

# Investigating the direct environmental impacts of emerging solar power and shale gas developments in two arid biomes of South Africa

by  
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## DECLARATION

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## ABSTRACT

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South Africa's energy system diversification involves the inclusion of a variety of energy resources as alternatives to coal. Amongst these energy technologies supported by various policy documents, alternatives include concentrating solar power (CSP), photovoltaic power (PV) and shale gas.

Solar power developments are predominantly located across the north-western interior of the country, coinciding with the distribution of the Nama-Karoo and Savanna biomes. The environmental impacts of individual solar power projects are currently being assessed by Environmental Impact Assessments (EIAs). The area for which shale gas exploration rights applications have been received slightly overlaps with the area for which solar power projects are being deployed. No shale gas exploration activities have as yet commenced, and the size of its resource in the Karoo Basin is still undetermined. Should the resource size be economically viable, shale gas development activities are expected to start and will require EIAs.

Due to the relative novelty of these energy developments (*i.e.*, solar power and shale gas) in South Africa, local peer reviewed literature based on experience-based impact data is largely absent. The objective of this thesis is to determine and investigate the direct environmental impacts resulting from these alternative energy developments across the landscapes of the Nama-Karoo and Savanna biomes. A mixed-method approach was followed.

Structured interviews were conducted with selected expert groups and included questions on direct environmental impact from developments, the EIA process and management of impacts. The results from the interview process were coded, grouped into themes and then thematically analysed. With slight differences for the two solar technologies, interview findings indicated that habitat transformation, the impact on avifauna and cumulative impacts are major concerns related to solar power development. These findings were supported by site visits, which provided an on-the-ground perspective of the impact experience from solar power plants. Shale gas interview findings indicated that all aspects of water related impacts are of very high concern. The widespread nature of shale gas developments are expected to cause distributed and repeated impacts to the landscape, especially during the production stage of development. The cumulative nature of these impacts and the uncertainty regarding baseline conditions in the Nama-Karoo were highlighted as key concerns. Simple spatial analysis was used to assess the footprints of solar power and shale gas development relative to other land uses in the study area. It was found that the current and expected footprint of future solar power development is relatively low. The exact locations for potential shale gas activities are still unknown, but given the distributed nature thereof, a notable proportion of the Nama-Karoo surface area is expected to be transformed if or when activities commence.

The management of- and strategic planning for environmental impacts of energy developments in the arid biomes of South Africa have been highlighted as critical and in need of effective coordination. This thesis provides an initial identification of the direct environmental impacts of energy developments in two arid biomes of South Africa, and a number of recommendations are made for future work.

## OPSOMMING

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Die diversifisering van Suid-Afrika se energiesisteem behels die insluiting van 'n verskeidenheid energie hulpbronne as alternatiewe tot steenkool. Van hierdie energietegnologieë wat ondersteun word deur verskeie beleidsdokumente, word gekonsentreerde sonkrag (GSK), fotovoltaïese krag (FK) en skalie gas as alternatiewe ingesluit.

Sonkragontwikkelinge is meestal geleë oor die noord-westelike binneland van die land, wat ook ooreenstem met die verspreiding van die Nama-Karoo en Savanna biome. Die omgewingsimpakte van individuele sonkragprojekte word tans geassesseer deur middel van Omgewingsimpakstudies (OISs). Die area waarvoor skaliegaseksplorasie-aansoeke ontvang is, oorkruis gedeeltelik met die areas waar sonkragprojekte ontplooi word. Geen skaliegaseksplorasie-aktiwiteite het al begin nie, en die grootte van die hulpbron in die Karoo Kom is steeds onbepaald. Skaliegasontwikkelingsaktiwiteite word verwag om te begin en sal ook OISs benodig sodra die hulpbrongrootte ekonomies vatbaar bevind word.

As gevolg van die relatiewe nuutheid van hierdie energieontwikkelinge (m.a.w. sonkrag en skaliegas) in Suid-Afrika, is literatuur wat gebaseer is op ondervinding-verwante impakte merendeels afwesig. Die doel van hierdie tesis is om die direkte omgewingsimpakte verwant aan bogenoemde alternatiewe energieontwikkelinge in die Nama-Karoo en Savanna biome te bepaal en ondersoek. 'n Gemengde-metode benadering was gevolg.

Gestruktureerde onderhoude was gevoer met geselekteerde kennergroepe en het vroeë ingesluit aangaande die direkte omgewingsimpakte van ontwikkelinge, die OIS proses en die bestuur van impakte. Die resultate van die onderhoudsproses was gekodeer en daarna tematies geanaliseer nadat die bevindinge in temas gegroepeer was. Met effense verskille tussen die twee sonkragtegnologieë het die onderhoudsresultate aangedui dat habitat transformasie, die impak op *avifauna* en kumulatiewe impakte die beduidendste bekommernisse is m.b.t. sonkragontwikkeling. Hierdie bevindinge was ondersteun deur besoeke af te lêer aan ses sonkragstasies wat praktiese insig gelewer het rakende die impak-ondervinding van sonkragstasies in Suid-Afrika tot op hede. Die onderhoudsbevindinge vir skalie gas het aangedui dat alle aspekte van water-verwante impakte besondere kommer inhou. Die wydverspreide aard van skaliegasontwikkelinge word verwag om verspreide en herhaalde impakte in die landskap te veroorsaak, veral gedurende die produksiestadium van ontwikkeling. Die kumulatiewe aard van hierdie impakte en die onsekerheid rakende die pre-ontwikkeling toestand in die Nama-Karoo was ook uitgewys as 'n rede vir kommer. Basiese ruimtelike analise was gebruik om die ontwikkelingsareas van sonkrag en skaliegas relatief tot ander grondgebruike in die studie area te assesseer. Dit was bevind dat die huidige en verwagte ontwikkelingsarea van sonkrag relatief laag is. Die presiese ligging van skaliegasaktiwiteite is steeds onbekend, maar gegewe die wydverspreide aard daarvan word dit verwag dat 'n noemenswaardige gedeelte van die Nama-Karoo oppervlakarea getransformeer sal word indien of wanneer skaliegasontwikkeling begin.

Die bestuur van- en strategiese beplanning van omgewingsimpakte van energie ontwikkelinge in die dorre biome van Suid-Afrika was verder uitgewys as baie belangrik en benodig effektiewe koördinasie. Hierdie tesis verskaf 'n aanvanklike identifisering van die direkte omgewingsimpakte verwant aan energieontwikkelinge in twee dorre biome van Suid-Afrika en 'n paar aanbevelings word gemaak vir toekomstige navorsing.

## DEDICATION

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*Vir my ouers wat my die geleentheid gegee het om op 'n plaas groot te word.*

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## ACRONYMNS AND ABBREVIATIONS

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BLSA	BirdLife South Africa
CO <sub>2</sub>	Carbon dioxide
CSIR	Council of Scientific and Industrial Research
CSP	Concentrating solar power
DEA	Department of Environmental Affairs
DOE	Department of Energy
EAP	Environmental Assessment Practitioner
ECO	Environmental Control Officer
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme
EMS	Environmental Management System
ESKOM	Electricity Supply Commission
GHG	Greenhouse gas
GIP	Gas-in-place
GIS	Geographical Information System
HTF	Heat transfer fluid
IBA	Important Bird Area
IEP	Integrated Energy Plan
IPP	Independent Power Producer
IRP	Integrated Resource Plan
KARIN	Karoo Research Initiative
kWh	Kilowatt hour
LCA	Life cycle assessment
MW	Megawatt
MWh	Megawatt-hour
NEMA	National Environmental Management Act
NDP	National Development Plan
NPAES	National Protected Area Expansion Strategy
NORMS	Naturally occurring radioactive materials
PV	Photovoltaic

REDZ	Renewable Energy Development Zones
REIPPPP	Renewable Energy Independent Power Producers Procurement Program
RSA	Republic of South Africa
SEA	Strategic Environmental Assessment
SEASGD	Strategic Environmental Assessment for Shale Gas Development
Tcf	Trillion cubic feet
TES	Thermal energy storage
VEC	Valued ecosystem component
WWF-SA	World Wide Fund for Nature South Africa

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## DEFINITIONS

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<b>Alternative energy</b>	The umbrella term 'alternative energy' refers to energy sources intended to reduce undesired consequences from the energy source(s) it replaces, this thus includes both renewable and petroleum energy sources considered to replace other resources (Spellman 2012).
<b>Base load</b>	The minimum amount of electric power delivered or required over a given period of time at a steady rate (US EIA n.d.). Usually given in MW demand over 24 hours.
<b>Biome</b>	A broad ecological unit having similar vegetation structure and exposed to similar macroclimatic patterns, often linked to characteristic levels of disturbance such as grazing and fire (Mucina & Rutherford 2006; Low & Rebelo 1998).
<b>Development footprint</b>	Used to refer to the direct area being affected by a solar power plant or shale gas well pad. Does not include peripheral infrastructure such as roads, power lines and gas infrastructure.
<b>Direct impact</b>	Impact on the natural environment directly from the construction or operational activities of a power plant/drill pad. This includes possible socio-economic impacts, but not impacts before construction or after a power plant/drill pad is decommissioned.
<b>Ecosystem service</b>	The conditions and processes through which natural ecosystems, and the species that live within them, sustain and fulfil human life (Daily 1997).
<b>Electricity generation system</b>	All power plants and generators typically in a transmission-connected system and controlled by a utility company. In this case, this is mostly the South African electricity grid.
<b>Energy</b>	In the context of this thesis, 'energy' refers to the conversion and use of the potential from various resources for society's need, e.g., electricity generated for domestic or industrial need.
<b>Energy mix</b>	The collection of resources which contribute to the consumable energy supply in a geographic region. Also referred to as the 'energy diversification plan' where used to refer to increased contribution from alternative energy sources.
<b>Energy technology</b>	A specific set of technological skills and physical components that contribute to the energy supply system.

<b>Energy system</b>	The broader energy system incorporating the electricity generation system, energy resource extraction from all sources, production, storage, transmission, distribution, transportation and heating.
<b>Exploration right areas</b>	Areas across the Northern, Eastern and Western Cape where applications for shale gas exploration rights have been received from Shell, Bundu and Falcon oil and gas.
<b>Hydraulic fracturing</b>	Fracturing of deep geological formations with pressurised fluid (CSIR 2015). A technique used to prepare a gas well for production. Together with the other stages of shale gas development also referred to as 'fracking' in public domain. Due to its emotive use and unclear definition in the public domain, 'fracking' is not used in this thesis.
<b>Impact</b>	The effective action of one thing or person on another; the effect of such action; influence; impression (Oxford English Dictionary 2016). Here with specific reference to that of solar power and shale gas development directly on the natural environment
<b>Land use</b>	The arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (FAO 1999).
<b>Renewable energy resources</b>	Energy resources that are naturally replenishing. These include sources considered renewable or sustainable energy resources considered inexhaustible over a 'short/human' time period (as opposed to geological time periods), but limited in the amount of energy that is available per unit of time.
<b>Shale gas</b>	The natural gas produced from shale formations. Shale is a fine-grained, sedimentary rock composed of mud from flakes of clay minerals and tiny fragments (silt-sized particles) of other materials. The shale acts as both the source and reservoir for the natural gas (CSIR 2015).
<b>Shale gas development</b>	The exploration, construction and production activities related to shale gas. This covers the entire life cycle up to and including eventual closure of facilities and restoration of the sites (CSIR 2015).
<b>Solar power</b>	Broadly refers to the converted energy from the sun to usable electrical power; not referring to the use of any specific technology to do so.
<b>Solar power development</b>	Used to collectively refer to all infrastructure and activities related to multiple solar power plants.
<b>Sub-station</b>	Facilities forming part of the national transmission network where electricity is fed into/contributed to the grid or distributed to electricity

demand-areas. Sizes of sub-stations vary according to the location and voltage associated with the incoming and outgoing transmission lines.

**Transmission infrastructure**

An interconnected group of electric transmission lines and associated equipment for moving or transferring electric energy in bulk between points of supply and demand. The transmission system breaks into the distribution system near the points where the electricity is used. Also referred to as 'transmission grid' or just 'grid.'

**Utility-scale**

The generation by electric systems engaged in selling electric energy to the public through a corporation, person, agency, authority, or other legal entity (*i.e.*, Eskom in SA) (CSIR 2015). Typically forms a network of large power plants or facilities.

**Vegetation type**

The work of Mucina and Rutherford (2006) which groups South Africa, Lesotho and Swaziland's flora into 440 types grouped per biome. This represents the National Vegetation Map; it is also available as GIS database.

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# TABLE OF CONTENTS

---

Declaration.....	I
Abstract.....	II
Opsomming .....	III
Dedication.....	IV
Acknowledgements .....	V
Acronymns and abbreviations .....	VI
Definitions .....	VIII
Table of figures .....	XIII
Table of tables .....	XVI
CHAPTER 1: INTRODUCTION.....	1
1.1. Background.....	1
1.2. Problem statement.....	6
1.3. Research objectives and questions.....	6
1.4. Research method .....	7
1.5. Assumptions .....	7
1.6. Definitions .....	8
1.7. Delineations and limitations.....	8
1.8. Significance and contribution.....	9
1.9. Chapter overview.....	9
CHAPTER 2: LITERATURE REVIEW.....	11
2.1 The bigger picture: sustainability and sustainable development.....	11
2.2 The status of South Africa’s energy system diversification .....	12
2.3 Policy and legislation for energy and the environment.....	14
2.4 Energy technologies and impacts overview .....	17
2.5 Study area: South Africa’s semi-arid interior .....	34
2.6. Impact assessment methods.....	37
2.6 Conclusion .....	40
CHAPTER 3: THE IMPACTS OF SOLAR POWER .....	41
3.1. Introduction .....	41
3.2. Method.....	43
3.3. Results.....	50

3.4.	Discussion .....	68
3.5.	Conclusion .....	72
CHAPTER 4: THE IMPACTS OF SHALE GAS PRODUCTION .....		73
4.1.	Introduction .....	73
4.2.	Overview of the environmental impacts associated with shale gas development .....	75
4.3.	Method .....	79
4.4.	Results .....	82
4.5.	Discussion .....	93
4.6.	Conclusion .....	97
CHAPTER 5: FINDINGS AND RECOMMENDATIONS FOR MANAGEMENT AND MITIGATION OF IMPACTS.....		98
5.1.	Introduction .....	98
5.2.	Management and mitigation for the impacts of solar power.....	99
5.3.	Management and mitigation for the potential impacts of shale gas .....	104
5.4.	Conclusion .....	109
CHAPTER 6: CONCLUSION .....		110
6.1.	Summary of findings .....	110
6.2.	Final conclusions .....	111
6.3.	Contributions.....	112
6.4.	Feedback and recommendations for future research.....	113
REFERENCES .....		115
APPENDICES.....		129