9: Maintenance of controls. ❖ Section 2: Supervision of machinery.

Question 9: In your opinion and experience (within the scope of the study):

Does the OHS Act and its Regulations appropriately support the management of people from hazards to health and safety at the RE power plant at which you are employed, for the said topic, while the plant is under normal operating conditions? Consider the listed hazards and potentially applicable OHS Act sections and Regulations identified above. (“Yes” or “No”).

When the response is “No,” then request the respondent to describe their experience for me to understand the shortcomings.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Question 10

Topic: Psychological hazards that may negatively impact human health and well-being.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
<p>Listed hazards identified within the literature:</p> <ol style="list-style-type: none">1. Psychological stress2. Heat stress3. Worker fatigue and fitness to work4. Working under the influence of intoxicating drugs or alcohol5. Shadow flicker	<p>The OHS Act:</p> <ul style="list-style-type: none">❖ Sections 2, 3, 4, and 6: Establishment of advisory council for occupational health and safety, functions, and constitution and technical committees.❖ Section 8: General duties of employers to their employees.❖ Section 9: General duties of employers and self-employed persons to persons other than their employees.❖ Section 14: General duties of employees at work.❖ Section 16: Chief executive officer charged with certain duties.❖ Sections 17, 18, 19, and 20: Health and safety representatives and committees and their functions.❖ Section 24: Report to inspector regarding certain incidents.❖ Section 26: Victimisation forbidden.❖ Sections 29, 30, 31, and 32: Inspectors, functions, powers, investigations and formal inquiries.

Potential hazards	Potentially applicable sections from the OHS Act and Regulations for guidance (the list is not exhaustive)
	<ul style="list-style-type: none"> ❖ Section 38: Offences, penalties, and special orders of court. ❖ Section 43: Regulations. ❖ Section 44: Incorporation of health and safety standards in Regulations. <p>General Safety Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2A. Intoxication. ❖ Section 3: First aid, emergency equipment and procedures. ❖ Section 5: Work in confined spaces. <p>Environmental Regulations:</p> <ul style="list-style-type: none"> ❖ Section 2: Thermal requirements. ❖ Section 4: Windows. ❖ Section 5: Ventilation. ❖ Section 6: Housekeeping.

Question 10: In your opinion and experience (within the scope of the study):

Does the OHS Act and its Regulations appropriately support the management of people from hazards to health and safety at the RE power plant at which you are employed, for the said topic, while the plant is under normal operating conditions? Consider the listed hazards and potentially applicable OHS Act sections and Regulations identified above. (“Yes” or “No”).

When the response is “No,” then request the respondent to describe their experience for me to understand the shortcomings.

Use probing questions to build upon the responses as required.

Generate hypothetical scenarios to test negative responses from prior interviews.

Section 5: Final closure and thanks

At the end of the interview, thank the respondent for participating and their valuable contribution.

Ask if they have any questions.

Repeat the offer to provide them with a summary of the concluded study's findings.

Offer the use of my services for one day.

APPENDIX L: Cover letter for the study

Cover letter for a study by a Master of Management Student at the University of the Witwatersrand (WITS) in the field of energy leadership.

Researcher: Mark Sloan

Student No.: 2584616

8th November 2023

Dear Sir/Mam,

My name is Mark, and I am a master's student at WITS. I am researching hazards to health and safety within South Africa's renewable energy power plants under the supervision of Prof. Anthony Stacey. I obtained your power plant's name from the Department of Energy's, Independent Power Producers, Unit project database. A random sample was taken from this database, and the power plant you are working at was selected. Your contribution would be extremely valuable to improve the understanding of these hazards. I invite you to participate in the study and share your unique experience and opinion. As these power plants are relatively new in South Africa and expanding rapidly, the research is crucial to ensure appropriate levels of health and safety are maintained. The study ultimately seeks to determine if the South African Occupational Health and Safety Act, Number 85 of 1993 and its supporting Regulations appropriately support managing people from hazards to health and safety at in-service, utility-scale, renewable energy power plants.

Should you accept this invitation to participate, I will schedule a remote interview to collect your experiences and opinions. The interview will consist of questions that require your opinion on ten hazard categories and will take approximately 60 minutes to complete.

In your consideration of offering your important time to the study, you may be assured of the following:

1. The significance of your participation is vital to furthering the level of understanding of hazards in these new renewable energy plants. The limited academic literature on the topic can illustrate this.
2. The study has the potential to positively impact various stakeholders, such as the Occupational Health and Safety Acts Advisory Council, users, management, investors, and South Africa's citizens at large.
3. Participation is voluntary, and you may withdraw or stop the interview at any time. Your participation is only required for one interview. When the interview is concluded, your participation will be completed. A consent form will be provided for you to select your preferred options, endorse, and return.
4. Participating will not expose you to risks other than those experienced in your normal day-to-day activities.
5. During the interview, all questioning will remain within the scope of the study, which is limited to in-service, grid-connected, utility-scale solar PV, CSP and wind power plants. Your input will be limited to the technology type at your power plant.
6. You will be offered a summary of the concluded study's findings.
7. All data collected will be considered confidential and not disclosed to any third party. All data shall be stored on a password-protected computer and destroyed five years after the report's conclusion.
8. Privacy will be respected, and anonymity will be ensured through the numerical coding of the data. No personal or power plant names will be mentioned in the final report. You will not be identifiable in any way whatsoever. Only the researcher will be able to link the source of data.
9. The study has been approved by the WITS Business School Ethics Committee, with the ethics protocol number listed as WBS/EL2584616/691.
10. Should you accept this invitation to participate, I will offer my service as a consulting engineer without charge after completing the research for a single day on any task where my skills may add value or be used.

Should you have any questions about the study, please contact me or my supervisor on the details below.

In closing, I offer my sincere expression of appreciation and gratitude to you for considering participating in the study.

Yours sincerely

Researcher: Mark Sloan

Cell: +27(0)721110784

Email: 2584616@students.wits.ac.za

WITS Supervisor: Prof. Anthony Stacey

Email: Anthony.Stacey@wits.ac.za

APPENDIX M: Consent form for the study

Consent form to participate in a study by a Master of Management Student at the University of the Witwatersrand in the field of energy leadership.

Researcher: Mark Sloan

Student No.: 2584616

5th January 2024

Title of project: Managing health and safety in South Africa's renewable energy power plants

I, agree to participate in the study. The research has been explained to me, and I understand what my participation will involve. I agree to the following.

Confirmation that:	Yes	No
I agree that my participation will remain anonymous		
I agree that the researcher may use anonymous quotes in the final research report		
I agree that the interview may be audio-recorded		
I agree that the information I provide may be used anonymously after the project has ended for academic purposes by other researchers subject to their own ethics clearance being obtained		

Respondent		Researcher	
Signature		Signature	
Name		Name	
Date		Date	

APPENDIX N: Data collection matrix

An extract from the Microsoft Excel data collection matrix is provided below. Due to its size, the sections were inserted separately.

Sequential respondent number	Respondents' folder number: RE Tech-RNG number	Technology			Remote interview										
					Format				Recorded audio		Transcribed		Annotated interview guide		Duration of interview (Minutes)
		PV	CSP	Wind	Telephone call	WhatsApp call	MS Teams	Zoom							
									Yes	No	Yes	No	Yes	No	

The remaining sections follow the same numbering format and details as the interview guide.

Section 2: Face sheet questions

Respondents Name and Surname				Respondents' appointment		Highest qualification				Duration of employment at current power plant (months)				Prior experience					
Type a: Apprenticeship		Type b: Eng Diploma		General Machinery Regulations: Competent person														Type c: Graduate Eng + GCC Law	
Postgraduate degree				Degree				GCC				Diploma				Other			
Duration of employment at current power plant (months)				Renewable energy				Power generation				Manufacturing				Construction			
Renewable energy				Power generation				Manufacturing				Construction				Engineering build			
Mining				Other				Position (Codify for types)				Yes				No			
Duration (Months)				Name of power plant				Location of power plant (Province)				Year of power plants commissioning				Power plant duration of operation			
Location of power plant (Province)				Year of power plants commissioning				Power plant duration of operation				Location of your normal employment				Capacity of power plant (MW)			
Capacity of power plant (MW)																			

Section 2: Face sheet questions, continued

Solar PV power plants							
Mounting			Technology		Number of panels	Spatial footprint	Other
Fixed	Single axis tracking	Dual axis tracking	Crystalline	Thin film			

CSP power plants									
Point focus		Linear focus		HTF		TES (Hours)	Number of reflectors	Spatial footprint	Other
SPT	PDC	PTC	LFR	Synthetic thermal oils	Organic oils				

Wind power plants										
Number of towers / turbines	Turbine capacity (Average MW)	Tower construction				Hub height (m)	Number of blades	Blade length (m)	Spatial footprint	Other
		Concrete	Steel	Tubular	Lattice					

Section 3: Addressing the first research objective

Note: The “B” part of each question is the open-ended questions when further understanding is required.

Q1		Q1B	Q2		Q2B	Q3		Q3B	Q4		Q4B	Q5		Q5B
Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	

Q6		Q6B	Q7		Q7B	Q8		Q8B	Q9		Q9B	Q10		Q10B
Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	

Section 4: Addressing the second research objective

Note: The “B” part of each question is the open-ended questions when further understanding is required.

Q1		Q1B	Q2		Q2B	Q3		Q3B	Q4		Q4B	Q5		Q5B
Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	

Q6		Q6B	Q7		Q7B	Q8		Q8B	Q9		Q9B	Q10		Q10B
Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	

APPENDIX O: Characterising the respondents

This section provides tables characterising the study's interviews, respondents and RE power plants.

Table 6. Characterising the interviews

	Number of interviews conducted	Interview platform: MS Teams	Average duration (Minutes)
Total	10	10	79 minutes
PV	3	3	66 minutes
CSP	3	3	65 minutes
Wind	4	4	98 minutes

Table 7. Characterising the respondents

	Respondents' appointment						Highest qualification					Average duration of employment at current power plant (months)	Prior experience									
	General Machinery Regulations: Competent person				OHS Act Safety representatives	Management							Industries							Relevant		Duration (Months)
	Type a: Apprenticeship	Type b: Eng Diploma	Type c: Graduate Eng + GCC Law	Type d: Certificated Eng			Postgraduate degree	Degree	GCC	Diploma	Other		Renewable Energy	Power generation	Manufacturing	Construction	Engineering build	Mining	Other	Yes	No	
Total	0	0	0	2	1	7	5	6	5	1	0	34.8	9	6	3	7	4	1	0	10	0	186
PV	0	0	0	0	0	3	3	1	1	0	0	20	3	2	1	2	1	0	0	3	0	163
CSP	0	0	0	2	0	1	0	3	3	0	0	37.3	3	1	0	2	1	1	0	3	0	152
Wind	0	0	0	0	1	3	2	2	1	1	0	44	3	3	2	3	2	0	0	4	0	159

Table 8. Characterising the RE power plants

	Solar PV power plants									
	Mounting			Technology		Number of panels	Spatial footprint	Location	Duration of operation (Months)	Capacity (MW)
	Fixed	Single axis tracking	Dual axis tracking	Crystalline	Thin film					
Total	2	1	0	3	0	298 610 (Ave)	151.7 hectares / 1.517km ² (Ave)	-	103.3 (Ave)	71.3 (Ave)
R2	1	0	0	1	0	275 000	125 hectares / 1.25km ²	Northern Cape	86	75
R8	0	1	0	1	0	343 200	210 hectares / 2.1km ²	Northern Cape	110	75
R11	1	0	0	1	0	277 632	120 hectares 1.20km ²	Free State	114	64

Table 8: Characterising the RE power plants, continued

	CSP power plants											
	Point focus		Linear focus		HTF		TES (Hours)	Number of reflectors	Spatial footprint	Location	Duration of operation (Months)	Capacity (MW)
	SPT	PDC	PTC	LFR	Synthetic thermal oils	Organic oils						
Total	0	0	3	0	2	1	5.43 (Ave)	300 960 (Ave)	198.5 hectares / 1.985km ² (Ave)	-	80 (Ave)	83.3 (Ave)
R1	0	0	1	0	1	0	9.3	241 920	-	Northern Cape	90	50
R4	0	0	1	0	0	1	4.5	360 000	87 hectares 0.87km ²	Northern Cape	59	100
R5	0	0	1	0	1	0	2.5	-	310 hectares 3.10km ²	Northern Cape	91	100

Table 8: Characterising the RE power plants, continued

Wind power plants													
	Number of towers / turbines	Turbine capacity (Ave MW)	Tower construction				Hub height (m)	Number of blades	Blade length (m)	Spatial footprint	Location	Duration of operation (Months)	Capacity (MW)
			Concrete	Steel	Tubular	Lattice							
Total	51 (Ave)	2.99 (Ave)	1	3	4	0	101 (Ave)	3 (Ave)	60.13 (Ave)	2364 hectares 23.64km ² (Ave)	-	35.8 (Ave)	138.7 (Ave)
R3	47	3.15	1		1	0	100	3	62.5	47 hectares 0.47km ²	Northern Cape	19	140
R6	35	4.2	0	1	1	0	90	3	71	-	Northern Cape	17	139.9
R9	61	2.3	0	1	1	0	115	3	53	3591 hectares 35.91km ²	Northern Cape	36	136.7
R10	61	2.3	0	1	1	0	99	3	54	3453 hectares 34.53km ²	Northern Cape	71	138

APPENDIX P: Ethics clearance certificate for the study

Graduate School of Business Administration
University of the Witwatersrand, Johannesburg



Wits Business School Ethics Committee
Constituted under the University Human Research Ethics Committee (Non-Medical)

Ethics Clearance Certificate

Ethics protocol number: WBS/EL2584616/691

This certificate is only valid with a legitimate ethics protocol number and signed by the Researcher (below).

Project title	Managing health and safety in South Africa's renewable energy power plants
Investigator / Researcher	Mr Mark Sloan
Nature of Project	MM (Energy Leadership)
Decision of the Committee	Approved, provided stakeholders and participants are guaranteed confidentiality.
Issue Date of Certificate	2023/09/15
Expiry date	Date of submission of the project / research report
Chairperson	Dr Pius Oba  +27 11 717 3976  +27 82 733 6587  pius.oba@wits.ac.za 

Declaration by Researcher

One copy must be signed by the Researcher and returned to the Chairperson of the Wits Business School Ethics Committee.

I fully understand the conditions under which I am authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I undertake to resubmit the protocol to the Committee.


Signature

18.09.2023
Date: