Renewable energy development for South Africa: a regional planning approach

WJ Kruger

orcid.org/0000-0003-3859-7335

Thesis accepted in fulfilment of the requirements for the degree *Doctor of Philosophy in Urban and Regional Planning* at the North-West University

Promoter: Prof. JE Drewes

Co-promoter: Prof. MM Campbell

Graduation June 2021

20539215

ACKNOWLEDGEMENTS

- My Heavenly Father for giving me the necessary strength and guidance.
- My supervisors, Prof. Ernst Drewes, and Prof. Malène Campbell for their continual support and leadership throughout the course of my studies.
- My parents, Erika Kotze and Johannes Kruger, for their continual support during my studies.
- Ms Corrie Geldenhuys for linguistic assistance.
- Mrs Carmen Nel for resource materials.

Philippians 4:13 – I can do all this through Him who gives me strength.

ABSTRACT

Since the mid-1990s there has been growing consensus around the world that greenhouse gas (GHG) emissions derived from burning fossil fuels for energy generation purposes (among others) are contributing to climate change, resulting in what has become known as global warming. This recognition has resulted in the adoption of several international treaties and agreements aimed at committing countries to reduce their GHG emissions through policy intervention.

South Africa has ratified the Paris Agreement and through its Nationally Determined Contributions (NDCs) vowed to reduce GHG emissions, particularly in the energy sector, as this is where the largest gains can be made. South Africa has subsequently prioritized renewable energy to generate electrical energy in many of its policies. In addition to the need to diversify the energy mix, South Africa is also in dire need to increase electrical energy capacity to support economic growth and development. To support economic growth, the South African National Treasury prepared an economic policy document in 2018 wherein it is highlighted that South Africa needs to improve the current electricity planning process to achieve economic growth and development.

Regional spatial planning as a professional discipline can be described as a future-orientated process concerned with fixing social and/or economic problems with the broad aim of achieving regional economic development and directing an ideal or ambition for a territory by making use of instruments such as planning regions for which development plans can be formulated. Development plans contain spatial directives that influence the future distribution of activities in space as well as a practical implementation framework. Theories of industrial location and regional development can be drawn on to make sound spatial planning decisions as such decisions will have a long-term impact. The ‘new growth theory’ postulates that regional development is a result of exploiting endogenous factors of production through spatially targeted policies, institutional arrangements and technology. Internationally, renewable energy is facilitated through policy frameworks wherein energy sector and spatial planning is integrated at a regional level.

Furthermore, it has been suggested by an international statutory planning council that spatial planning professionals and departments need to be directly involved in the energy planning process. However, the current electricity planning system in South Africa is detached from spatial planning necessitating the need for intervention in this regard. It was found that increasing renewable energy in South Africa can achieve both economic development as well as lower GHG emissions. Internationally, successful renewable energy implementation is done via a holistic approach wherein energy sector and spatial planning is integrated. This study

makes proposals for how the energy sector and spatial planning can be combined to form an integrated policy framework to facilitate renewable energy deployment in South Africa to achieve regional economic development.

Keywords – Regional planning, infrastructure planning, energy planning, regional economic development, policy, sustainability, renewable energy, technology.

OPSOMMING

Sedert die middel van die negentigerjare is daar wêreldwyd toenemende konsensus dat kweekhuisgas (KHG)-emissies wat deur die verbranding van fossielbrandstowwe vir energieopwekkingdoeleindes (onder andere) verbrand word, bydra tot klimaatsverandering wat lei tot wat bekendstaan as aardverwarming. Hierdie erkenning het gelei tot die aanvaarding van verskeie internasionale verdrae en ooreenkomste wat daarop gemik is om lande te verbind om hul kweekhuisgasvrystellings deur middel van beleidsintervensie te verminder.

Suid-Afrika het die Parys-ooreenkoms bekragtig en deur sy Nasionaal Bepaalde Bydraes (NBBs) belowe om KHG-emissies te verminder, veral in die energiesektor, want dit is waar die grootste winste behaal kan word. Suid-Afrika het hernieubare energie vooropgestel om elektriese energie op te wek in baie beleids domumente. Benewens die behoefte om die energiemengsel te diversifiseer, is Suid-Afrika ook dringend nodig om elektriese energiekapasiteit te verhoog om ekonomiese groei en ontwikkeling te ondersteun. Om ekonomiese groei te ondersteun, het die Suid-Afrikaanse Nasionale Tesourie in 2018 'n ekonomiese beleidsdokument opgestel waarin beklemtoon word dat Suid-Afrika die huidige elektrisiteitsbeplanningsproses moet verbeter om ekonomiese groei en ontwikkeling te bewerkstellig.

Streeks ruimtelike beplanning as 'n professionele dissipline kan beskryf word as 'n toekomsgerigte proses wat verband hou met die oplossing van maatskaplike en/of ekonomiese probleme met die breë doel om streeksekonomiese ontwikkeling te bewerkstellig en 'n ideaal of ambisie vir 'n gebied te rig deur gebruik te maak van instrumente soos beplanningsstreke waarvoor ontwikkelingsplanne geformuleer kan word. Ontwikkelingsplanne bevat ruimtelike voorskrifte wat die toekomstige verspreiding van aktiwiteite in ’n gebied beïnvloed, asook 'n praktiese implementeringsraamwerk. Teorieë oor industriële ligging en streeksontwikkeling kan gebruik word om goeie ruimtelike beplanningsbesluite te neem, aangesien sulke besluite 'n langtermyn-impak sal hê. Die 'nuwe groeiteorie' postuleer dat streekontwikkeling ’n gevolg is van die ontginning van plaaslike produksiefaktore deur ruimtelik gerigte beleide, institusionele reëlings en tegnologie. Internasionaal word hernubare energie gefasiliteer deur middel van beleidsraamwerke waarin energiesektor- en ruimtelike beplanning op streeksvlak geïntegreer is.

Verder is deur 'n internasionale statutêre beplanningsraad voorgestel dat professionele persone en departemente vir ruimtelike beplanning direk by die energiebeplanningsproses betrokke moet wees. Die huidige elektrisiteitsbeplanningstelsel in Suid-Afrika is egter los van ruimtelike beplanning wat noodsaak vir ingryping in hierdie verband. Daar is gevind dat deur hernubare energie in Suid-Afrika te te gebruik ekonomiese ontwikkeling sowel as laer KHG-emissies kan bewerkstellig. Internasionaal word die suksesvolle implementering van hernubare energie

gedoen deur middel van 'n holistiese benadering waarin energiesektor en ruimtelike beplanning geïntegreer is. Hierdie studie maak voorstelle oor hoe die energiesektor en ruimtelike beplanning gekombineer kan word om 'n geïntegreerde beleidsraamwerk te vorm om ontplooiing van hernubare energie in Suid-Afrika te vergemaklik om ekonomiese ontwikkeling te bewerkstellig.

Kernwoorde – Streekbeplanning, infrastruktuurbeplanning, energiebeplanning, streeks-ekonomiese ontwikkeling, beleid, volhoubaarheid, hernubare energie, tegnologie.

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LIST OF ABBREVIATIONS

A	Amps
AF	Availability Factor
CHP	Combined Heat and Power
CO2	Carbon Dioxide
COD	Commercial Operation Date
COP	Conference of the Parties
CSIR	Council for Scientific and Industrial Research
CSP	Concentrated Solar Power
DBSA	Development Bank of Southern Africa
DHI	Direct Normal Irradiation
DEA	Department of Environmental Affairs
DFA	Development Facilitation Act
DGCMSP	Directors General Committee on Marine Spatial Planning
DoE	Department of Energy
DPME	Department of Performance Monitoring and Evaluation
DME	Department of Minerals and Energy
DMRE	Department of Mineral Resources and Energy
DPO	Draft Plan Options
EC	European Commission
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EMEC	European Marine Energy Centre
ERA	Electricity Regulations Act
EU	European Union
EV	Electric Vehicles
FIT	Feed in Tariff
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GFCP	Gross Fixed Capital Formation
GHD	Global Horizontal Irradiation
GHG	Greenhouse gas
GIS	Geographic Information System
GNI	Gross National Income
GTI	Global Tilted Irradiation
GVA	Gross Value Added
GW	Gigawatts

HAWT	Horizontal Axis Wind Turbine
HDI	Human Development Index
IEDC	International Economic Development Council (IEDC)
IEP	Integrated Energy Plan
IMF	International Monetary Fund
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
IRP	Integrated Resource Plan
ISMO	Independent Systems and Market Operator
kWh	Kilowatt hours
LCA	Life Cycle Assessment
LDPs	Local Development Plans
LF	Labour Force
MAP	Marine Area Plan
MAPG	Marine Area Planning Group
MDG	Millennium Development Goals
MPS	Marine Policy Statement
MRDLR	Minister of Rural Development and Land Reform
MSDF	Municipal Spatial Development Framework
MSP	Marine Spatial Planning
MSPA	Marine Spatial Planning Act
MSPF	Marine Spatial Planning Framework
MSPs	Marine Spatial Plans
MSFD	Marine Strategy Framework Directive
MW	Megawatt
NCCRWP	National Climate Change Response White Paper
NEA	National Energy Act
NERSA	National Energy Regulator of South Africa
NDC	Nationally Determined Contributions
NDP	National Development Plan
NDRC	National Development and Reform Commission
NEC	National Energy Commission
NGO	Non-Government Organizations
NGP	New Growth Path
NHREC	Non-Hydro Renewable Energy Consumption
NIP	National Infrastructure Plan
NIPF	National Industrial Policy Framework
NMP	National Marine Plan

NMPi	National Marine Plan Interactive
NPC	National Planning Commission
NSAA	National Strategic Action Area
NSDF	National Spatial Development Framework
NSDP	National Spatial Development Perspective
NWGMSP	National Working Group on Marine Spatial Planning
OCIMS	Ocean and Coast Information System
OECD	Organization for Economic Co-operation and Development
PAR	Participation Action Research
PFOW	Pentland Firth and Orkney Waters
PICC	Presidential Infrastructure Coordination Committee
PPA	Power Purchase Agreement
PV	Photovoltaic
RED	Regional Economic Development
REDZs	Renewable Energy Development Zones
REI4P	Renewable Energy Independent Power Producers Procurement Programme
REL	Renewable energy Law
REM	Resource Endowment Market
REPA	Renewable Energy Purchasing Agency
RMPs	Regional Marine Plans
RPS	Renewable Portfolio Standards
RSDF	Regional Spatial Development Framework
SADC	Southern African Development Community
SAP	Structural Adjustment Programmes
SARi	South African Renewables Initiative
SAWEP	South African Wind Energy Programme
SBO	Single Buyers Office
SDF	Spatial Development Framework
SDG	Sustainable Development Goals
SEA	Strategic Environmental Assessment
SEZ	Special Economic Zone
SIPs	Strategic Integrated Projects
SMPs	Sectoral Marine Plans
SNPF	Scottish National Planning Framework
SPLUMA	Spatial Planning and Land Use Management Act
TBL	Triple Bottom Line
TDP	Transmission Development Plan
TREC	Total Renewable Energy Consumption

TSMO	Transmission Systems Market Operator
TWh	Terawatt Hours
V	Volts
VAWT	Vertical Axis Wind Turbine
W	Watts
WASA	Wind Atlas for South Africa
WFD	Water Framework Directive
WEC	Wave energy converter
WDR	World Development Report
WPRE	White Paper on Renewable Energy
UK	United Kingdom
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNFCC	United Nations Framework Convention on Climate Change
USA	United States of America

CHAPTER 1: INTRODUCTION

1.1 Research orientation

On 27 September 1998, the former Prime Minister of the United Kingdom (UK), Margaret Thatcher, addressed the UK's national academy of science on the matter of climate change, which highlighted the growing global recognition that economies around the world are contributing to what is referred to as 'man-made global warming' through greenhouse gas (GHG) emissions, particularly deriving from the burning of fossil fuels in the energy sectors (IPCC, 2018:6, Nulman, 2015:8). This recognition has led to the adoption of several international treaties, agreements and goals, beginning with the Kyoto protocol in 1997, followed by the United Nations (UN) Millennium Development Goals (MDGs) in 2000, and more recently the Paris Agreement and the UN Sustainable Development Goals (SDGs) in 2015 (UN, 1998:2; UN, 2015:2-3; UN, 2019:3-57). As a result, the world has been transitioning into an era that requires more sustainable methods for producing energy (among others) and has led to the prioritization of renewable energy by world leaders around the globe (Annecke & Swelling, 2012:14; EEA, 2016:13).

The global wind energy market grew by more than 10 percent in 2019, with close to 60 GW of newly installed renewable energy added to electricity grids (IRENA, 2020b:14). The global solar (PV) energy market grew by more than 20 percent in 2019, with nearly 100 GW of newly installed capacity added to electricity grids (IRENA, 2020:25). One of the most effective instruments that have been used to achieve renewable energy deployment on a global scale is through policy intervention (REN21, 2020:58). Electricity is increasingly being generated with renewable sources on a global scale, as 166 countries have set renewable energy targets and 151 countries have introduced renewable energy policies by the end of 2019 (REN21, 2020:70). Renewable energy policies can broadly be divided into two categories; the first being regulatory policies aimed at providing a framework for renewable energy planning and implementation, and the second, fiscal policies aimed at incentivising developers to invest in renewable energy projects (REN21, 2020:75-79).

Electricity in South Africa is also largely generated in seemingly environmentally damaging methods (by burning fossil fuels, mostly in the form of coal), which need to be addressed, due to the country being a signatory to the above-mentioned Paris Agreement through which it vowed to reduce GHG emissions as stipulated in South Africa's Nationally Determined Contributions (NDCs) (Department of Mineral Resources and Energy, 2016:46; Department of Environmental Affairs, 2018:9). South Africa's dependence on coal is well documented; however, according to Cock (2019:863), the South African government is not allocating sufficient resources towards

the country's transition towards a low-carbon economy. The Department of Energy (DoE) and the South African Energy Regulator (NERSA) have been revising energy policy on a regular basis since 2005 in an effort to increase the diversification of energy sources and to reduce South Africa's over-reliance on fossil fuels for energy generation (NERSA, 2015:3; Department of Energy, 2016:44). According to South Africa's primary energy resource policy, i.e. the Integrated Resource Plan (IRP 2019), renewable energy (particularly wind and solar energy) is set to make a significant contribution to generation capacity in the country over the next decade (Department of Mineral Resources and Energy, 2019:42).

In addition to South Africa's heavy reliance on coal, the country has a shortage of electricity generation capacity, as has been made evident by the rolling black-outs known as 'load shedding' implemented by the country's primary electricity provider, Eskom, since 2008, which has had an adverse effect on the South African economy (Coetzee & Els, 2016:268). South Africa's shortage of generation capacity is set to get worse if action is not taken soon, due to ageing coal-fired power stations planned to be decommissioned over the next decade, adding up to a loss of 1 707 Megawatts (MW) of generation capacity after taking into account that new coal-fired and nuclear power stations are set to come online during this time (Department of Performance Monitoring and Evaluation, 2019:10). Energy capacity is crucial for economic growth and development to occur, and the South African government has recognised the need for policy intervention in this regard.

In addition to the New Growth Path (NGP, 2011) and the National Development Plan (NDP, 2012), which highlights South Africa's need for economic intervention, the National Treasury has prepared an economic policy document in 2018, which outlines five areas of economic opportunity, one of which refers to the modernization of network industries including energy, and another to the promotion of export competitiveness and harnessing regional growth opportunities (National Treasury, 2018:19, 50). The former recognizes "a highly imperfect electricity planning process", and the need for electricity grid infrastructure investment, as well as the benefits of harnessing renewable energy (National Treasury, 2018:19-21), whereas the latter recommends a regional approach to energy systems in terms of generation and distribution (National Treasury, 2018:53).

Adopting new energy policies and in particular renewable energy policies are important for establishing a practical framework in which renewable energy practices can function (Eberhard & Naude, 2017:57). Spatial planning professionals need to gain and possess the correct set of skills to develop renewable energy strategies as, according to Vanderkamp *et al.* (2016:3-6), spatial planning is the profession with the greatest ability to coordinate the complex technical, spatial and infrastructural linkages that make up energy planning, and that planning

departments must become more involved in developing and implementing energy plans at local, regional and national levels to mitigate the adverse effects of climate change by promoting environmentally friendly and sustainable energy solutions. It is, however, important to take note that spatial planning policies around the world differ from one another, and that each country must utilize their own policy frameworks to achieve effective [renewable] energy planning (Vanderkamp *et al.*, 2016:7).

Terrestrial and marine spatial planning in South Africa is governed by the Spatial Planning and Land Use Management Act (SPLUMA) (16 of 2013) and the Marine Spatial Planning Act (MSPA)(16 of 2018), respectively. The former makes provision for the Minister of Agriculture, Rural Development and Land Reform (DRDLR) to declare any geographic area in the Republic a region, for the purpose of guiding strategic spatial planning and land-use management in that area, known as a Regional Spatial Development Framework (RSDF), whereas the latter makes provision for the adoption of Marine Area Plans (MAPs) to guide spatial planning and sectoral marine activities within South Africa's Exclusive Economic Zone (EEZ). Furthermore, strategic development and spatial planning on a national scale in South Africa is done through the National Development Plan (NDP, 2012) and the National Spatial Development Framework (NSDF, 2019), respectively. Energy planning in South Africa is governed by the National Energy Act (34 of 2008), which mandates that the Minister of Mineral Resources and Energy (DMRE) prepare an Integrated Energy Plan (IEP) with a planning horizon of 20 years while ensuring the natural resources are managed effectively through the Integrated Resource Plan (IRP). Infrastructure planning on a national scale is carried out by the Presidential Infrastructure Coordinating Committee (PICC) through the National Infrastructure Plan (NIP). By integrating the energy, infrastructure, and spatial planning systems in South Africa, renewable energy planning can be done in a comprehensive and coherent manner.

1.2 Problem statement

Given South Africa's need to reduce its carbon emissions due to global pressures and commitments, develop its economy, and boost electricity generation capacity to fuel the economy, combined with regional spatial planning's presumed ability to guide and facilitate renewable energy development and achieve regional economic development, South Africa should be utilizing regional spatial planning policy frameworks and systems to plan for renewable energy. The problem, however, is that renewable energy planning in South Africa is largely detached from spatial and infrastructure planning on a regional level (Department of Performance Monitoring and Evaluation, 2019:111). This disjointed approach may lead to a situation where renewable energy efforts do not achieve the desired outcome.

1.3 Research questions

Considering the problem statement, the following questions need to be considered:

1. What are the founding principles of regional planning as a development instrument?
2. How can sustainable regional development be achieved in an environmentally sustainable manner?
3. Can renewable energy deployment have a positive impact on regional development?
4. What are the renewable energy sources and technologies used in practice and how do they relate to spatial and infrastructure planning?
5. What are the best practices for planning and implementing renewable energy on a regional planning level?
6. What energy, infrastructure and spatial planning policies do South Africa currently have in place to facilitate renewable energy implementation?

1.4 Research aims and objectives

The primary aim of this study is to formulate an integrated policy framework in which regional development can occur through renewable energy deployment. As such, the research objectives include:

1. To gain a clear understanding of the founding principles on which regional planning as a development instrument is based.
2. To determine how sustainable regional development can be achieved in an environmentally sustainable manner.
3. To determine the potential impacts of renewable energy deployment on regional development.
4. To gain a broad understanding of the relevant renewable energy sources and technologies and how they relate to spatial and infrastructure planning.
5. To evaluate best-practice policy frameworks for renewable energy planning and implementation on a regional planning level.
6. To identify energy, infrastructure and spatial planning policies that can form a framework for renewable energy implementation in South Africa.

The above-mentioned aim and objectives each constitute a chapter in this study.

1.5 Research approach

A predominantly qualitative research approach will be used for this study; however, in exploring certain avenues, quantitative data will also be used to support qualitative data, making this a mixed-method study (Kabir, 2016:202-203). Mixed-method approaches are less rigid in their designs and make use of both numeric and textual data (Du Toit, 2010:50). This study will use both meta-research (non-empirical) and empirical research to reach the study objectives.

The literature section for this study will be carried out by means of a theoretical literature review, a systematic literature review, and a traditional literature review. A theoretical literature review establishes what theories already exist and how they relate to a research topic (Onwuegbuzie & Frels, 2016:24-25). A systematic literature review critically appraises and synthesizes literary results from existing research to answer a specific research question often posed in a cause-and-effect form, whereas a traditional literature review provides a broad overview of a research topic (Demeyin, 2016). During the first part of the theoretical literature review, generic regional planning principles will be discussed by firstly examining theories on planning in general, and secondly by defining the regional concept, which will be followed by examining regional location theories. During the second part of the theoretical literature review, relevant regional growth and development theories will be examined. The systematic literature review will analyse existing empirical studies relating to the causal relationship between renewable energy and development. The traditional literature review will examine general principles relating to energy, energy infrastructure, and renewable energy sources and technologies as well as their spatial planning implications.

The empirical section of this study will be carried out by employing a variety of research designs including; intervention research, evaluation research, mapping and visualization, and case studies. Intervention research will take the form of policy analysis during which various national energy, infrastructure and spatial planning policies in South Africa will be analysed. The evaluation research will take the form of implementation evaluation by evaluating the effectiveness of implemented energy, infrastructure, and spatial planning policies from selected countries. Mapping and visualization refer to maps on which renewable resource potential is illustrated. Lastly, case studies will be examined to determine best-practice policies for renewable energy planning and implementation. Specific cases will be purposely selected due to them possessing unique qualities, which refer to a purposive sampling technique.

1.6 Research layout and structure

This study is divided into four units consisting of nine chapters (refer Figure 1.1). The remaining eight chapters will be briefly outlined in the following section to provide the necessary context and a frame of reference for the reader. As stated above, each of the objectives and primary aim constitute a chapter in this study.

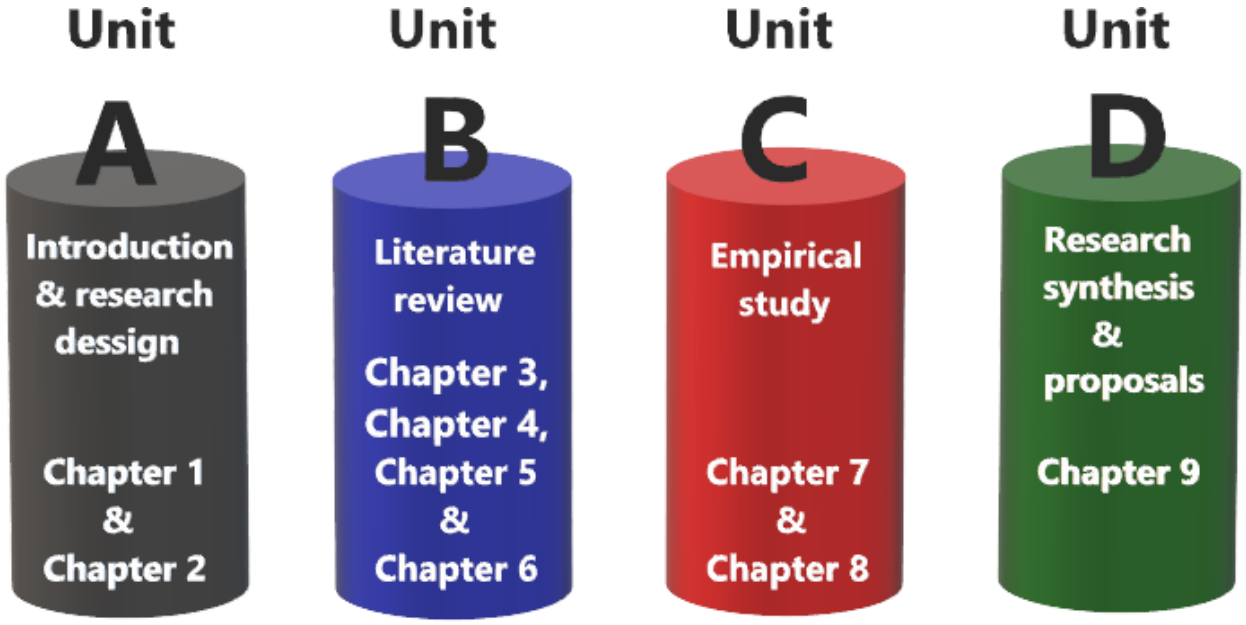

Figure 1.1: Structure of study

Source: Own compilation (2020)

Chapter Two will indicate the research methodology used for this study in more detail. Doctoral research students need to disclose their epistemological and ontological assumptions to provide justification for the chosen research design and for validating the findings. The chapter will begin by contextualising the field of study in terms of its knowledge base, whereafter the chapter will pinpoint the research purpose. The chapter will then highlight the methodological dimension, commencing with the methodological paradigm, then the methodological approach and finally the source of data. Once the above-mentioned focus has been established, the chapter will identify the specific research design(s) used in this study.

Chapter Three will focus on providing a clear understanding of the founding principles on which regional planning is based by examining the basic principles of regional planning as a professional discipline. As this study is written from a regional planning perspective, it is important to establish exactly what regional planning entails and how it can be used to achieve the overall aim of this study. Firstly, this chapter will define the regional concept to gain a clear understanding of the scale on which this study focuses. Secondly, this chapter will define the act of regional planning to gain a clear understanding of the activity and the main purpose of such an activity. Thirdly, this chapter will provide a brief description of the various ideologies

from which regional planning can be carried out as personal worldviews can influence the way professional spatial planners apply their knowledge. The chapter will then briefly explain the various regional economic concepts that will be used during the study to provide a point of reference. Finally, this chapter will examine prominent location theories to illustrate the significance of space in the spatial planning process.

Chapter Four will focus on explaining how sustainable regional development can be achieved. As this study was aimed towards achieving regional development through policy interventions it is important to understand why certain regions develop while others do not, and to determine the most likely outcome of policy interventions aimed at achieving regional development in practice. This chapter will commence by firstly examining various theories of regional development, followed by structuralist theories and modernist theories. Secondly, this chapter will examine regional development policies, followed by regional development measuring techniques.

Chapter Five will focus on the impact renewable energy can potentially have on regional development by examining the causal relationship between the two variables to determine whether renewable energy can be used to achieve regional development. This will be approached by firstly defining what exactly is meant by the term ‘development’ in the context of this study as there is no universally accepted definition for what development means. This chapter will then build on this definition by examining the relationship between development and energy in general, before examining the environmental sustainability of this relationship, and finally narrowing down the search to the relationship between development and renewable energy.

Chapter Six will focus on providing a broad understanding of the relevant renewable energy sources as well as technologies and their impact on energy, infrastructure and spatial planning by examining basic principles relating to energy, energy infrastructure and renewable energy technologies as well as their spatial implications. As this study aimed to utilize renewable energy to achieve regional development, it is important to gain a basic understanding of electrical energy (electricity) principles such as volts, amps and power due to their implications for electricity infrastructure planning. Once such an understanding has been gained, this chapter will examine the various naturally occurring renewable energy sources (applicable to the South African context) from which electricity can be generated, the various technologies used to generate electricity from such renewable energy sources, as well as their spatial implications.

Chapter Seven will focus on illustrating best-practice policy frameworks for renewable energy planning and implementation on a regional scale by examining international trends in renewable

energy planning and implementation. As this study aimed to utilize renewable energy to achieve regional development through regional planning practices, it would be wise to consider examples of how other countries around the world have done so successfully. Firstly, this chapter will highlight international trends that led to the prioritization of renewable energy, how renewable energy is being facilitated from a general global policy perspective and which renewable energy practices are leading the charge and why. Secondly, this chapter will examine individually selected countries that have successfully implemented renewable energy (specifically renewable energy that is relevant to the South African context) by examining their planning and implementation policy frameworks.

Chapter Eight will focus on identifying an integrated policy framework that can facilitate renewable energy development in South Africa by examining South African energy, infrastructure and spatial planning policies. As this study aimed to utilize an integrated and comprehensive policy framework to achieve regional development through renewable energy, the current policy framework must be examined carefully to identify shortcomings as well as potential areas of opportunity. The chapter will commence with highlighting South Africa's renewable energy resource potential both on land and within the oceans surrounding the mainland. Thereafter the chapter will provide background policy information relating to the topic. The chapter will then proceed to examine current policy including energy- and spatial planning legislation, energy, infrastructure and spatial development plans and initiatives as well as regulatory and institutional structures.

Chapter Nine is the final chapter of this study and will focus on formulating an integrated and comprehensive policy framework that is capable of facilitating renewable energy development in South Africa to achieve regional development, as this is the main aim of this study. The chapter will commence by synthesising all the relevant information from the previous chapters into a coherent unit capable of providing the necessary detail from which to draw meaningful insight. The chapter will then proceed to present proposals in the form of practically applicable policy frameworks that can facilitate renewable energy development in the South African context.

1.7 Limitations to research

While carrying out the research study the following limitations were experienced:

- Obtaining strategic spatial planning policies from China could not be achieved.
- Obtaining printed theoretical textbooks on regional planning and regional development could not always be achieved.

- As this study proposes to utilize Regional Spatial Development Frameworks (RSDFs) and Marine Area Plans (MAPs) for renewable energy implementation prior to either of these instruments being developed in South Africa, this study was limited in terms of ensuring contextual applicability.
- This study makes the assumption that better planning will lead to better results.

CHAPTER 2: RESEARCH METHODOLOGY

2.1 Introduction

Before the findings of this study are presented and discussed, it is important to explain the research methodology that was used to provide justification for the arrangement of the study, the methods used in acquiring the relevant data as well as the presented findings. According to Knight and Turnbull (2008:73), it is of vital importance for researchers to make clear their methodological and epistemological assumptions, especially for those defending a doctoral thesis. Blaikie (1993:6-7) explains that epistemology is the theory of knowledge and refers to the grounds of knowledge itself, and what criteria new-found information must satisfy in order to be labelled true knowledge, as opposed to beliefs. Knight and Turnbull (2008:73) state that the researcher's ontological assumptions on which the research is based should be made explicit to the reader and be coherent with the methodology used. According to Blaikie (1993:6-7), the term ontology refers to the study of reality. From this, it can be concluded that a researcher's personal beliefs and ideologies influence what constitutes as reality (ontological assumptions) and findings under such a paradigm (refer Section 2.4), and must be justified as being true knowledge (epistemological validation) by making explicit their research methodology.

Both ontology and epistemology can therefore be seen as falling within the philosophical realm of research (refer Figure 2.4) as they are concerned with the claims or assumptions about reality and the claims or assumptions about knowledge, respectively, or what is also referred to as meta-science. Meta-science is best illustrated by Mouton (2001:139) in the *Three world* framework (refer Figure 2.1) where World 1 represents the world in which we live and where lay knowledge is used by all people to interact with the real world. World 2 goes beyond World 1 and represents the world of science where scientific knowledge is used by scientists to understand the real world. World 3 goes beyond World 2 and represents the world of meta-science and is the critical analysis of World 2 (or the philosophy of science), which includes research methodology.

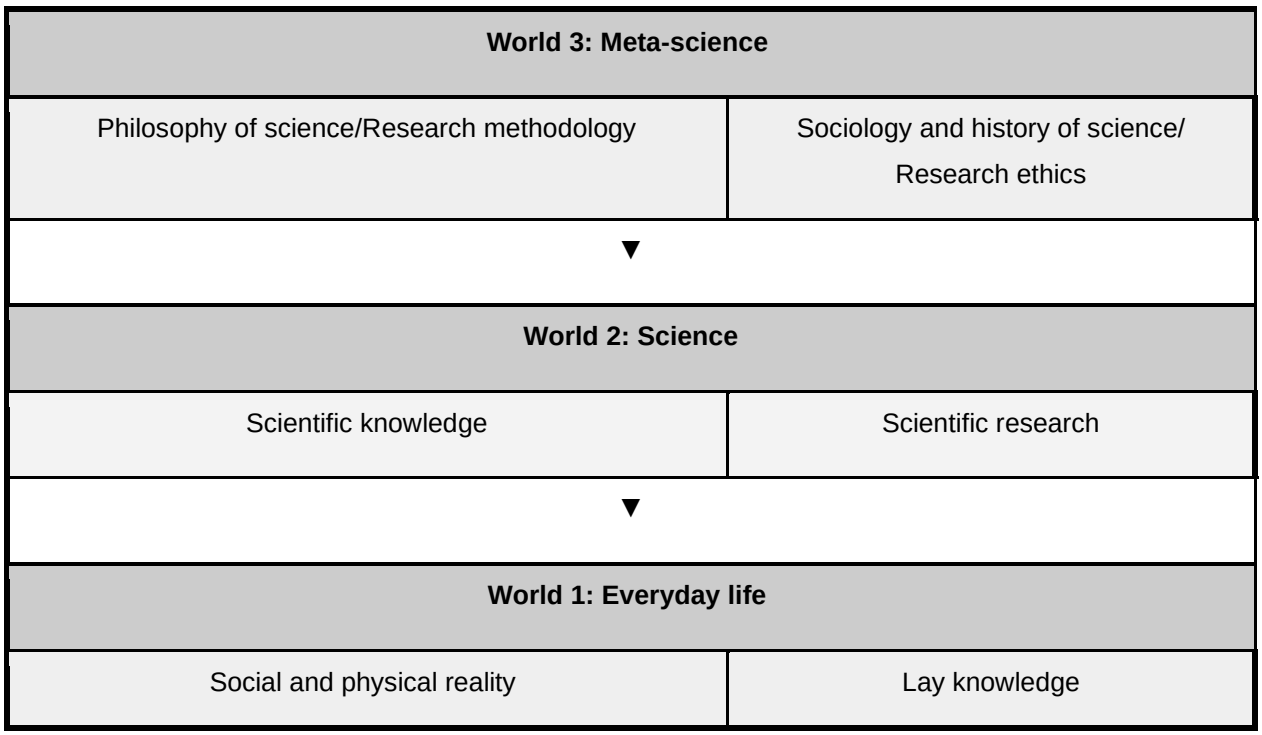

Figure 2.1: The 'three worlds' framework

Source: Mouton (2001:139)

The meaning of the term 'research methodology' can be confusing, as it has been widely used in academic research. Similarly, terms such as 'research design' and 'research method' have also been widely used. However, when discussing research methodology, it is important to make the distinction between these terms clear from the beginning. Blaikie (1993) points out that we often use these terms interchangeably, even though they have different meanings. He goes on by describing research methodology as "the analysis of how research should or does proceed. It includes discussions of how theories are generated and tested – what kind of logic is used, and what criteria they need to satisfy" (Blaikie,1993:7). Therefore, research methodology entails the use of both research designs and research methods.

Even though the term 'research design' is commonly accepted to refer to the overall plan a researcher uses to conduct research, Du Toit (2010:12) points out that surprisingly little effort is made by academics to explain the purpose of the research design. To that end, Hedrick *et al.* (1993:39-40) explain that the purpose of a research design is to maximize the validity of findings. De Vaus (2001:9) explains that the purpose of a research design is to answer the research question(s) as unambiguously as possible. The latter clarification is shared by Robson (2002:79), stating that a research design should be appropriate for the questions one wants to answer. Du Toit and Mouton (2013) developed a typology of research designs for social research in the built environment, during which they narrowed the criteria down to six considerations, including: (1) research context, (2) research aim, (3) research purpose, (4) methodological paradigm, (5) methodological approach, and (6) the source of data. However,

according to Du Toit (2010:182), the research context and research aim can be combined due to them being sufficiently similar. To determine which research design was used as well as to provide a motivation for the chosen research design, this chapter will be structured around the above-mentioned considerations.

2.2 Research context and aim

Since the time of ancient Greece, the academic society has found it useful to categorize the various forms of knowledge (Chynoweth, 2009:302). Categories of knowledge can take a variety of forms; firstly, knowledge can be categorized according to disciplines; secondly, knowledge can be categorized as either pure or applied; and thirdly, knowledge can be categorized as being either a science or an art (refer Figure 2.2) (Chynoweth, 2009:302; Neuman, 2006:26). Therefore, to determine the context and aim of this study accurately, it is necessary to first define the discipline in which this study is conducted. The 'built environment' subject area is now an established field of study; however, it has traditionally been defined in terms of a collection of disciplines such as architecture, construction management and economics, urban design, and planning, and can therefore be categorized as being multidisciplinary (Chynoweth, 2009:302; Du Toit, 2010:12).

It is, however, generally acknowledged that the built environment disciplines, especially architecture and planning, are applied sciences due to the focus being on the application of knowledge as opposed to the generation of knowledge (Chynoweth, 2009:302; Klosterman, 1983:216; Knight & Turnbull, 2008:73). The built environment disciplines are consequently not as concerned with research methodology as disciplines that focus on the generation of knowledge (Du Toit & Mouton, 2013:126). The built environment's applied research orientation can be illustrated by pinpointing its knowledge base within the Biglan model (refer Figure 2.2). This exercise additionally illustrates the vast diversity of the built environment which seems to span almost the entire spectrum of sciences and arts. According to Chynoweth (2009:306), the latter point can lead one to ask whether the built environment field can even be described as an academic discipline at all, or whether it is more accurately defined as an amalgamation of disciplines aimed to serve the various fields of application.

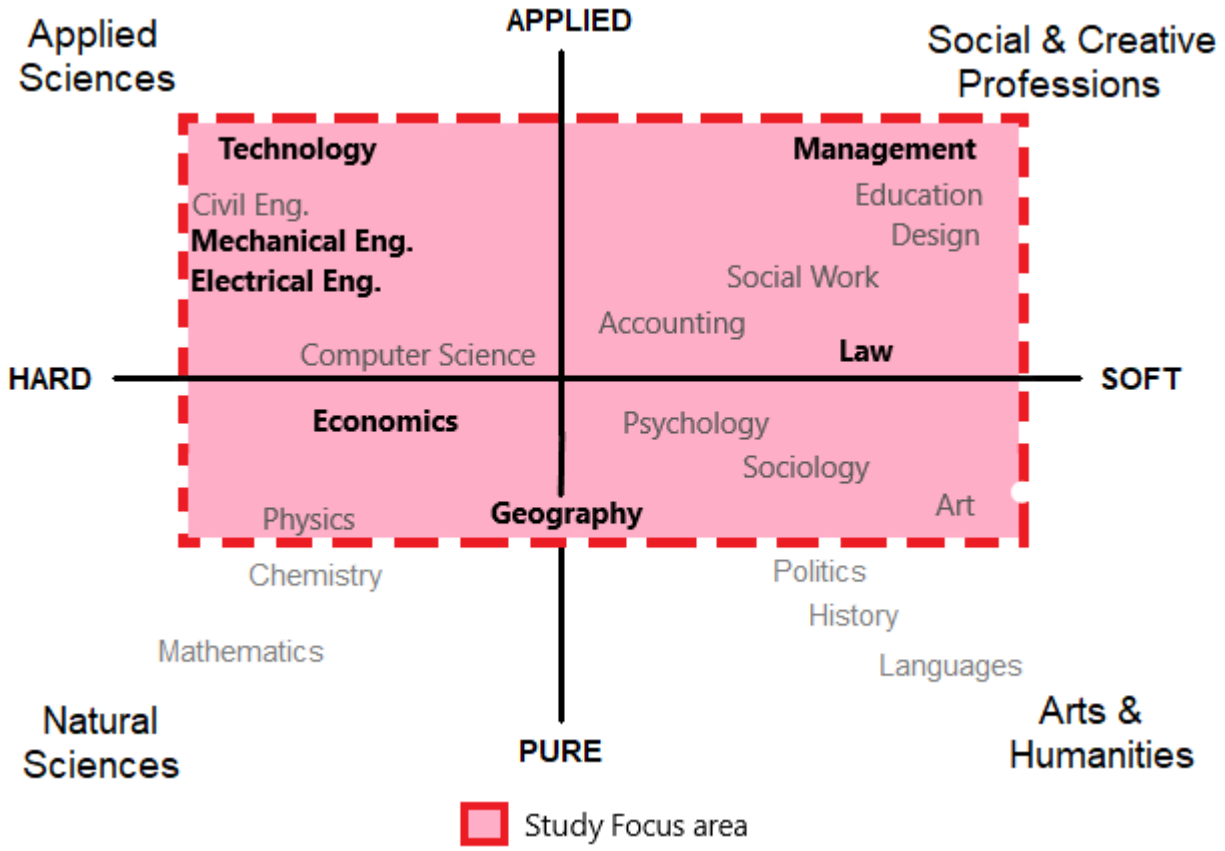

Figure 2.2: The built environment knowledge base according to the Biglan model

Source: Chynoweth (2009:307)

In order to contextualize this particular study more accurately, Table 2.1 is used, which makes a focused comparison between pure and applied research from which the following observations can be made: The primary audience for this research is practitioners in the public sector responsible for making energy, infrastructure and spatial planning policy decisions and will therefore be best evaluated by such practitioners. As this study will make recommendations that should be accommodated by existing policies, autonomy is relatively low. In acquiring the necessary data for making proposals, a mixed-method, yet predominantly qualitative research approach will be taken (refer Section 2.5), which compared to quantitative research approaches, makes the research rigour more varied. Due to this study's primary goal of formulating an integrated policy framework in which regional development can occur through renewable energy deployment (refer Section 1.3), the aim is to solve a practical problem with the highest priority being relevance, and the success will be indicated by its applicability. It can therefore conclusively be deduced that this research falls within the 'applied' research context.

Table 2.1: Basic vs applied research contexts

Criteria	Research context	
	Basic	**Applied**
Primary audience	Scientific community	Practitioners
Evaluators	Research peers	Practitioners, supervisors
Autonomy of research	High	Low-moderate
Research rigour	Very high	Varies, moderate
Aim	Creating new knowledge	Solving practical problems
Highest priority	Verified truth	Relevance
Success indicated by	Publication and impact on knowledge/scientists	Direct application to address a specific concern/problem

Source: Neuman (2006:26)

2.3 Research purpose

As stated in the previous section, a study's research design must be suited to answer the research question(s) as unambiguously as possible (De Vaus, 2001:9; Robson, 2002:79). The primary research question is based on achieving the overall purpose of the study. Within the teleological dimension, a variety of terms including 'research aims', 'research purposes', and 'research objectives' are used interchangeably, even though they have distinct meanings (Fouché & De Vos, 2005:104). For this study, each one of these terms will be defined individually.

According to Thomas and Hodges (2010:38-39), the term 'research aim' normally refers to the overall goal of a research project and is expressed in a brief yet general manner, whereas the term 'research objectives' normally refers to two or more measurable and attainable outcomes in pursuit of the research aim, expressed in a more specific manner. The 'research purpose' refers directly to the research aim expressed using a single methodological term (Du Toit, 2010:35). As stated in the previous section, the research context (i.e. pure vs. applied) depends in part on the research aim (i.e. generating new knowledge vs. applying existing knowledge to solve a problem), resulting in the distinction being made between two categories of aims,

namely theoretical vs. practical aims where the former relates to pure research, and the latter to applied research contexts (Du Toit, 2010:33). Where theoretical aims are concerned, methodologists generally refer to three main research purposes, namely: (1) explanatory, (2) exploratory, and (3) descriptive studies (Du Toit, 2010:33). As it has already been established that this study falls within the applied research context, theoretical aims will not be discussed in further detail.

Due to practical research outcomes generally being aimed at practitioners, as opposed to the scientific community (refer Table 2.1), research in the applied context realm is allowed a greater degree of flexibility in the research process (Du Toit, 2010:34) and is perhaps the reason why textbooks seldomly refer to practical research purposes. However, Neuman (2006:26-31) proposes that practical purposes may include any aims directed towards improving the quality of life and generally take the form of 'evaluative' and/or 'emancipatory' research purposes. Du Toit (2010:34) argues that seeing as planners tend to do research that will enable them to intervene in the built environment, practical research may also include 'formative' research purposes such as formulating policy guidelines among others. As this study's primary aim is to formulate an integrated policy framework in which regional development can occur by means of renewable energy deployment (refer Section 1.3), this research can conclusively be categorized as having *a* formative research purpose.

2.4 Methodological paradigm

The methodological dimension (refer Figure 2.4) entails the study of how to conduct research of which the most important considerations include the methodological paradigm, the methodological approach, and the source of data (Du Toit, 2010:41). The methodological paradigm plays an important role in how one conducts research as it refers among others to 'basic assumptions' when seeking answers and is, therefore, the first consideration within the methodological dimension acting as the link between the philosophical realm of research (such as epistemological and ontological considerations) on the one hand, and more tangible methodological considerations (such as research approach and source of data) on the other (Feilzer, 2010:8; Neuman, 2006:79-80). Consequently, in order to obtain an adequate theoretical understanding of how the methodological paradigm influences the way in which research is conducted and ultimately the chosen research design, one must take a step back towards the philosophical realm of research.

Philosophical considerations are commonly expressed implicitly in research, even though they influence research practices on a fundamental level and must therefore, according to Cresswell (2009:305-306), be expressed explicitly. As Du Toit (2010:41) explains, various philosophical

considerations have over time contributed to the emergence of well-defined methodological paradigms. Due to epistemological considerations dealing with ideas revolving around the 'search for truth' and the 'grounds for knowledge', Du Toit (2010:40) and Knight and Turnbull (2008:64) believe that in built environment research (which is predominantly applied in nature), this 'assumption about true knowledge' is less of a concern and that researchers in this field should merely aim to provide information that is at least contextually valid without grappling with irresolvable philosophical issues. On the other hand, as ontological considerations deal with 'claims or assumptions about reality', it is important for researchers in the built environment to be aware of and declare their ontological ideologies (Du Toit, 2010:36).

The ontological dimension can be divided into two considerations, namely (1) conceptions of social reality, and (2) objects of study (Du Toit, 2010:36). Within 'conceptions of social reality', methodologists highlight two main concepts, namely (1) an objectivist, and (2) a social constructivist (Du Toit, 2010:36). However, due to the predominantly applied nature of built environment research, a third concept can be added, namely (3) a realist concept (Du Toit, 2010:36). An objectivist believes that social phenomenon occurs outside the sphere of human influence, therefore, social reality can be observed objectively (Bryman & Teevan, 2005:12). A social constructivist believes that social phenomenon occurs as a result of human influence; therefore, social reality can only be observed subjectively, while a realist believes that social phenomena can be observed both objectively and subjectively (Bryman & Teevan, 2005:3). The applied nature of this study lends itself to a 'realist' conception (refer Figure 2.4).

Within the 'objects of study' consideration, three main distinctions can be made: The first relates to social objects, physical objects, and the interaction between the two; the second relates to the substantive vs. procedural dichotomy; and the third relates to the positive/descriptive vs. normative/prescriptive dichotomy (Du Toit, 2010:37-38).

The first of these distinctions refers to a researcher's perception of the built environment's social objects such as public works of art and historical events, and physical objects such as settlements and buildings, as well as the interaction between the two (Næss & Saglie, 2000:729). This study will focus on the interaction between social and physical objects (refer Figure 2.4). The social component is relatively subtle and will include economic principles and how they relate to economic development on a regional scale. The physical component is relatively obvious and will include physical infrastructure and renewable energy technologies.

The second of these distinctions refers to the various uses of theory in social research in the built environment where substantive theory is typically *for* planning and procedural theory is typically *on (or about)* planning where the former exclusively pursues practical aims (Næss & Saglie, 2000:732-733; Friedman, 1967a:123). This study will use a predominantly substantive

theoretical approach (refer Figure 2.4). Theoretical principles relating to regional planning and locational decision making will be discussed in Chapter 3 and can be considered to be procedural theory (on planning); however, theories relating to regional economic growth and development discussed in Chapter 4 are considered substantive theory (for planning) and will provide the majority of the theoretical guidance for this study.

The third of these distinctions refers to theory on the built environment's characteristics where positive/descriptive theory is about 'what is', i.e. what does the built environment look like and normative/prescriptive theory is about 'what should be', i.e. what should the built environment look like (Næss & Saglie, 2000:732). This study will use a normative/prescriptive theoretical approach (refer Figure 2.4). Due to this study aiming to formulate an integrated policy framework wherein regional development can occur through renewable energy deployment, it proposes how infrastructure, energy, and spatial planning should be.

Now that an adequate understanding of the philosophical realm has been gained, the methodological dimension can be discussed further. As stated earlier, the methodological paradigm is the first consideration in the methodological dimension and acts as a link between the philosophical considerations and more tangible research considerations (refer Figure 2.4). These paradigms are broad philosophical ideas on how to conduct research and include four main paradigms, namely (1) positivism, (2) interpretive social science, (3) critical social science, and (4) pragmatism (Du Toit, 2010:42).

- Positivism is primarily applicable to 'hard' and 'pure' sciences; therefore, falling within the natural sciences quadrant of the Biglan model (refer Figure 2.2) and it is largely concerned with discovering natural laws in order to make predictions (Neuman, 2006:105).
- Interpretive social science is primarily applicable to 'soft' and 'pure' sciences; therefore, falling within the arts and humanities quadrant of the Biglan model and is largely concerned with understanding social human interactions (Neuman, 2006:105).
- Critical social science is also primarily applicable to the 'soft' and 'pure' sciences, but takes a critical stance against common social human behaviour in an attempt to help people navigate their way through the myths and misinformation that serve to harm them; therefore, gravitating more towards the applied sciences, compared to the interpretive social science paradigm (Neuman, 2006:105).
- Pragmatism is primarily applicable to 'applied' sciences, as this paradigm is aimed at solving problems in the real world to improve the human condition. However, there does not seem to be any clear orientation towards 'hard' or 'soft' sciences, thus favouring multidisciplinary research in the applied sciences (Robson, 2002:42-44). Formative

research purposes are renowned for having a more pragmatic attitude towards research (Chynoweth, 2009:302; Du Toit, 2010:35).

As this study is based on a multidisciplinary academic field within the applied research context (refer Section 2.2) and has an established formative research purpose aimed at solving problems in the real world (refer Section 2.3), it can be concluded that this study falls within the pragmatic research paradigm.

2.5 Methodological approach

Methodological paradigms steer towards the second consideration within the methodological dimension i.e. the methodological approach (Du Toit, 2010:46). The methodological approach refers to the types of data used to acquire the most reliable results and can be divided into two types, namely (1) quantitative and (2) qualitative data, where the former refers to data that generally take the form of numbers or statistics aiming to answer the 'what' of a programme, and the latter refers to data that generally take the form of words or images aiming to answer the 'how' and 'why' of a programme (Du Toit, 2010:46; Kabir, 2016:202-203). According to Bhattacherjee (2012:56), reliability in research refers to how dependable and consistent the source is and goes on to say that qualitative sources are at a greater risk of being unreliable due to the subjective (or interpretive) nature of qualitative data in comparison to quantitative data.

However, according to Du Toit (2010:65) and Creswell (2009:10-11), issues regarding reliability are less of a concern in research with a pragmatic attitude and applied context (as is the case in this study), resulting in built environment researchers often following a mixed-method approach using both quantitative and qualitative data. According to Newman and Benz (1998:78), qualitative and quantitative approaches should not be seen as dichotomies, but rather as different ends of a continuum. Cresswell (2009:3) takes a similar stance, stating that most studies tend to follow a mixed-method approach, albeit generally favouring either a qualitative or quantitative approach. The latter explanation is extended upon by Johnson and Onwuegbuzie (2004:17), explaining that even though a mixed-method approach uses both quantitative and qualitative methods, the specific use of either method in the combination should be tailored towards achieving the desired outcome. According to Kabir (2016:203-204), mixed-method approaches include a multifaceted approach aimed to combine quantitative and qualitative methods that will enable the researcher to take advantage of the strengths and reduce the weakness that can result from using a single method. Steckler *et al.* (1992) illustrats the use of mixed method approaches by making use of four models (refer Figure 2.3), each combining quantitative and qualitative methods in varying combinations.

Model 1 illustrates the use of qualitative methods to help develop quantitative measures and tools. For example, it can be beneficial for a researcher to conduct focus groups prior to developing a structured questionnaire (Steckler *et al.*, 1992:4). Model 2 illustrates the use of a predominantly quantitative approach, using qualitative data to help explain quantitative findings (Steckler *et al.*, 1992:4). Model 3 illustrates the opposite to Model 2 whereby a predominantly qualitative approach is used and highlighting such findings by means of quantitative data (Steckler *et al.,* 1992:4). Model 4 illustrates the equal use of qualitative and quantitative methods in parallel, often used to cross-validate the findings from both (Steckler *et al.*, 1992:5).

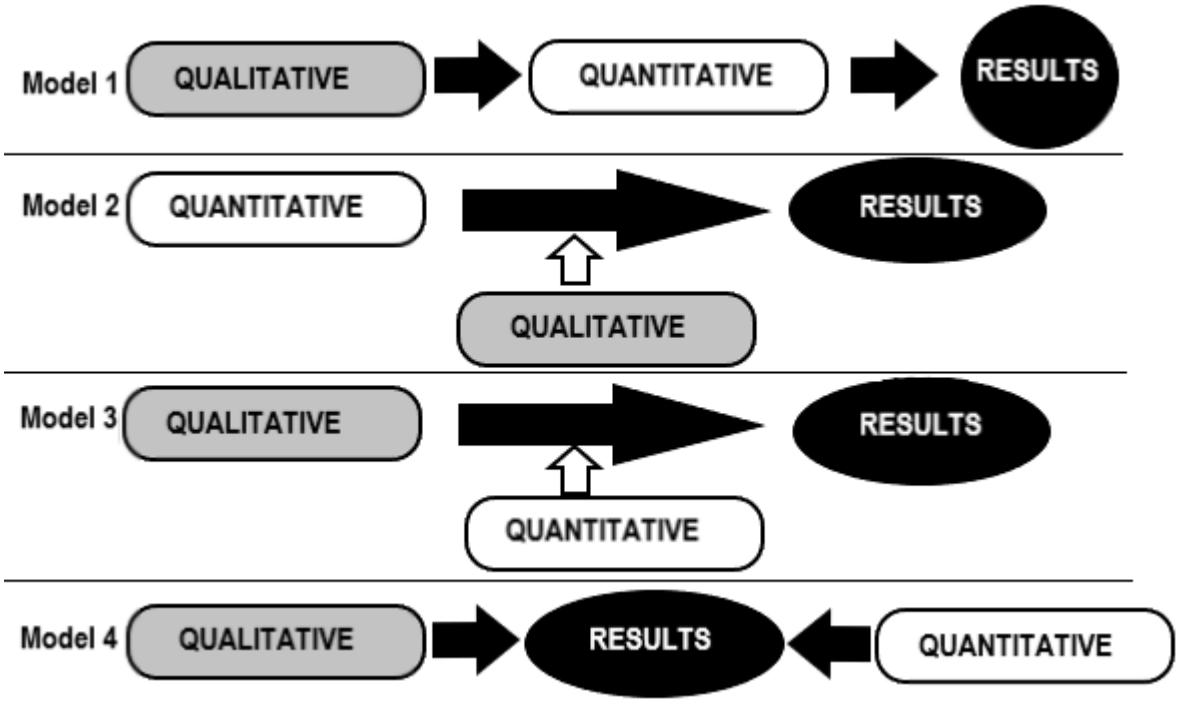

Figure 2.3: Mixed-method options

Source: Steckler *et al.* (1992:5)

This study will make use of a mixed-method methodological approach favouring qualitative data in accordance with Model 3 where quantitative data will be used to embellish or support qualitative data. As Du Toit (2010:50) points out, mixed-method approaches tend to use more flexible research designs making use of both numeric and textual data. Theoretical chapters discussing planning theory (refer Chapters 3 & 4) will make use of qualitative textual data to achieve the desired results, whereas theoretical chapters discussing renewable energy and economic development principles (refer Chapters 5 & 6) will make use of both numeric and textual data to achieve the desired results. Empirical chapters evaluating energy, infrastructure, and spatial planning policies (refer Chapters 7 & 8) will again use both numeric and textual data to achieve the desired results.

2.6 Source of data

The source(s) of data is the third consideration in the methodological dimension (refer Figure 2.4) and typically refers to the origin of the information used in the research process (Du Toit, 2010:50; Kabir, 2016:202). While the chosen research design may vary between different types of research projects, the importance of gathering data in an efficient and honest fashion while maintaining the integrity of the research remains the same (Kabir, 2016:202). There are many methods of classifying data; however, a common classification method is based on who gathered the data. Data that have been gathered by the researcher from first-hand experience is known as primary data, whereas data gathered from a source that has already been published by someone else for a particular purpose is known as secondary data (Du Toit, 2010:50; Kabir, 2016:204-205). It is commonly accepted that primary data are more authentic and objective than secondary data, as the information has not been altered or manipulated by other human beings, as is the case with the latter (Kabir, 2016:204). Research designs that typically use primary data include experiments, surveys, field studies, and case studies, whereas research designs that typically use secondary data include mapping and visualization, and textual and narrative studies (Du Toit, 2010:196; Kabir, 2016:204-205).

For this study both primary and secondary data were used or what is also referred to as hybrid data (Du Toit, 2010:58). There is some confusion as to whether government documents such as legislation and statistical data are primary or secondary data. According to the UNSW library (2020), primary and secondary source categories are not fixed and often depend on the context in which the sources are used in the research being undertaken. If legislation is analysed for policy formulation purposes, it can be considered as primary data. However, if legislation is analysed to determine the impact thereof on people's lives, it can be considered as secondary data. The following section will provide an overview of the sources used in this study.

Primary data sources include:

- Government documents (statistics reports, policy documents, white papers, bills, and acts).

Secondary data sources include:

- Government documents (reports, public policy briefs, and consultation papers).
- Theoretical research textbooks (chapters in edited textbook compilations intended for theoretical research in research methodology, regional planning, regional development, and economic development).

- Applied research textbooks (chapters in edited textbook compilations intended for applied research in renewable energy technologies and economic development).
- Theoretical research journal articles (focussing on research methodology, regional planning, regional development, environmental planning policy, economics, political economy, economic geography, and public policy).
- Applied research journal articles (focusing on regional planning, regional development, renewable energy technologies, economics, economic development, and public policy).
- Non-Government Organizations (NGOs) documents (including renewable energy reports, and renewable energy conference proceedings).
- Professional trade sources (technology handbooks and manuals).
- Conceptual papers.
- Theses and dissertations (focusing on research methodology, regional planning, and regional development).
- Internet articles (focusing on research methodology, regional planning, regional development, renewable energy, and public policy).

This research was conducted using: (1) the University of the Free State (UFS) online library platform, (2) the internet, and (3) printed textbooks.

2.7 Research design

During a comprehensive study of designs for research in the built environment, Du Toit and Mouton (2013:125) identified 25 research design subtypes emanating from a total of 10 prototypical research designs, including (1) surveys, (2) experiments, (3) modelling, simulation, mapping and visualization, (4) textual and narrative studies, (5) field studies, (6) case studies, (7) intervention research, (8) evaluation research, (9) participatory action research (PAR), and (10) meta-research. The term ‘research design’ can be defined as “the overall plan a researcher uses to conduct research in order to maximize the validity of findings” and the purpose of a research design is to answer the research question(s) as unambiguously as possible (refer Section 2.1). According to Du Toit (2010:119-120), the aforementioned statements suggest that “core logics” can be used to select an appropriate research design, since all studies have a research question (which is based on achieving the overall purpose of the study), meaning that the most logical plan will have the best chance to answer the question.

The overall aim (or purpose) of this study is to formulate an integrated policy framework in which regional development can occur through renewable energy deployment (refer Section

1.4). The core logic of intervening in the built environment is typically associated with applied research aimed at practitioners to affect development through, among others, policy analysis and assessment, indicating that an intervention research design is best suited to achieve the overall purpose of this study (Du Toit, 2010:121; Du Toit & Mouton, 2013:133). However, it must be noted that policy analysis and assessment in applied research can also be included under a number of other research designs due to this activity's analytical requirements within the planning process, meaning that 'intervention research' normally incorporates other research designs (Du Toit, 2010:124; Du Toit & Mouton, 2013:131). Research designs typically associated with policy analysis and assessment will now be discussed to pinpoint the various designs used in this study accurately (refer Figure 2.4).

1. Intervention research:

Intervention research can be subdivided into two subtypes, namely (1) site/settlement analysis, and (2) plan/policy analysis and assessment, where the former refers to the investigation of physical space, and the latter refers to the investigation of plans and policies (Du Toit, 2010:127; Zeisel, 2006:53-59). In this study, existing national infrastructure, energy, and spatial planning policies in South Africa will be analysed (refer Section 8.3) to identify a framework in which renewable energy development can be facilitated.

2. Evaluation research:

Evaluation research can be subdivided into three subtypes, namely (1) diagnostic evaluation, (2) implementation evaluation, and (3) impact evaluation (Du Toit, 2010:108). Diagnostic and impact evaluation make use of site/settlement analysis and are typically applied in the planning for sustainable settlements (Ellis, 2005:143), whereas implementation evaluation is typically applied in policy analysis to determine the effectiveness thereof (Talen, 1996:82). This study will make use of implementation evaluation (during the course of two case studies) in order to evaluate the effectiveness of implemented energy, infrastructure, and spatial policies in Scotland and China (refer Sections 7.3 & 7.4).

3. Modelling, simulation, mapping, and visualization:

Modelling, simulation, mapping, and visualization is aimed at predicting or illustrating future scenarios in the real world and can be subdivided into two subtypes, namely (1) modelling and simulation, and (2) mapping and visualization, where the former use prediction techniques, while the latter use illustration techniques such as maps, among others (Du Toit, 2010:125). This study will use mapping and visualization to illustrate the potential for renewable energy in South Africa (refer Section 8.2) as well as in Scotland and China (refer Sections 7.3 & 7.4).

Maps will also be used to illustrate spatial planning policies in South Africa (refer Section 8.3) in addition to using maps to illustrate the proposals for this study (refer Section 9.3).

4. Textual and narrative studies:

Textual and narrative studies can be subdivided into three subtypes, namely (1) content and textual analysis, (2) discourse/conversational analysis, and (3) historiography/biography. The former two subtypes refer to plan/policy analysis and assessment (Gaber & Gaber, 2007:103-134) and socio-spatial analysis of spatial policy, respectively (Richardson & Jensen, 2003:8), whereas the latter refers to philosophical/conceptual historical research (Leedy & Ormrod, 2010:164-181). This study will make use of content and textual analysis to discuss regional development policy from a theoretical perspective (refer Section 4.5). Place-based vs place-neutral policies are theoretical understandings of how to use spatial policy and are therefore not empirical by nature, but rather theoretical.

5. Case studies:

Case studies are in-depth investigations used to examine phenomena in their own unique context and can be subdivided into two subtypes, namely (1) single/multiple case studies, and (2) comparative case studies (Du Toit, 2010:117; Kabir, 2016:253). Single/multiple case studies are generally selective, choosing to examine a single phenomenon in one or more study area, with the aim of replicating the findings, whereas comparative case studies examine two or more phenomena in a way that produces more generalizable knowledge (Kabir, 2016:253; Yin, 2003:12). This study will make use of a multiple case-study approach to evaluate the effectiveness of implemented energy, infrastructure, and spatial planning policies (i.e. implementation evaluation) in Scotland and China (refer Section 7.3 & 7.4).

Case study selection should be aimed to maximize what can be learned from the case during the time available for the study, which means that one should apply a great deal of consideration when selecting cases (Kabir, 2016:254). There are a variety of selection techniques, each aimed to achieve the above-mentioned goal. However, for the purpose of this study, the purposive sampling technique was used, also called judgemental, selective, or subjective sampling, whereby cases are deliberately chosen, based on certain qualities, they possess as opposed to choosing cases based on other criteria such as convenience, for example (Etikan *et al.*, 2016:2). Simply put, the researcher decides what needs to be known and sets out to find cases that can provide the necessary information (Bernard, 2002:51). There are several purposive sampling methods; however, for the purpose of this study, the 'extreme or deviant' case sampling technique was used, as such cases have unique qualities that often

provide significant insight into a particular phenomenon, which can be used to develop best-practice guidelines (Etikan *et al.*, 2016:3).

Scotland was chosen due to the country's world-renowned expertise in ocean-based renewable energy application. As South Africa has ocean-based renewable energy resources that can be exported, Scotland can provide valuable best-practice guidance for how to plan for such renewable energy developments. In addition, Scotland also uses an integrated planning approach whereby energy, infrastructure, and spatial planning is done in tandem with one another, which could provide valuable best-practice insights into how to integrate such planning processes. China was chosen due to the country's world-renowned solar and wind energy application. As South Africa has a considerable comparative advantage in solar and wind energy resources, China can provide valuable best-practice insights into how to plan for such renewable energy developments.

6. Meta-research

Meta-research deals with non-empirical objects of research and can be subdivided into four subtypes, namely: (1) Literature reviews and research synthesis, (2) Conceptual analysis, (3) Typology/model/theory construction, and (4) Philosophical/logical/normative argumentation (Du Toit, 2010:176). Meta-research differs from empirical research in that it is not subject to many of the design considerations such as research paradigm and research approach (Du Toit, 2010:14), in addition to not having a specific core logic to distinguish it from other designs (Du Toit, 2010:122). This means that researchers in the built environment can conduct meta-research on existing research from related disciplines to support their own research (Næss & Saglie, 2000:734).

This study will make use of literature reviews and research synthesis. For achieving research objectives one and two (refer Section 1.4), a theoretical literature review will be carried out to gain a deeper understanding of the main theoretical principles on which the research is based (refer Section 3.2, 3.4, 4.2, 4.3, 4.4 & 4.6). For achieving research objective three, a systematic literature review will be carried out to evaluate the causal relationship between renewable energy and development critically (refer Section 5.2, 5.3, 5.4). To achieve research objective four, a traditional literature review will be carried out to gain a broad understanding of renewable energy principles (refer Section 6.2, 6.3 & 6.4). To achieve the primary research aim, a research synthesis will be carried out to synthesize the findings (refer Section 9.2).

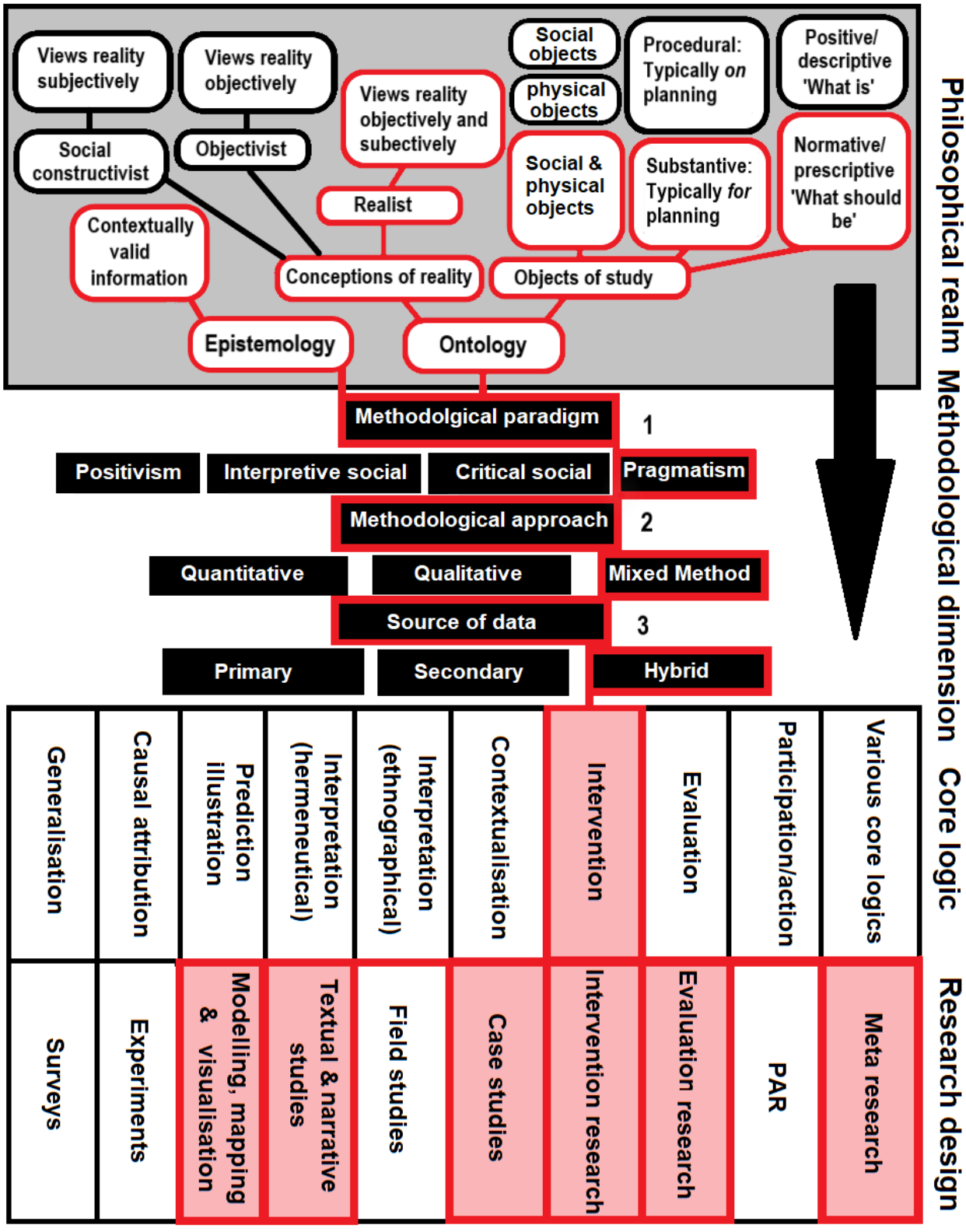

Figure 2.4: Research methodology considerations for this study

Source: Own compilation from literature (2020)

2.8 Conclusion

This chapter has provided valuable insight into the manner in which this study has been conducted by firstly establishing that this study falls within the applied research context where the purpose is to apply existing knowledge to solve practical problems, as opposed to generating new knowledge. Secondly, this chapter established that this study has a formative research purpose aiming to utilize a policy framework to intervene in the built environment. Thirdly, this chapter established that this study falls within the pragmatic research paradigm due to its multidisciplinary nature, applied research context, and formative research purpose. Fourthly, this chapter established that this study follows a mixed-method methodological approach, favouring qualitative data using quantitative data to embellish and support qualitative findings. In the fifth instance, this chapter established that this study makes use of hybrid data, combining both primary and secondary data. Finally, this chapter has established that the core logic of this study is to intervene in the built environment, thus making use of an intervention research design that, by design, will incorporate other research designs, including evaluation research, mapping and visualization, textual and narrative studies, case studies, and meta-research.

CHAPTER 3: REGIONAL PLANNING FUNDAMENTALS

3.1 Introduction

Chapter Three is aimed towards achieving research objective number one of this study, i.e. **to gain a clear understanding of the founding principles on which regional planning as a development instrument is based.** This will be accomplished by firstly defining what a region is in order to give context to the scale on which the discussion is taking place, and secondly by defining the act of regional planning in order to give context to the professional discipline on which the study is based. Once such an understanding has been gained, this chapter will briefly discuss the various ideologies from which the purpose of regional planning can be interpreted before universally accepted regional economic concepts will be discussed to provide a point of reference for when these concepts are used in varying contexts during the course of the study. Economic location theories will then be discussed as they can provide useful insight to planners for formulating effective policies that have a spatial impact. This chapter will then conclude by summarizing the most important findings.

3.2 Regional planning principles

Research objective number one relates to theoretical and practical principles. Principles are fundamental truths that form the basis of a system, behaviour, or in this case, a professional discipline. Regional planning principles will therefore be examined in the following section, commencing with the definition of the regional concept, followed by defining the act of regional planning.

3.2.1 What is a region?

To comprehend the principles underpinning regional planning, the regional concept must first be defined. However, there does not appear to be a single or universally accepted definition for what constitutes a region, as the concept differs internationally both in terms of scale and characteristics. Regional development theorists have studied regional growth and decline but among such individuals, there does not seem to be consensus as to how the term region should be defined (Dawkins, 2003:133). The term ‘region’ (which derives from the Latin word *regio* meaning province) can be used in several different contexts. There is also no need for spatial plans to fit tightly into a particular scale or functionality, as an overlapping of both exists in most cases, making it extremely difficult to compare regions (Nel & Barclay, 2011:10).

There are naturally several definitions put forth for what constitutes a region and are normally based on either the scale or characteristics thereof or both. Some of the definitions include; an area typically larger than a city but smaller than a nation, a geographical area with specific homogeneous characteristics, and a geographical area that serves some sort of function. Glasson (1974:7-9) states that regions are typically based on a scale between a city or town, and an entire country when referred to in general terms and that regions are stretches of land with distinct economic and social characteristics. Glasson (1974:9) goes on to say that the economic and physical elements in regions are more closely intertwined compared to town or city planning, as the one element has a more predominant impact on the other on this scale, adding physical characteristics to the list.

The importance of regions was debated in many social and environmental sciences during the 1990s when economic geographers such as Scott (1998) and Stroper (1997) showed their interest in the 'new regionalism', arguing that economic forces have placed an even greater emphasis on regions than ever before. Each discipline viewed regions from their own perspectives and whether or not a region should be linked to a particular scale, as it has been suggested that a region can range between sub-national, national, multinational, and global scales (Friedman, 1967:119). The historical and spatial context in which a region is viewed directly influences what is seen as a region, meaning that the concept of regions is extremely elastic (Glasson & Marshall, 2007:6). The above-mentioned elasticity is fortunately not completely limitless, as it is commonly agreed in the planning profession that the regional scale is in most instances smaller than an entire country (or sub-national), and almost always larger than a municipality (or local government). However, the latter can be a source of confusion, as each country has its own unique demarcation systems relating to local authorities (Glasson & Marshall, 2007:8).

German geographer Walter Christaller (1966) made early attempts to define this subjective concept in the 'central place theory', suggesting that regions are based on hierarchical geographic areas linked through the inner workings of larger cities and their surrounding towns, where each region will have a small number of large towns, and a large number of small towns. The cities' order is determined by the diversity of goods and services they offer, which is also directly determined by the size of the market for said goods and services. Christaller's theory hypothesizes that lower-order towns are net importers, whereas the larger cities are net exporters which, according to Dawkins (2003:133), complicates the act of regional definition as the central place theory overwhelmingly explains regions in a market-orientated spatial context. The concept of a region is therefore subjective and as James (1952:205) aptly puts it "no system of regions is right and all the others wrong: there are as many regions as there are problems worth studying". Other attempts by regional economists such as Hoover and

Giarratani (1984:125) concede that the definition of a region depends on the particular use of said region, but then goes on to say that a region is commonly known by some or other unique characteristic that when thought of, brings to mind that particular geographical area.

Arguments as to what constitutes a region can be subjective or objective (Glasson, 1974:19). The former is more widely accepted by planning professionals and advocates that a region can be used as a tool to achieve a particular purpose such as economic development (Hartshorne, 1959:31), whereas the latter asserts that regions are a natural phenomenon and nothing more (Glasson, 1974:19). Both objective and subjective views allow for regional classification based on homogeneity or heterogeneity, where the former is known as a formal region, and the latter is known as a functional region (Glasson, 1974:20). Within the formal region, lies the 'natural region', as it refers to the homogeneity in the natural environment based either on climate, land configuration, vegetation, or population density (see Hebertson, 1905). It is, therefore, possible to demarcate a region based on homogenous natural characteristics. It is noteworthy that the formal region does not have to be homogeneous in all aspects; merely those that are of concern. Economic formal regions can be seen as a form of natural regions, as they are based on areas where a particular type of industry will flourish based on homogenous physical characteristics (Glasson, 1974:21), for instance, agricultural activities based on favourable soil conditions, or in the case of this study, renewable energy development based on naturally occurring and renewable forms of energy sources.

Regions may be functional or formal, based on single or multiple criteria; however, it has become accepted that regions are mainly used by regional planners as a means to an end or 'tool', if you will, as opposed to being an end in itself, thus favouring the subjective view (Glasson, 1974:22). The subjective view can draw on functional regions to achieve a predetermined goal by making use of the interdependence and relationships between various heterogeneous elements within any given area, or on formal regions by achieving said goal by making use of homogeneous characteristics (refer Figure 3.1) (Glasson, 1974:21).

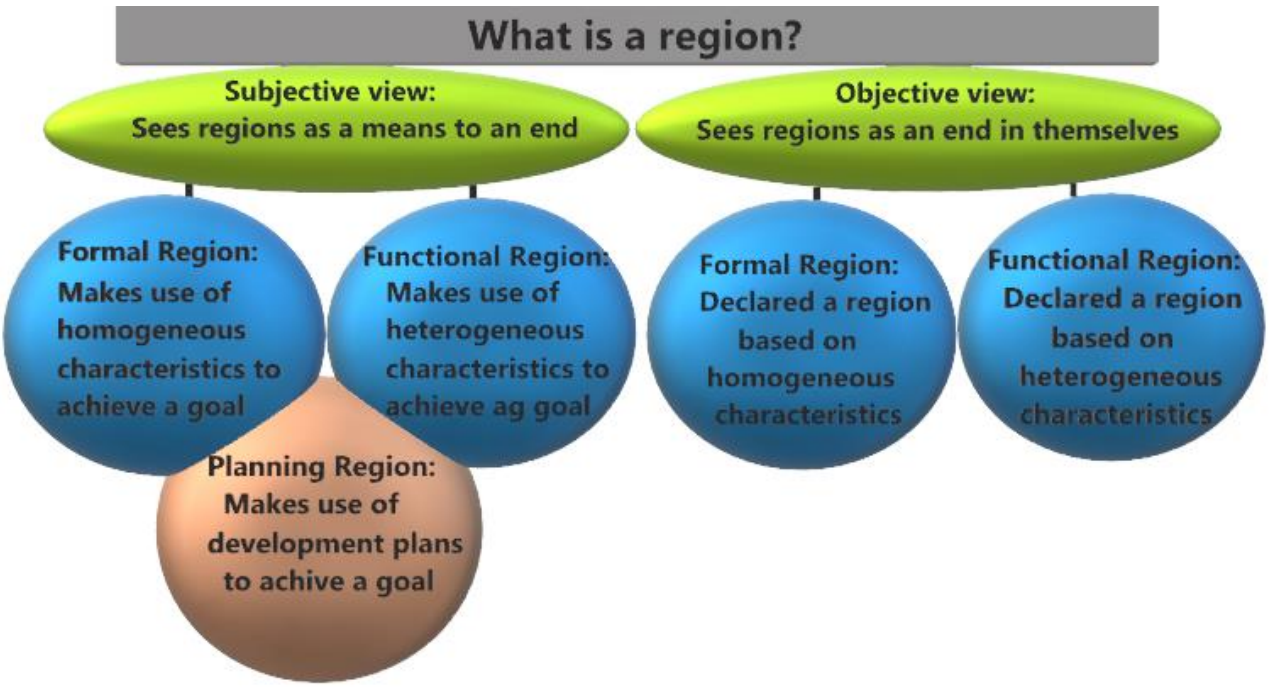

Figure 3.1: Regional differentiation

Source: Own compilation from literature (2020)

There is also a third type of region that can be either formal or functional, or a combination of the two, and it is classified as a planning region (refer Figure 3.1). Boudeville (1966:11) defines a planning region as a single stretch of land that supports economic decisions. Keeble (1969:47) describes a planning region as being large enough to see substantial changes in population distribution, yet small enough for problems to be easily identifiable. Planning regions, therefore, differ from both formal and functional regions in that they are defined not by their homogeneous or heterogeneous characteristics, but rather by the purpose for which they are used. Friedmann (1966:41-44) identified five types of planning regions:

- core regions,
- upward transitional regions,
- resource-frontier regions,
- downward transitional regions, and
- specialist problem regions.

These five planning regions are based on the core-periphery model (Friedmann, 1966), which proposes that nations can be divided into two development regions; the first being the core, and the second being the periphery that surrounds the core. The core planning region exists within the core, and the upward transitional region falls within the semi-periphery, while the downward transitional region, the resource-frontier region, and the special problems region falls within the periphery (see Figure 3.2).

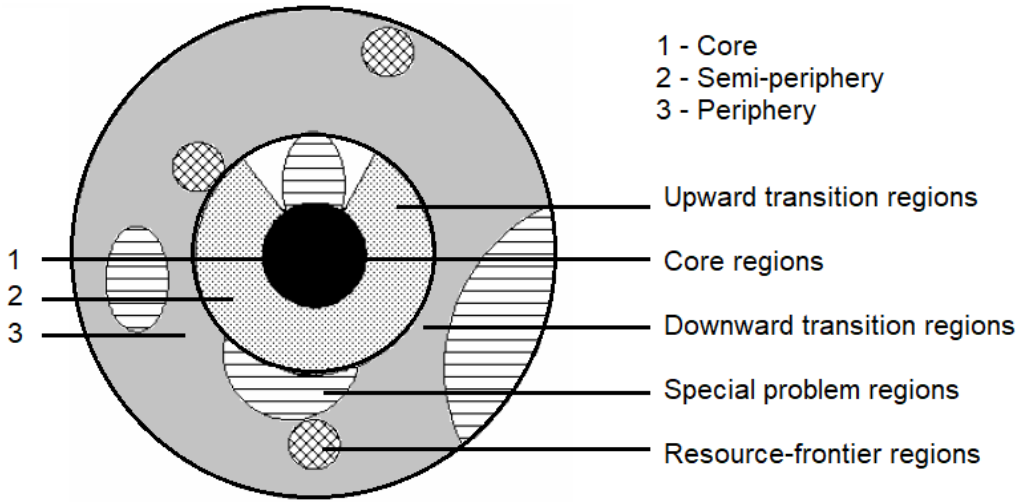

Figure 3.2: Planning regions

Source: Adapted from Friedmann (1966)

The core regions are characterized by rapid growth with established and sophisticated social and economic infrastructure (Friedmann, 1966:41). The upward transitional regions are emerging regions characterized by growth and newly established infrastructure (Friedmann, 1966:41). The resource-frontier regions are characterized by newly discovered resources (usually natural resources) that can be exploited (Friedmann, 1966:42). The downward transition regions are characterized by a declining economy with aging infrastructure, whereas the special problem regions require special approaches due to their unconventional character (Friedmann, 1966:43). Based on the above literature, this study will explore the use of resource-frontier regions to achieve regional [economic] development.

To utilize a planning region to achieve economic development, one must first demarcate the region to establish clear boundaries within which the necessary administration can occur. Administrative regions are used by governments to achieve the desired goal (Glasson, 1974:32). The demarcation of regional boundaries and the delineation process differs, depending on whether the region is formal or functional. In the case of the former, the weighted index number method (see Boudeville, 1966) is a simple process, but not without limitations, especially when referring to isolating the chosen criteria, whereas the factor analysis method (see Berry, 1961) has been proven equally effective. In the case of the latter, flow analysis (using the flow of people, goods, or activities as the criteria) or gravitational analysis (using forces of attraction between places as the criteria) can be used (Glasson, 1974:26-32).

The weighted index number method attaches a numerical ‘weight’ to selected criteria and simply includes those areas where the numerical outcome is significantly more or less than desired or in comparison to other areas. For instance, if annual solar radiation and proximity to grid infrastructure are used as the selected criteria, a numerical weight can be added to the

solar radiation value (the higher the radiation, the higher the numerical weight) as well as the distance from grid infrastructure (the shorter the distance, the higher the numerical weight) and only include areas in the region with a satisfactorily high enough numerical value. The factor analysis method uses mean averages (X) and standard deviation (SD) to either include or exclude areas from the region (R). Simply put, all areas where the average measurement based on the selected criteria is prevalent will be included in the demarcated region, including those areas where the standard deviation from the mean average is less than initially agreed upon (Glasson, 1974:24). This method, however, is more suitable for demarcating regions where the average values can be used as opposed to minimum and maximum values. Flow analysis uses the direction and intensity of existing and predictive movement between the dominant centre and surrounding satellites (Supriya, 2014:9). The closer to the core, the higher the intensity of the flow and vice versa. The demarcation boundary cuts off where flow significantly drops (Supriya, 2014:9). The gravitational analysis method is based on Newton's law of universal gravitation, which states that mass attracts every other mass (Supriya, 2014:10). The force between two centres therefore is proportional to their size and the demarcated area cuts off where there seems to be no attracting forces left in play (Supriya, 2014:10).

Planning regions make use of regional plans to affect development and therefore regional planning will be discussed in the following section, commencing with defining the act of planning itself before adding the regional scale component.

3.2.2 What is regional planning?

Before one can define regional planning as a professional discipline, it would be a good idea to clarify and define the term planning first to provide the necessary context. Unfortunately, what is meant by the term 'planning' is not universally understood across the globe, between various professions, or even within the same country (Glasson & Marshall, 2007:3). The *Merriam-Webster* online dictionary defines planning as "the establishment of goals, policies, and procedures for a social or economic unit" (Merriam-Webster Inc., 2020). This definition does convey that planning is an activity aimed at achieving one or more outcomes by utilizing certain instruments. Useful as this definition may be, it is generalized to some degree and for the purpose of this study, should ideally be combined with definitions put forth by professionals and scholars in the built environment.

Friedmann (1964:61) agrees with the above definition by stating that planning should be concerned with fixing social and economic problems that may arise in the future by setting appropriate goals and achieving them by means of attainable objectives in the form of comprehensive policies and programmes. According to Robinson (2009:13), planning is a purposeful action aimed at achieving a future-orientated goal that involves a sequential step-by-

step process, beginning with answering questions such as: Where are we now; Where do we want to go; How do we get there; What are the possible implications for each of the various routes that one can take; Which option should one take and what does one need to reach the desired destination. Hall (1975:276) presents a similar definition, proposing that planning involves a process of sequential steps beginning with the identification of an overall goal and objectives, which should be redefined on a continual basis throughout the planning process. It should be explained at this point that goals are abstract targets one wishes to reach, whereas objectives are more specific and capable of both measurement and attainment (O'Neill, 2018). Glasson and Marshall (2007:3) highlight that planning (in the built environment) can be divided into two silos; one is concerned with the physical structure and/or land-use of a territory (also known as statutory planning), and one is concerned with directing an ideal or ambition for a territory (also known as strategic planning). The purpose of planning is to reach an ideal social, economic, and/or physical goal after a sequential process has been followed (Nel & Barclay, 2011:9).

Literature on planning additionally indicates that there are certain *types* of planning. Prominent regional planners have elaborated on the various types of planning, resulting in four distinctions that can be made: The first distinction is between physical planning and economic planning, where the former is concerned with the use of land or space, and the latter is concerned with the welfare of people in any particular area (Robertson, 1965:59). The second distinction is between allocative planning and innovative planning, where allocative planning aims to enhance the present state of matters and usually involves policy restructuring (also referred to as regulatory planning), and innovative planning aims to enhance both the present and future by making changes on a larger scale with a wider range of influence (also referred to as development planning) (Friedman, 1967b:238). The third distinction is between single- and multi-objective planning, where the former aims to resolve a single problem, and the latter aims to solve multiple problems with one plan (Young, 1966:78). The final distinction that can be made is between indicative planning and imperative planning. This refers to the different methods of implementation, where indicative planning merely lays down general guidelines, and imperative planning is more specific (Glasson, 1974:7).

From the above literature, one can see that just as Glasson and Marshall (2007:3) suggest, the definition of the term ‘planning’ varies to some degree, depending on the source, even within the planning profession. There are, however, sufficient similarities to conclude that planning is a purposeful action that makes use of abstract goals and more specific objectives to achieve the desired outcome sometime in the future. But why should planning be carried out in the first place? According to Glasson (1974:3), planning has been part of human behaviour since the dawn of civilization, and it can be debated whether the urge to plan stems from our biological

make-up, i.e. our basic instinct acting as a sort of ‘social driver’, preventing the destruction of human civilization, or whether it is something that is learned and passed on through the generations. Although the former argument does seem to make sense, this does not explain why there has been a dramatic increase in planning since the industrial revolution, which began in the late 1970s. Perhaps humans began to take planning more seriously after the undesirable living conditions that persisted after the Second World War, combined with population growth and wanting to create a better future.

Another distinction, or rather sub-categorization of planning as an activity within the planning profession, is the act of spatial planning, which again is also to some degree subjective due to the different definitions thereof. For instance, the European Commission (EC) defines spatial planning as “the methods used largely by the public sector to influence the future distribution of activities in space” and goes on by stating that spatial planning should aim to achieve economic development within and between regions by regulating how land is used (Shaw & Nadin 1995:24). Spatial planning, therefore, includes both regional policy formulation and land-use planning. According to Healey (2004:46), spatial planning should be utilized towards attracting investment in infrastructure by means of land-use regulation. Although regional plans do have certain similarities, each one is unique and can differ from other regional plans based on the desired goal and the ideological motive, the area being planned for and the sphere of government (i.e. local, provincial or national) being planned for (Nel & Barclay, 2011:10). It is clear that regional [spatial] planning is highly subject to political and government interference as well as the socio-economic and ideological contexts within which it is undertaken (Friedman, 1967b:227).

A comprehensive definition of regional planning is provided by the South East Joint Planning Team led by Sir Wilfred Burns (1970:4) in their strategic plan for the South East of England by stating that, on the one hand, regional planning is merely an extension of local planning, dealing with the movement of people and people-based activities that are social, economic and recreational in nature; however, on a scale much larger than that of local planning authorities (i.e intra-regional planning). On the other hand, regional planning is concerned with the movement of people and resources between regions (i.e. inter-regional planning) with the aim of achieving regional economic development. The latter sentiment resonates with Albrechts (2006:1150), stating that as regions differ from one another, strategic spatial planning should aim to use whatever resources are available to achieve regional development.

It should be noted, however, that regional development is a more subjective concept as it may appear due to regional planners' individual ideological viewpoints (Friedman, 1967b:227). For this reason, development will be contextualized in the following section.

3.3 Contextualising development

3.3.1 Preamble

Regional planners are subject to biased thoughts and/or behaviours as they are susceptible to outside physical, socio-economic, political, and philosophical influences that affect their worldviews, and therefore affect their perspectives and motives when carrying out regional planning itself (Nel & Barclay, 2011:4). The physical components referred to above include all things tangible such as the natural environment as well as all man-made structures and influences such as physical infrastructure, buildings, and pollution (Nel & Barclay, 2011:4). The socio-economic components include all man-made activities within the physical environment as well as the outcomes thereof such as wealth and/or poverty creation (Nel & Barclay, 2011:4). The political components refer to the impact of government on the physical and socio-economic elements aimed at achieving a predetermined political agenda, whereas the philosophical component refers to everything that a person learned during their upbringing, including values and beliefs (Nel & Barclay, 2011:4).

All the above-mentioned influences will have a profound impact on individual planners, the planning profession, and the planning agency during the time of planning, and as a result, for decades to come. The following section will discuss the various philosophical, economic, and political factors that have influenced regional planning and continue to do so in order to provide context for what is known to be one of the primary objectives of regional planning, i.e. to achieve regional development.

As mentioned above, regional planning primarily aims to achieve regional development, however, the question may be asked: What is meant by development? It is generally accepted that development refers to a growing economy. However, how does development differ (if indeed) from growth and how does one measure development? Economic growth is generally measured in Gross Domestic Product (GDP), Gross Value Added (GVA), Gross National Income (GNI) and/or changes in employment, whereas development is a much broader term and includes both economic growth, as well as factors that enhance the wellbeing or quality of life of a community such as health and education (CGDEV, 2016:19; Feldman *et al*., 2014:1; IEDC, 2000:3). Geographer Katie Willis describes development as having the availability of greater wealth as well as people's expanding autonomy and choice (Willis, 2005:224). Development must include open markets, high standards for education, and infrastructure assisted by an honest government and legal system wherein human rights are prioritized (Wiarda & Boilard, 1998:14). According to De Visser (2009:9), development means that citizens' material needs are met, and that wealth is distributed more equally. From the above it is clear

that individuals define development differently and, more specifically, according to their own varying ideological beliefs.

3.3.2 Varying ideologies

Even though there is no universally accepted definition for development, there are several commonalities that one can draw on to formulate a definition, which will typically include the following: An increase in economic growth, which ought to lead to greater opportunities and choices for employment, increasing household incomes, as well as improved social conditions such as health, education, and equality of income and opportunities. Even though such a broad definition of development may be commonly accepted, the varying ideologies from which individuals define development for themselves may differ substantially. The following section will discuss the idea of development from different perspectives.

3.3.2.1 Modernism

Modernism, as the name suggests, means to move away from simple hand-made means of production towards more modern technology-based means of production which among other things lead to a move from a non-secular agrarian society towards an urbanized secular society that uses science to gain a deeper understanding of the world and universe as opposed to religion (Nel & Barclay, 2011:5). Modernism is viewed from varying standpoints as some argue that modernism implies development, while others believe it to be destructive, as it has caused damage to both the environment and traditional societies alike (Nel & Barclay, 2011:5). Nevertheless, the modernist definition of development has had a profound impact on the way both capitalist and Marxist thinkers have viewed development (Nel & Barclay, 2011:5).

3.3.2.2 Capitalism

Capitalism is an ideology that supports unregulated economic markets or a free flow of capital (Nel & Barclay, 2011:5). The following section will discuss the evolution of capitalist ideas.

3.3.2.2.1 Free market

Author Adam Smith (cited by Willis, 2005:36) is probably one of the most recognizable figures in economic literature and with his book in 1776 entitled, *An inquiry into the Nature and Causes of Wealth,* argued that governments should have a smaller influence on economic markets, which should rather be left to its own devices or what some have come to refer to as the invisible hand of the market and has been dubbed ‘laissez-faire’ economics.

3.3.2.2.2 Keynesian model

The influential book *General Theory of Employment, Interest, and Money* written in 1936 by British economist John Maynard Keynes (cited by Willis, 2005:39), the idea of moving away from the laissez-faire or free-market approach was introduced and instead advocated for an increased role of government in public infrastructure spending, which would lead to positive multipliers (refer Figure 3.4) and stimulate the economy from the supply side.

3.3.2.2.3 Neoliberalism

The Keynesian model was used to rebuild Europe after the devastation caused by the Second World War (WWII); however, the free-market ideas made a resurgence in the early 1980s, advocating that state intervention in the economy be kept to a minimum, limiting the government's role to investment in public infrastructure (Willis, 2005:52). Neoliberal thinking also meant that fewer funds were made available for social and foreign welfare, marking the dawn of a liberal democracy epitomized by the Thatcher and Reagan administration in the United Kingdom (UK) and the United States of America (USA), respectively (Willis, 2005:54). It was during this time that the World Bank adopted this more liberal economic approach and based its Structural Adjustment Programmes (SAP) thereon, which meant that loans to countries came with the condition that governments had to reduce their influence in their own economies and instead allow private capital acquisition to fuel the economy (Willis, 2005:57).

The SAPs did, however, prove to be to the detriment of poor countries who now had to reduce their spending on social welfare, while seeing foreign direct investment devalue their own currencies and subsequently led to the World Bank and the International Monetary Fund (IMF) develop a Poverty Reduction Strategy using the 'Asian Miracle' as the 'poster child' for neoliberal economic reform, but which then also collapsed in late 1990 with the collapse of the Asian Markets (Willis, 2005:58-60).

3.3.2.3 Marxism

Marxist ideology aims to liberate the poor from their enslaved circumstances brought on by the capitalist system by using socialist policies to ultimately achieve a communist state. Marxism was developed by Karl Marx after it was observed in the international capitalist economic system that certain regions declined (especially in the Third World), while others developed (Dawkins, 2003:144). According to David Gordon (1971) (cited by Dawkins, 2003:144), the Marxist ideology views urban and regional growth and/or decline as a direct result of society's main mode of economic production and the social outcomes thereof is seen as the result of the inherent conflict between the upper class and the worker class. This sentiment is shared by Castells (1972:44), stating that the modern level of underdevelopment can only be understood

when seen in the context of the historical capitalist mode of production, adding that the level of underdevelopment in particular regions is due to them being exploited by capitalist regions through colonial domination.

3.3.3 Regional economic concepts

As seen from the above evidence, development is defined differently, based on varying political and economic ideologies. Conversely, there are certain economic concepts that have universal meaning. However, using these concepts in varying contexts without having a clear understanding of their meaning can lead to confusion and will therefore be explained briefly in the following section.

3.3.3.1 Agglomeration economies

Agglomeration economies are one of the best-known economic principles and refer to cost-reduction benefits that industries gain due to them being in close physical proximity to one another. The proximity creates a scenario where firms can share machinery and technology and even imitate competitors, thus directly benefiting the industries involved (Chapman & Walker 1990:116). The proximity can also create an environment where customers flock to one location for comparison shopping, benefiting both the supply and demand side of the market. In some instances, the proximity between industries can result in a pool of skilled labour to emerge in the vicinity of those industries, leading to specialized services being offered and even creating an environment for entrepreneurs to develop (Blair, 1995:59; Chapman & Walker 1990:116). For example, locating an automotive repair shop near an automotive parts dealer can attract customers to the area, as they will generally need to do business with both.

3.3.3.2 Comparative advantage

Comparative advantage refers to an individual business (or region)'s ability to produce any given good or service at a lower opportunity cost than their competitors due to naturally occurring factors of production (both human and natural), or innovation (Willis 2005:33). This allows them to sell the same goods or services at a lower price than their competitors. For example, a fishing company that is located in close proximity to the ocean spends less money on travel expenses than a fishing company that is located far from the ocean, thus enabling the first company to sell their products for cheaper due to the lower input costs.

3.3.3.3 Economies of scale

Increasing economies of scale refer to the relative diminishing number of inputs necessary to produce a fixed level of outputs due to increased efficiency (Celli, 2013:255). For example,

manufacturing one motor vehicle requires a factory and an assembly line consisting of specialized machinery and a team of specialized labourers working together for a set amount of time. However, producing two motor vehicles requires the same factory, assembly line and labourers, working for double the amount of time. This means that to double the output, only a fractional amount of additional inputs (in this case time) is required, as opposed to double the amount. Diminishing economies of scale refers to the diminishing number of outputs relative to the inputs.

3.3.3.4 Backward and forward linkages

Backward linkages refer to an industry's relationship with its suppliers, thus an increase in output by the industry in question leads to an increase in supply from industries further back in the supply chain (Tesafa, 2014:16). For example, an increase in wholesale grocery sales leads to an increase in supply from farmers who supply the wholesaler. Forward linkages refer to an industry's relationship with its customers; thus an increase in output by the industry in question leads to an increase in demand from industries further down the supply chain (Tesafa, 2014:18). For example, an increase in wholesale grocery sales leads to an increase in demand from local grocery stores that buy from the wholesaler.

3.3.3.5 Convergence/Divergence

In regional economics, these concepts refer to the gaps in prosperity between regions as illustrated in Figure 3.3 below. Convergence means that the gap is closing or becoming smaller, whereas divergence means that the gap is increasing or becoming larger.

These concepts can be broken down into conditional and absolute (Maier & Trippl, 2009:55):

- Conditional convergence refers to the closing of the wealth gap in one region in the initial stages.
- Absolute convergence refers to the closing of the wealth gap between all regions over time.

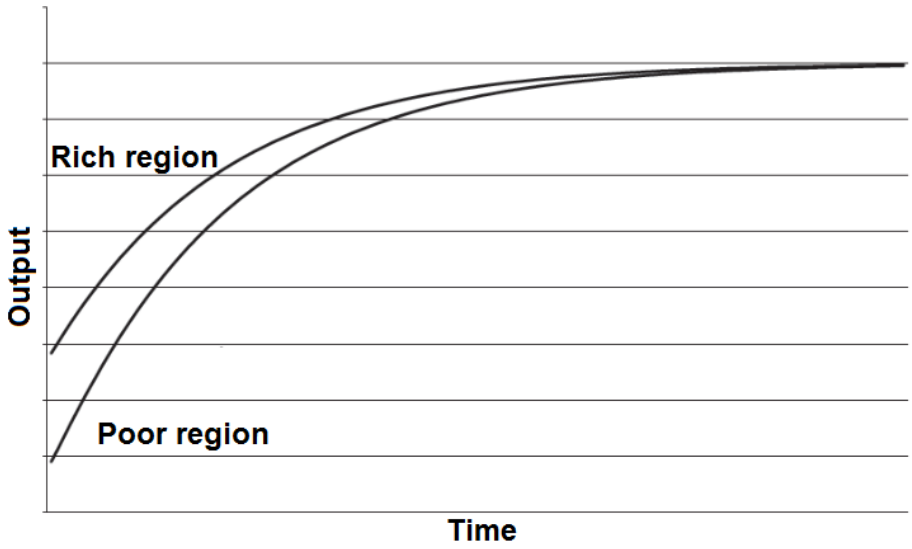

Figure 3.3: Convergence

Source: Adapted from Maier and Trippl (2009:55)

3.3.3.6 Backwash and spread effect

The backwash-and- spread effect refers to the flow of factors of production such as labour and/or capital between regions or within regions. Backwash effects occur when such factors move from the hinterland or periphery towards the centre or core (Nel & Barclay, 2011:20), for example, when labourers leave their families to move from rural regions towards cities for better employment opportunities. Should development continue, this will spread out towards the surrounding hinterland, which is known as the spread effect (Nel & Barclay, 2011:20). For example, when the labourers have made enough money to support themselves and have some left over, they typically send money back to their families who live in the rural regions.

3.3.3.7 Multiplier effect

The multiplier effect refers to the additional spending throughout the economy that occurs because of an initial investment as illustrated in Figure 3.4 below (Willis, 2005:39). For example, if R1 million is invested into building a motor vehicle factory and the sales from manufactured vehicles equal R2 million which are then either invested back into the factory or spent in other parts of the economy, will lead to an increase in the demand side of the economy leading to an increase in supply, which means more employment opportunities; therefore further increasing the demand.

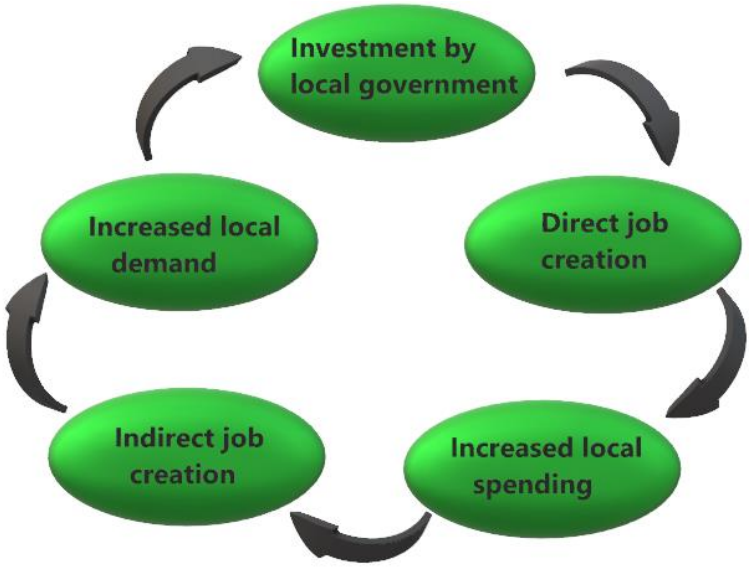

Figure 3.4: Example of the multiplier effect
Source: Adapted from Willis (2005:39)

3.3.3.8 Trickle down

Trickle down refers to the belief that it is good for the poor when the rich accumulate wealth as such wealth will eventually trickle down to the poor enabling them to acquire wealth themselves (Norton, 2002:263). For example, when a large company receives a large capital investment, they claim that poor members of the community will also benefit from the investment due to an increase in job opportunities.

3.3.3.9 Regional development theories

As with many other sciences, regional planning has provoked several theories, put forth by scholars to make sense of certain phenomena. These theories form the basis of planning thought, which ultimately leads to regional planning policy and implementation.

Over the past couple of decades, several theories of how regional economic growth and development occur collectively called regional economics have emerged (Capello, 2009:33). One of the most important questions that need to be answered in developing such theories is the manner in which ‘space’ can be reconciled with the abstract theme of economic growth and development, as space clearly has an influence on economic processes simply because of the fact that naturally occurring factors of production such as natural resources are not homogeneously distributed across the surface of the earth (Capello, 2009:33).

Introducing the concept of space into economic theory may seem obvious, however, this has not always been given due consideration as, according to Isard (1954:306), omitting space is a result of oversimplifying the process. In order to correct this oversimplification, Capello

(2009:34) identifies two main theoretical groups that combined make up regional economics: The first group is collectively called location theories and deals with how economic mechanisms distribute activities across space, and the second group is called growth and development theories and deals with economic growth and income. This study will examine both groups of theory, commencing with the location theories in the next section, followed by the growth and development theory in Chapter Four.

3.4 Economic location theories

Economic location theories focus largely on formulating mathematical models aimed at determining the optimal location of industries taken into consideration factors such as transportation costs and the location of input materials, among others (Dawkins, 2003:136). The following section of the study will discuss such location theories to gain a better understanding of how space influences economic growth and development.

3.4.1 Central place theory

Comprehension of the 'laws' that underpin the structure of regions is essential for the regional planner in order to be able to predict the reaction of regions to particular economic development policies and initiatives (Glasson, 1974:102). One of the earliest attempts to explain the spatial structure of regions came in the form of the central place theory first developed by German geographer Walter Christaller in 1933, who formulated the theory in an attempt to explain the distribution of cities of varying sizes within southern Germany. One of the basic principles of central place theory is that within any given area, there are a small number of large towns or centres (which are called central places) providing goods and services to a large number of small towns or centres that surround it (Nel & Barclay, 2011:32) and within a large enough region, one will find that centres of a similar size are located equal distances away from one another. The aforementioned phenomenon is based on the idea that should transportation costs alone be taken into consideration, a pattern of neighbouring hexagons will form (see Figure 3.5), and since some centres have a larger market area than others, particularly centres offering a larger variety of goods and services, a hierarchy will naturally emerge (Dawkins, 2003:155).

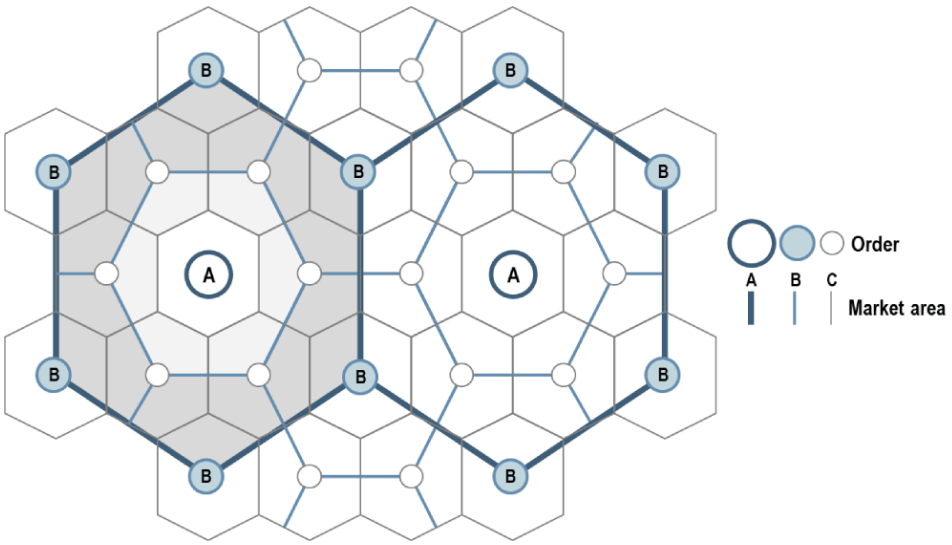

Figure 3.5: Central place theory: hierarchy of market regions

Source: Christaller (1966)

The central place theory was later expanded upon by German economist August Lösch in 1954, by using it in an economic context substituting lower and higher-order centres with lower- and higher-order firms (Dawkins, 2003:137). The theory makes use of abstract ideas such as population thresholds and market range, where the former refers to the minimum number of people required to sustain a firm and the latter refers to the distance people are willing to travel to obtain any given goods and services, which naturally increases in distance the higher the order becomes (Glasson, 1974:127). The size of the marketplace is therefore a combination between population threshold and market range. For example, a local grocery store generally sells lower-order goods and attracts customers from a small area surrounding the store, which is adequate to sustain itself, provided that there is sufficient buying power in that small area which is also referred to as the demand threshold. A motor vehicle dealership generally sells higher-order goods attracting buyers from further away, but generally needs fewer customers to sustain itself.

3.4.2 Growth poles theory

Perroux's (1950) growth pole theory was one of the first to discard the idea that space is utilized uniformly. Instead, he suggested that growth and development occur at certain points in space as well as along certain channels due to an intangible outward force (Glasson & Marshall 2007: 76). The theory of growth poles provides a model for understanding the economic spatial structure of regions and how industries influence space, enabling us to make predictions of future spatial changes. The central belief of growth pole theory is one of 'economic space' wherein dominant industries exert a sort of centripetal (inward) force before succumbing to a centrifugal (outward) force spreading growth towards the surrounding space (Dawkins, 2003:140; McCann & Van Oort, 2009:22). Perroux's (1950) theory was formulated within an

economic context, while Boudeville (1966) added a geographic component, seeing leading industries in towns and cities as expanding forces leading to new developments in the surrounding hinterland (refer Figure 3.6)(Dawkins, 2003:140; Nel & Barclay, 2011:37).

This occurs as a result of innovations by the original dominant industry, creating a demand greater than it can supply on its own, opening the door to similar industries within the original industry's sphere of influence, also known as the backwash effect (refer Section 3.3.3.6), eventually accumulating the necessary infrastructure for the industries to grow out into surrounding areas via the spread effect (refer Section 3.3.3.6) (Dawkins, 2003:140; Nel & Barclay, 2011:37). Hirschman (1958, in McCann & Van Oort, 2009:22) identified that backward linkages (refer Section 3.3.3.4) causes input firms to draw closer towards the leading industry using agglomeration economies to their advantage, whereafter the forward linkages (refer Section 3.3.3.4) creates demand further down the supply chain causing a trickle-down effect (refer Section 3.3.3.8) within the lagging region.

The growth pole theory is further elaborated upon by Friedmann (1966) arguing that as the export base theory (refer Section 4.2.4) suggests, growth is caused by external demand. However, he then moves away from the export base theory by highlighting the importance of entrepreneurship and local leadership as a driver of growth. Friedmann (1966) also highlights the fact that regions differ in terms of how their supply chain will be able to support or limit development. The varying definitions and interpretations of the growth pole theory may be because of semantic inconsistencies used to describe the phenomenon. According to Darwent (1969:5), the terms 'growth pole', 'growth points, and 'growth centres' have been used interchangeably, even though they have different meanings. According to Glasson (1974:146-147), the term 'growth pole' does not have a particular geographical dimension, whereas a growth centre within a growth point does, which adds to the confusion.

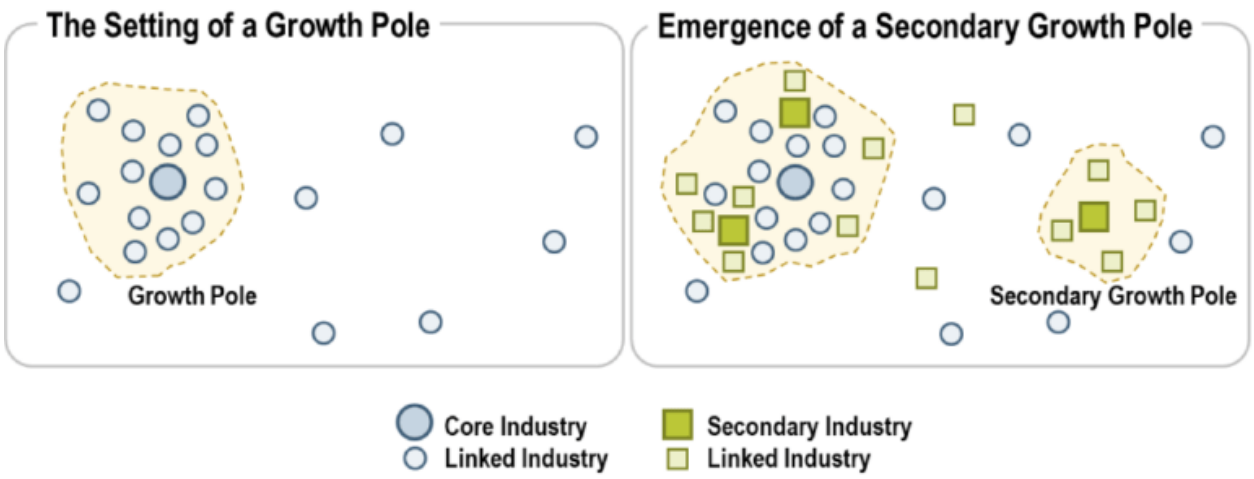

Figure 3.6: Growth pole theory within a spatial context

Source: Boudeville (1966).

3.4.3 Location of industry

The study of industrial location can be divided into two main themes; firstly there is the theoretical approach undertaken by economists due to their love for abstract theories, and secondly, there is the empirical approach undertaken by geographers due to their concern for real-world situations (Glasson, 1974:103).

The first economist to prepare a comprehensive theory was Alfred Weber (1909, cited by Friedrich, 1929:20-33). This is based on the premise that industrialists would determine their location based on where the operational costs would be minimal taking into account factors such as labour (both the cost and availability of labour), transportation costs (both in terms of backward and forward linkages) as well as local factors such as agglomeration economies. The theory depends on what Hoover and Giarratani (1984:5) refer to as the foundational cornerstones of economic location, which are (1) the uneven distribution of natural resources which are immovable and therefore very influential in terms of where their exploitation can occur; (2) the economies of concentration, i.e. agglomeration economies; and (3) transport and communication costs. Weber's theory is illustrated in Figure 3.7 below. The 'locational triangle' aims to balance the forces exerted through material sources (S1 & S2) by dividing the weight of material inputs by the weight of final products taken into consideration the fixed location of the marketplace (M) in order to determine the optimal location (P) for said industry (Glasson, 1974:106).

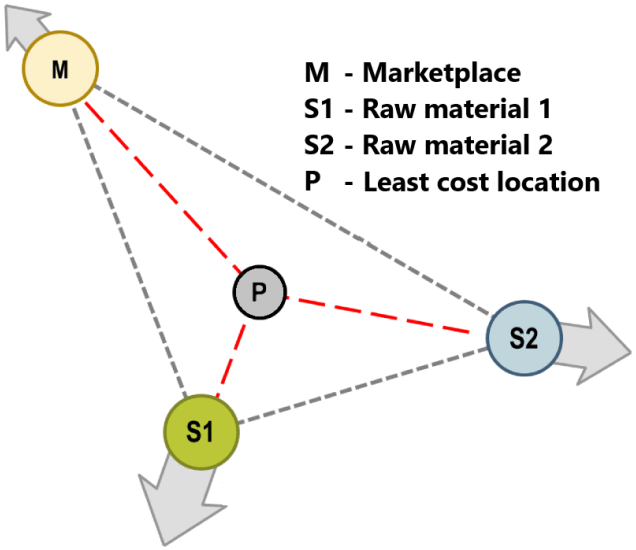

Figure 3.7: Least-cost location

Source: Webber (1909)

Lösch (1954:16) diverted from Weber's theory, proposing that industries would locate at a point of maximum profit by considering demand against distribution costs of outputs while ignoring input costs. The theory asserts that higher transportation costs of final outputs will increase the price of final outputs, thus creating a 'demand core' or 'market area' (Glasson, 1974:110). Figure 3.8 below illustrates the market area (F) as demand (Q) decreases with distance (D) from the industry.

The empirical evidence suggests that locational decisions are not always as straightforward as theorists suggest. Industries are unlikely to locate somewhere between the source of inputs and the marketplace as suggested by Weber, as this will cause logistical hardship due to double loading and off-loading being required, which usually only occur where there is a break in a transportation network such as harbours and airports (Nel & Barclay, 2011:31). Due to the falling cost in transportation, the value of goods relative to the cost of transportation has increased minimizing the importance of the latter enabling industries to be more adaptable in choosing a location (Chapman & Walker 1990:44).

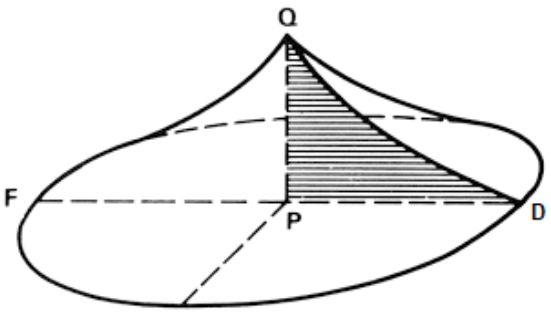

Figure 3. 8: Market area

Source: Lösch (1954)

Less tangible factors such as convenience and quality of life have also increased in the decision-making process (Blakely 1989:63). In modern times, factors such as skilled labour and communication infrastructure have become more important than transportation costs, as was previously the case (Castells 1989:146; Glasson, 1974:102; Nelson 1993:44). It has also been noted that environmental factors such as climate have increased in importance when it comes to location factors (Glasson, 1974:102). The latter is particularly important to this study as climate conditions are one of the main factors that will determine where renewable energy can be harvested.

3.4.4 Industrial clusters and districts

There is an increasing volume of literature that deals with the importance of industrial clusters and districts functioning through backward and forward linkages (refer Section 3.3.3.4) that refer to the acquisition of inputs and the sale of outputs in a specific manner and location (Nel & Barclay, 2011:35). The work of Porter (1998) on industrial districts and clusters has had a major influence on regional development literature as the concept of comparative advantages (refer Section 3.3.3.2) at both national and regional levels that arise from the spatial concentration of industries is a powerful tool used not only for the immediate regions in which such clusters are found, but also for surrounding lagging regions following the principles of the growth pole (refer Section 3.4.3) (Benedek *et al.,* 2013:238). Cluster-based policies have increasingly been used to affect both national and regional economic growth and development (Cumbers and Mackinnon, 2004:959).

Industrial clusters and districts constitute a specific form of agglomeration (refer Section 3.3.3.1) between firms that usually depend on the same supply chains and/or specialize in similar products creating a natural interdependency between such firms (Capello 2007:207). Strong backward and forward linkages between firms foster cooperation and trust and, in many instances, can lead to greater competition and innovation (Malecki 1991:232; Rabellotti 1995:30). This occurs by sharing information and infrastructure between firms and in some cases even marketing strategies (Nel & Barclay, 2011:35). The level of sophistication of the final outputs will in some cases determine where such clusters will establish themselves, as highly innovative products require skilled labour whereas mass-produced products normally do not; hence firms will in some cases look to locate in areas where their labour inputs occur naturally (Nel & Barclay, 2011:35). However, with advancements in communication and transportation infrastructure, research and development (R & D) departments of firms may locate in areas close to research institutions such as universities, while the manufacturing departments may locate near low-wage areas (Nel & Barclay, 2011:36).

3.5 Conclusion

This chapter sought to answer research question number one of this study by highlighting the theoretical principles on which regional planning is based and subsequently revealed several important findings: Firstly, defining the regional concept was not a straightforward task as there are many different definitions based on scale and characteristics, usually depending on the context within which it is used. However, it is generally accepted that a region is somewhere between city scale and national scale. It was further established that regions can be viewed from either a subjective or objective perspective, where the former implies that a region can be used as a tool to achieve a predetermined goal, and the latter implies that a region is a naturally occurring end in itself. Regions can also be classified as either formal or functional, where the former refers to defining the region based on homogeneous characteristics, and the latter defines regions based on interlining heterogeneous characteristics. Both these classifications allow for what is known as a planning region, which is defined as a single stretch of land that supports economic decisions that can be used by regional planners to achieve the desired goal by making use of development plans. There are five types of planning regions, but for the purpose of this study, the resource frontier regions are key, as they are areas where naturally occurring resources can be exploited.

Secondly, it was established that planning is a purposeful action aimed at achieving a future-orientated goal and is usually done in a set of sequential steps. Planning should be concerned with fixing social and economic problems that may arise in the future by setting appropriate goals and achieving them by means of attainable objectives in the form of comprehensive policies and programmes. Planning in the built environment can be divided into two silos; one concerned with the physical structure and/or land-use of a territory (also known as statutory planning), and one concerned with directing an ideal or ambition for a territory (also known as strategic spatial planning). The European Commission defines spatial planning as the methods used largely by the public sector to influence the future distribution of activities in space.

Thirdly, it was established that the primary goal of regional planning is to achieve regional development by making use of regional [development] plans. Although it is generally accepted that development includes both economic growth as well as factors that enhance the overall quality of life, development can still be interpreted differently depending on the ideology from which it is viewed. For modernist followers, development means to move from an agrarian to technology-driven societies, capitalists seek unregulated markets and free trade, whereas Keynesian followers seek more government intervention in the economy as opposed to less, where the latter is the view of Neoliberalists. Marxists want to use socialist policies to liberate the poor to ultimately achieve communism.

This chapter additionally defined regional economic concepts to provide a reference point for when such terms are used in varying contexts throughout the study. Agglomeration economies refer to the economic benefits businesses gain by clustering together in proximity. Comparative advantage refers to the ability of a business to sell the same goods or service at a lower cost to customers than their competitors due to lower opportunity costs. Economies of scale refer to the relatively diminishing number inputs required to produce a fixed level of output due to efficiency. Convergence refers to the closing gap in wealth between rich and poor regions over time and can be divided into conditional convergence, which refers to the initial stages of the process in one region and absolute convergence, which refers to the closing gap between all regions. The backwash effect refers to the flow of factors of production from the hinterland or periphery of a region towards the core, whereas the spread effect refers to the flow of factors of production from the core towards the hinterland. The multiplier effect refers to the additional spending within an economy due to an initial investment. The trickle-down effect refers to the belief that it is good for the poor when the rich accumulate wealth as such wealth will eventually 'trickle down' to the poor, enabling them to acquire wealth themselves.

Finally, this chapter discussed economic location theories including the Central Place theory, which explains the structure of regions in terms of higher- and lower-order centres. The Growth Pole theory explains how industries branch out into the hinterland due to operational growth; the Location of Industry theory uses cost-reduction explanations as to why industries settle where they do; whereas the Industrial Clusters theory describes a specific form of agglomeration based on backward and forward linkages.

The following chapter will specifically look at regional development theories and policies to gain a deeper understanding of how to achieve regional development in practice.

CHAPTER 4: REGIONAL DEVELOPMENT THEORIES

4.1 Introduction

In the previous chapter, the regional planning principles were discussed, revealing among others the main purpose of regional planning, which is to achieve regional development. Chapter Four is aimed towards achieving research objective number two of this study, i.e. **to determine how sustainable regional development can be achieved in an environmentally sustainable manner.** This will be accomplished by firstly examining relevant growth and development theories to gain more insight into how regions develop and what causes regional growth and development to occur. The discussion will commence by explaining the difference between endogenous and exogenous growth factors, after which the equilibrium theory, cumulative causation theory, and the export base theory will be discussed.

Secondly, structuralist theories of regional development will be discussed as they provide meaningful insights, enabling policymakers not only to assess the level of development of any given region by examining their structural make-up, but also to make short-term predictions as to what changes can be expected once specific policy measures are introduced. Thirdly, modernist theories of growth and development will be discussed, as this study aims to use technology to achieve sustainable regional development. The role of technology and the concept of sustainable development will be discussed to gain a deeper understanding as to what constitutes sustainable development, and what role technology plays in achieving sustainable regional development.

Fourthly, economic development policies will be discussed from both place-neutral and place-based perspectives to determine whether market intervention based on specific geographic locations are justified or not. Regional development techniques such as interregional trade multipliers, the input-output model, and shift/share analysis will then be examined in order to supplement the real-world shortcomings of the aforementioned development theories, as such techniques can be used to assess the level of development in addition to making predictions. This chapter will then conclude by summarizing the most important findings.

4.2 Growth and development theories

As explained in Section 3.3.3.9, regional development theories can be divided into two main groups, namely (1) location theories (refer Section 3.4), and (2) growth and development theories (Capello, 2009:34). Regional development theorists have devoted their careers to examine how individual regions develop to answer the important question as to why some

regions develop while others do not. However, there is no universally accepted general theory (Capello, 2009:44) and according to Glasson (1974:84), it is doubtful whether such a comprehensive theory can even be formulated, but one can draw meaningful conclusions based on a number of theories. The general belief is that regional growth must originate from endogenous and/or exogenous factors, where the former refers to factors that are naturally occurring within the region such as natural resources and skilled labour, whereas the latter refers to factors that come from outside the region such as foreign investment or sales from exports (Glasson, 1974:84). The following section will discuss some of the relevant growth and development theories.

4.2.1 Endogenous vs. exogenous growth

Traditional approaches to economic growth and development were vested in neoclassical exogenous growth theories such as the export base theory developed by Homer Hoyt in 1939 (refer Section 4.2.4), and such models as developed by Robert Solow and Trevor Swan in 1956 (Dawkins, 2003:139; Glasson, 1947:85). The Solow-Swan model emphasizes the importance of exogenous inputs by illustrating the diminishing returns to scale (refer Section 3.3.3.3) for endogenous factors such as savings (capital investment) and labour, predicting conditional convergence of growth in per capita income over time by using endogenous factors alone (meaning that income will become relatively smaller as time goes on), and further predicts absolute convergence (refer Section 3.3.3.5) should growth parameters be the same across all regions (Dawkins, 2003:139).

However, since the 1980s, theories regarding regional economic growth and development have seen a paradigm shift from an emphasis on exogenous factors to endogenous factors, i.e. from factors that arise from inside the region as opposed to factors arising from outside the region and has been dubbed the 'new growth theory' (Stimson *et al.,* 2009:354). Endogenous growth refers not only to the importance of factors of production such as capital and local resource endowments as one would normally expect, but also emphasizes the importance of technology, entrepreneurship, leadership, and institutional capacity arising from within the region (Stimson *et al.*, 2009:354). The theory was founded by Romer (1986) emerging as a response to the criticisms levelled against neoclassical theories and aimed to prove why there is a divergence in income between countries (Stimson *et al*., 2009:355). Romer's (1986) model illustrates that in some countries, per capita output could be persistently slower than in others; therefore, introducing the concept of economic divergence (refer Section 3.3.3.5), as opposed to perpetual convergence as proposed by the neoclassical models (cited by Dawkins, 2003:147).

It must be noted that the new growth theory allows for both convergence and divergence, the important distinction to be made is that regional economic growth and development arises

particularly from endogenous factors, i.e. local resource endowments that are harnessed through good institutional capacity, leadership, entrepreneurship and the use of innovation and the adoption of new technologies (Blakely, 1994:53). Accordingly, Stimson *et al.* (2005:27) present the following formula to encompass the above: Regional Economic Development (RED) is a function of Resource Endowment Market conditions (REM) mediated by Labour (L), Institutions (I) and Entrepreneurship (E), i.e. RED = f[REM mediated by (L, I, E)]. Simply put, the above equation proposes that RED is achieved by utilizing local Resource Endowments (RE) within a market where entrepreneurs (E), the labour force (L), and Institutions (I) can facilitate growth. This relates to the function of strategic regional spatial planning as proposed by Albrechts (2006:1150), i.e. to achieve regional development by utilizing whatever local resources are available to do so (refer Section 3.2.2) through the use of new innovation and technology. It is significant to highlight that this study will aim to achieve regional development by making use of local renewable energy resources, combined with renewable energy technologies, entrepreneurs, labour and institutions.

While developing economic theory, it was proposed by Rees (1979:40) that technology is the primary driver of regional economic development. Since then, other variants of the endogenous theories have also included technological change and innovation as inherent to the model, as economists such as Romer (1990) and Rebelo (1991) sought to explain how technology and innovation can affect regional development, as opposed to accepting the neoclassical view of growth being a result of exogenous factors. Rees (2001:107) later highlights that technology needs to be used to achieve regional economic development in true endogenous theory fashion by combining it with entrepreneurship and leadership which can lead to the development of industrial regions (refer Section 3.4.4) and/or the regeneration of older ones.

One of the inherent outcomes of endogenous growth theory is that policy measures can be put in place to affect long-term regional economic growth and development by means of a higher savings (investment) rate, endogenous technology, and human capital (Stimson *et al*., 2009:355). The ability to achieve long-term economic growth via policy measures is an extremely appealing prospect for economic geographers and regional planners alike and may be the reason for the relatively recent revival of endogenous growth theories, compared to exogenous theories (Stimson *et al.*, 2009:355). It is worth noting that this study will make use of policy mechanisms to achieve regional development. Exogenous factors should not be discarded altogether, as they do play a role in regional economic development over time. However, the new growth theory places an emphasis on endogenous factors and how local capacity can be used and enhanced not only to affect regional development through policy initiatives but to make regions more resilient in an increasingly competitive global environment as well (Stimson *et al*., 2009:357).

The evolutionary process of regional growth and development theories as described above are welcome for development analysts and regional spatial planners due to the explicit introduction of a spatial dimension into growth theory, which was largely missing in neoclassical theories and is particularly important with regional economies playing an increasingly larger role in national economic growth and development since the 1970s (Stimson *et al*., 2009:358). This sentiment is shared by Dawkins (2003:147), stating that other than early models of agglomeration and endogenous technical change as presented by Harry Richardson in the early 1970s*,* endogenous growth theories brought back the role of space in regional growth and decline.

4.2.2 Equilibrium theory

One of the central theories arising from the neoclassical period is that if factors of production such as capital are left to flow without being restricted, i.e. capitalism (refer Section 3.3.2.2), the system would eventually reach equilibrium, as capital seeking a higher return on investment would leave regions where wages are high (and costs are high) to areas where costs are lower, and as investment in the poor region continues, competition for factors of production increases, thus raising costs, which leads to equilibrium (Nelson, 1993:31). This theory underlies many of the deregulation policies that were introduced by the neoliberal governments of the early 1980s (Blakely 1989:60). This theory also resonates with the growth pole theory (refer Section 3.4.2), which advocates that growth in leading regions trickles down (refer Section 3.3.3.8) into lagging regions, as the latter usually have a comparative advantage in some area that can be exploited, resulting in an inflow of investment until equilibrium has been reached (Nelson 1993:31).

4.2.3 Cumulative causation theory

The theory of circular and cumulative causation was developed by Swedish economist Gunnar Myrdal (1957). It suggests that market forces do not lead to regional balance as suggested by the neoclassical equilibrium theory (refer Section 4.2.2), but instead sets into motion a reinforcing and self-perpetuating cycle of either growth or decline (refer Figure 4.1). This ultimately leads to an increase in inequality, as factors of production such as resources and capital are oftentimes prevented from moving to locations of lower cost (Blakely 1989:64; Glasson & Marshall 2007:66; Howland 1993:69). Kaldor (1970:341) expands on Myrdal's theory by introducing elements of export base theory (refer Section 4.2.4), implying that early industrialization combined with international trade can add to cumulative causation.

The negative cycle begins with a decline in output, leading to a decline in an area's per capita income. As a result, banks restrict lending, leading to lower demand, which negatively affects the rest of the local economy. This leads to further unemployment reinforcing decay in public

services and infrastructure due to lower tax revenues, discouraging outside investment due to the decline in the attractiveness of the region and finally migration out of the area for those who can afford to move to more prosperous regions (Nel & Barclay, 2011:25). The positive cycle begins with investment into a region, leading to increased output, leading to an increase in per capita income positively affecting demand in the rest of the regional economy, leading to increased tax revenues and subsequent investment in public services and infrastructure, increasing the attractiveness of the region, finally leading to further investment and a flow of capital and labour (Nel & Barclay, 2011:25).

This process can also be described in terms of leading and lagging regions where the former have comparative advantages (refer Section 3.3.3.2) and buy factors of production such as natural and human resources from the latter, diminishing their ability to utilize such factors to enrich themselves and can only be corrected by means of foreign investment, without which the leading regions maintain their dominance over the lagging regions (Nelson 1993:32). As Malecki (1991:82) explains, “knowledge, skills, and capital, once acquired, do not vanish, but become an endogenous source of future endowments”. Mydral (1957) argues that lagging regions may initially benefit from the growth in leading regions due to the ‘spread effect’ fostering growth through the diffusion of innovation into the lagging region, but continues by stating that such benefits will ultimately be offset by the ‘backwash effect’ (refer Section 3.3.3.6) as a result of the flow in capital and resources from the lagging region towards the leading region.

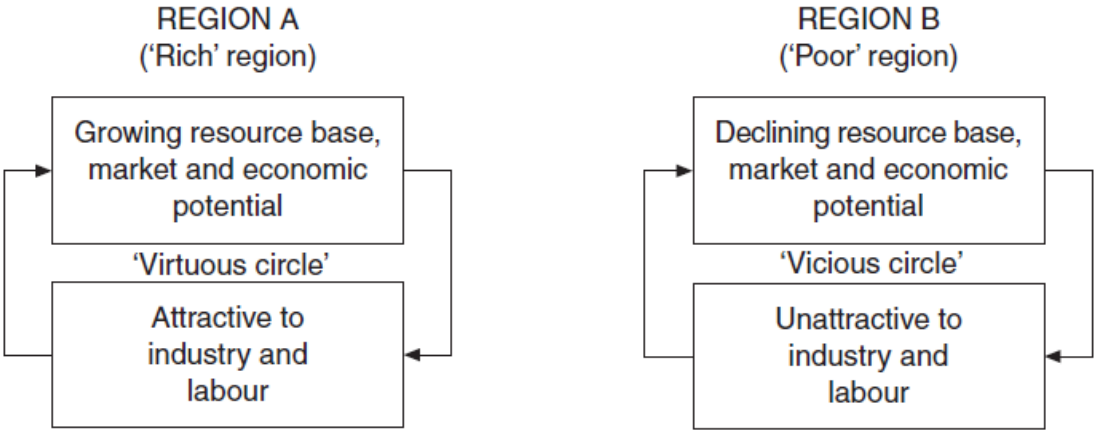

Figure 4. 1: Simplified description of cumulative causation

Source: Glasson & Marshall (2007:66)

4.2.4 Export base theory

The export base theory is one of the most influential theories in economic development literature and identifies exports to be the main driver behind regional growth and development, whereas local trade is seen as a by-product of income generated from exports (Hoover &

Giarratani, 1984:173). The first model was prepared by Hoyt (1939) to illustrate the physical growth of a city; however, the model was later developed into a theoretical economic model by Tiebout (1956) and North (1955).

The basic premise of the theory, according to North (1955), is that all economic activity can be divided into non-basic (local market) and basic (exports) activities, where the former uses local resources (natural resources, labour & capital) to generate growth within the region, but is limited in terms of growth potential due to finite local resources, whereas the latter can generate growth as it expands beyond the regional boundaries, bringing capital from outside, generating growth and creating wealth inside the region (Glasson, 1974:63-64). The cycle is completed when non-basic activities lead to more exports. For instance, manufacturing is generally categorized under basic activities; however, other non-basic activities such as research and development can attract basic activities into the region, leading to more basic activities. As regions' economies grow, their local markets tend to become more sophisticated and diversified, which leads to an increase in local production and ultimately to more exports (North, 1955: 258). The principles of the export base theory are simply illustrated in Figure 4.2 below. North (1955:254) also highlights that regions do not necessarily have to become industrialized to grow, as exports can come from raw materials to manufactured goods and even services.

The export base theory can be used to predict short-run future growth in employment in the region by means of the 'employment multiplier' equation. The formula is (Glasson, 1974:64): x = (nb + b)/b, where 'x' represents the multiplier, 'nb' represents the non-basic sector employment numbers and 'b' represents the basic sector employment numbers. Any change in employment in either the basic or non-basic sector will influence the other in the same ratio as the multiplier. The theory can also be used to determine what is known as the 'base multiplier', where an injection of export income will generate local income greater than the original export value (Dawkins, 2003:140) due to the multiplier effect (refer Section 3.3.3.7).

Figure 4.2: Export base theory

Source: Own compilation from North (1955)

The export-base theory is widely accepted as being useful and relevant; however, the theory is not without criticism. One of these is the assumption that demand is primarily generated from outside the region, whereas another deals with the difficulty in identifying industries as either wholly basic or wholly non-basic, which cannot always be done, leaving industries that can fall in both categories (Glasson, 1974:65).

Another shortfall of the theory is that it is more applicable in regions with strong backward and forward linkages (refer Section 3.3.3.4) where local multipliers exist, as opposed to areas where incomes flow out of the region and are not recycled locally (Howland, 1993:71). At the other end, the export base theory also does not take into account that communities tend to spend their money locally when the local market is large and diverse enough, thus limiting the amount spent on imports (Capello 2007:129). The same argument can be applied when considering that an increase in local productivity will generate local income not tied to the non-basic sector (Blair 1995:135).

Critics of the export-base theory such as Malecki (1991) is quick to point out that it is the tertiary sector (services) that is the main driver behind development and that exports are the result of growth, as opposed to the cause thereof. Malecki (1991) continues to highlight the fact that services play an influential role in innovation. According to Malizia (1985:38), innovation is the driving force behind a broader and more diversified export base. The following factors are important for regional growth and development (Malecki, 1991:60-69): the diversity and quality of local resources, quality of local institutions, and social and economic infrastructure, including local markets.

4.3 Structuralist theories

Another body of regional economic growth and development theories is focused on the structural changes that occur within and outside the region as a result of development and are therefore not concerned with the factors of growth as in the case of the theories discussed in Section 4.2, but rather explains regional growth in terms of an evolutionary path through which regions move as development occurs (Dawkins, 2003:140). These are called structuralist theories and will be discussed in the following section in order to be able to approximate the level of development of regions simply by examining their structural composition, with the aim of making short-term predictions as to the region's future.

4.3.1 Marxist theory

Classic Marxism (refer Section 3.3.2.3) was adopted by Karl Marx and represents a theory wherein countries move through stages of development, each stage representing a more advanced state than the one before and is based on the relationship between labour and capital as well as the ownership of the means of production (Willis, 2005:71). The stages commence with a pre-industrial society and then evolves into a capitalist society, followed by a socialist society and finally ending up with a communist society (Nel & Barclay, 2011:7). The pre-industrial society represents a state wherein there is little technology and the economy is largely dominated by craft manufacturing. The means of production are largely in the hands of the private sector who labour themselves, whereas the capitalist society represents a state wherein the advances in technology has made it possible to exploit natural resources to a larger degree, the economy and means of production is also largely in the hands of the middle and upper-class private sector buying labour from the lower-class in return for minimal compensation (Nel & Barclay, 2011:7). The following stage comes when the capitalist system has exhausted all the resources and brings with it a socialist state wherein the means of production is equally distributed among all citizens, and then finally a communist society, wherein the state owns all the means of production (Mitchell, 2009:103).

Marxist literature conflicted with traditional theories of economic growth and development concerning the convergence/divergence debate (refer Section 3.3.3.5) as Marxist supporters claimed that regional growth is neither convergent nor divergent, but rather 'episodic' by nature, meaning that capital acquisition passes through stages of progression, fuelled by specific crises (Martin & Sunley, 1998:202). According to Harvey (1985:11), economic systems will naturally move towards balanced growth due to natural competition for profits. However, he goes on to state that this will never materialize due to the unbalanced structure of social relations that cause the periodic crises used by capitalists through waves of investment and disinvestment.

Similar arguments are made by Smith (1984:152) who defines uneven development as the "geographic expression of the contradiction of capital".

4.3.2 Stages of growth

Similar to the Marxist ideology, the theory of economic growth put forth by Rostow (1960) describes countries as moving through stages (refer Figure 4.3), each more productive and with a greater capital-to-labour ratio than the last, starting with the primary economy, i.e. mining and agriculture, then moving through to the secondary economy, i.e. industrialization and finally ending with the tertiary economy, i.e. services (Rostow, 1960:2; Willis 2005:46). The theory mainly refers to economic growth as opposed to development; however, the distinction is clearly made between less developed and more developed countries (Rostow, 1960:2), giving this theory credibility in the development discussion.

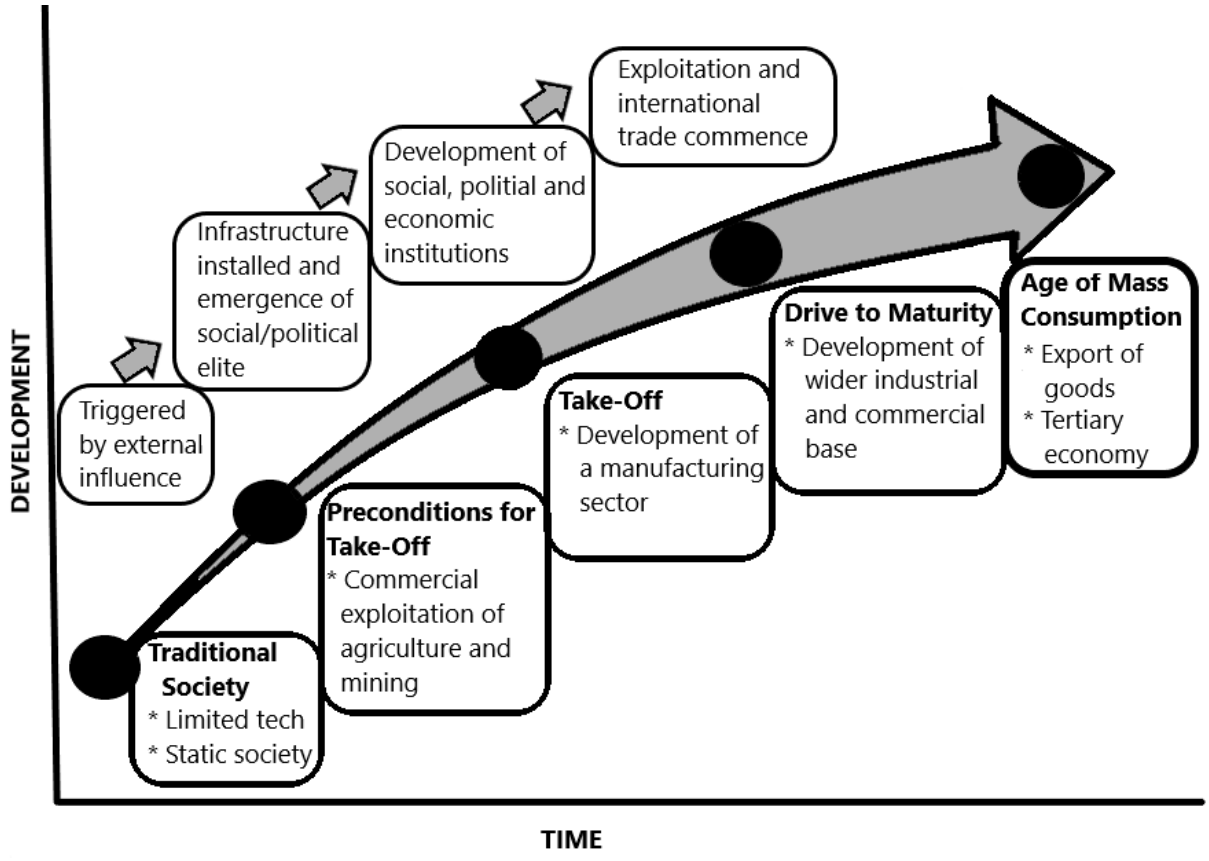

Figure 4.3: Stages of growth

Source: Own creation from Rostow (1960:4-13)

The growth stages are as follows (Rostow, 1960:4-13): (i) Traditional society, (ii) Preconditions for take-off, (iii) Take-off, (iv) Drive to maturity and (v) Age of mass-consumption. A traditional society is characterized by limited technology based largely on a primary economy and subsistence farming; preconditions for take-off is triggered by outside investment in the region enabling the primary economy to be exploited to a larger degree. Take-off occurs when

investment in infrastructure continues enabling the development of a manufacturing economy while seeing the beginning of class separation. The drive to maturity occurs when social, economic, and political institutions are established, and primary goods are processed for the industrial and commercial sectors. Finally, the age of mass consumption implies exploitation of the local market seeing previously imported goods now being exported along with the establishment of a tertiary economy (Rostow, 1960:4-13). The stages of growth theory is one of the earliest and most basic of the classical development theories (Nel & Barclay, 2011:21).

4.3.3 Waves of development

Another prominent structuralist theory is that of 'long waves of regional development' (see Marshall, 1987), which came after Kondriatief-like 'waves' had been identified in the world economy of cycles, lasting approximately 50 to 60 years (Glasson & Marshall 2007:64). In accordance with this theory, it is possible to predict economic outcomes due to the cyclical nature of products, markets, the use of resource inputs and technology. It has been called waves of 'creative destruction', as one cycle is destroyed to create the next (Goldstein & Luger, 1993:152). The process can be described as follows:

In terms of innovation, the cycle begins with entrepreneurs who introduce new technology into the market and for the first period, the innovators reap great profits as they enjoy a monopoly position (Goldstein & Luger, 1993: 152). Initially, demand for the new product or service is small, coming only from the local market where the technology is known, but increases rapidly as more consumers are exposed (Nel & Barclay, 2011:26). This is the time when imitators enter the market after seeing the high demand and result in the technology becoming more price-sensitive due to natural market competition and continues to fall as mass-production commences (Nel & Barclay, 2011:26). As technology spreads and becomes available in other regions, so does manufacturing (Nelson, 1993:33). During the latter stages of the cycle, the demand for technology becomes saturated in relation to supply, and profit starts to decline (Goldstein & Luger, 1993:152). According to Malizia (1985:39), the waves of cycles theory underline the importance of innovation in economic development.

4.4 Modernist theories

Modernism (refer Section 3.3.2.1) is an ideology that aims to achieve sustainable development through advances in innovation and technology among others (Nel & Barclay, 2011:5). This study aims to provide a framework for achieving sustainable development by means of renewable energy technology; therefore necessitating the need to examine modernist theories

of development. The section to follow will firstly look at the role technology plays in achieving development, followed by establishing what is meant by sustainable development.

4.4.1 The role of technology

To fully comprehend what impact technology can have on development, one must first clarify what exactly is meant by the term 'technology'. Technimetrics is the study of technology and does so by firstly clarifying what technology is; then once such understanding has been gained, it describes how technology impacts on development (Ramanathan, 1988:234). Technology is simply the practical application of new information or knowledge, as inputs to produce new and in most cases, more efficient outputs and therefore drives economies forward (Nel & Barclay, 2011:44). It can be observed that the growth of newly industrialized countries is largely due to their application of new technology (Malecki, 1991:27).

Speaking in general terms, technology is perceived to be one of the most important elements in achieving economic growth and development (Malecki, 1991:26; Steenhuis & De Bruijn, 2012:1). When looking for an explanation why one region or location has succeeded in achieving economic development, technology is one of the primary causes (Steenhuis & De Bruijn, 2012:5). According to Malecki (1997:5), technology is the primary instigator for regional change, both in terms of development and destruction. While technology can help to achieve economic development, new technology can also harm the environment in some instances. Similarly, technology can create jobs through innovation, but also destroy jobs by means of mechanization. Technology also has the potential ability to change the structure of a region's economy (refer Section 4.3) by changing the goods and services available for both local consumption and exports (Malecki, 1991:26-29).

It should, however, be noted that investment in technology does not always translate into economic growth and development due to the complexity of the subject, which includes numerous factors such as the implementation thereof as well as the acceptance of the relevant technology into the market (Nel & Barclay, 2011:44). The latter points out that demand will ultimately determine the success of a technology company. According to Melkers *et al.* (1993:233-234), stimulating innovation and transferring technology from research programmes into production will not necessarily lead to success, as technology needs to be accepted and transferred across a range of disciplines, professions, and sectors. For technology to lead to market success, firms need to have the necessary capacity to do so (Melkers *et al.,* 1993:235).

4.4.2 Sustainable development

Since the dawn of the 21st century, it has increasingly been emphasized that environmental considerations need to be incorporated into regional economic development (Gibbs, 2006:193;

Jovocic *et al*., 2017:256). Sustainable development is currently one of the most important challenges of humanity (Raszkowski & Bartniczak, 2018:229). The importance of achieving sustainable regional development has been reawakened by emerging concepts such as New Regionalism and Smart Growth (Scott, 2007:15). The term 'sustainability' has in the recent past been used more often on a global scale as it highlights the need for sustainable development. The terms are often used interchangeably (Glasson & Marshall 2007:82).

However, as stated in 2005 by Faber *et al.* (2005:1), it must be noted that the concept of sustainability is a confusing one with no clear consensus of its meaning. The debate on whether environmental conservation and economic development are two mutually exclusive concepts, and whether or not sustainable development is even achievable is on the increase (Nel & Barclay, 2011:44). This came after Brundtland (1987:7) rejected the notion that these two concepts are mutually exclusive, as far back as 1987. Sustainable development should encompass both environmental and economic goals, preferably by means of appropriate techniques for more efficient agricultural production, energy use and natural resource use (Jovovic *et al.*, 2017:256). This study will aim to use appropriate techniques to use natural resources for energy production, potentially achieving several of such important outcomes.

Over the years, many scholars have researched sustainability and sustainable development, resulting in a plethora of definitions ranging from abstract terminology such as the 'triple bottom line' (TBL) which refers to three outcomes; increasing fiscal profits, improving the planet earth and improving people's lives (refer Figure 4.4) (Glasson & Marshall 2007:7; Jovocic *et al.*, 2017:256) to one of the most commonly accepted definitions in that sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Willis 2005:159). The aforementioned definition merely highlights the fact that economic and civilization development of the current generation must be done in a way that preserves non-renewable natural resources (Raszkowski & Bartniczak, 2018:229), or one can argue the dichotomy would be to make increasing use of renewable resources.

In attempting to achieve regional development, it is important not to focus solely on the social and economic dimensions, as the natural environment can suffer as a result, which can lead to a downward spiral from which it will be hard to recover (Glasson & Marshall 2007:80). For sustainable development to be achieved, there must be an integration of, and synergy between development objectives as we as humans cannot survive without the natural environment and all the amenities it provides such as fresh water and fertile soil; the social systems that ensure safety, social justice; and cultural identity as well as a sense of place in addition to productive economic systems (Nel & Barclay, 2011:51). Maintaining the natural qualities of the ecological

systems in conjunction with social and economic development is significant (Raszkowski & Bartniczak, 2018:231). Although there is no consensus on the exact balance between the above-mentioned dimensions, it is commonly accepted that a holistic approach needs to be undertaken wherein natural resources are used more efficiently and responsibly through the use of regional planning instruments such as policies and development plans, as well as by means of government institutions and NGOs (Jovocic *et al*., 2017:257; Nel & Barclay, 2011:51; Raszkowski & Bartniczak, 2018:227). This sentiment is particularly important, as this study will attempt to use natural energy sources to achieve sustainable regional development through policy mechanisms and development plans.

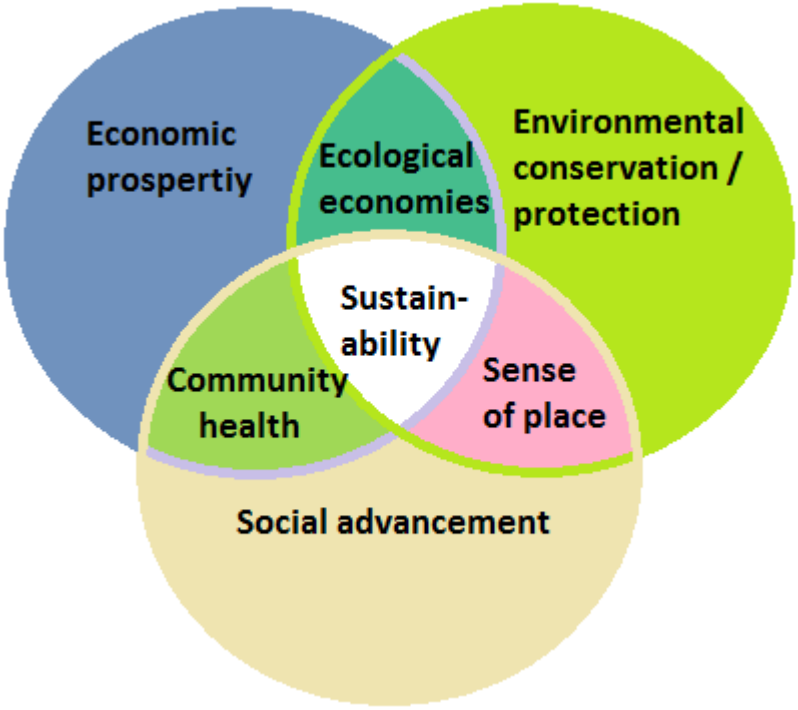

Figure 4.4: Dimensions of sustainability

Source: Glasson and Marshall (2007:82)

The achievement of sustainable development is particularly appropriate when dealing with development at a regional level (Glasson & Marshall 2007:80). Sustainable development should be implemented at the regional level to both enhance the exploitation of emerging opportunities and to overcome emerging problems (Raszkowski & Bartniczak, 2018:227). For planning professionals, the regional scale is the most appropriate for achieving sustainable development as, according to Glasson and Marshall (2007:82) and Jovocic *et al.* (2017:261), the region is sufficiently large to incorporate most socio-economic and environmental systems and may well be the most appropriate level to affect territorial integration between social, economic and environmental systems. According to Jenkins *et al.* (2003:60), after aiming to implement

Agenda 21 on a national scale, it has become clear that in order to achieve the desired goal, the appropriate scale on which to address the issue is at the regional and/or sub-national levels.

4.5 Regional development policy

Understanding economic development theories are beneficial for regional planning purposes only if such theories form the basis of policies that can be used by governments to affect the desired outcomes. Economic policies in general prescribe certain rules that must be followed by both private and public industries with the aim of achieving economic growth (Glasson, 1974:14). However, one of the most heated discussions in development literature is whether market failures justify public intervention (Dawkins, 2003:149). On the other hand, Richardson (1978:179) argues that it is the mandate of regional planners to foster growth within regions and therefore justifies intervention. The following section will discuss public policies based on these arguments.

4.5.1 Place-based vs place-neutral policies

As mentioned above, there are two contrasting arguments in public policy; the first insists that economic markets should be left to their own devices, and the second that intervention is required. In other words, the former advocates that governments should not give special treatment to certain regions (place-neutral) whereas the latter proposes the opposite (place-based). The contrast in approaches was spurred on by 'new growth theories' (refer Section 4.2.1) highlighting the importance of endogenous factors within regions to achieve regional economic growth such as natural resources, and institutional capacity, among others (Barca *et al.*, 2012:136). Literature is increasingly pointing to the fact that place-based policies should not be discarded so easily as regional development makes a significant contribution to national economic growth and development (see Barca *et al.*, 2012; Richardson 1978; World Bank, 2009). What is important to remember is that local context matters, hence policies should be formulated keeping in mind the inherent growth potential of each specific location (Todes & Turok, 2015:4).

Supporters of the place-neutral approach state that it is very difficult to foresee which regions will naturally prosper and which will not and that governments should avoid wasting public funds in areas where development may not occur, but rather formulate policies that will integrate towns, industries, and institutions allowing natural market forces to determine where development occurs (Streeten, 1959:167). Supporters of the place-based approach state that market forces alone cannot form the basis of public policy as growth potential exists in many areas other than big cities, and that governments should rather formulate policies aimed to

enhance the natural comparative advantages (refer Section 3.3.3.2) of regions and equip institutions to support endogenous growth. These policies can take various forms as each application is unique. The following section will discuss these policies and their implementation in more detail.

4.5.1.1 Spatial rebalancing

Spatial rebalancing policies is a form of spatial targeting or place-based policies and was initially introduced to reduce regional inequalities between leading and lagging regions, i.e. to promote regional economic convergence (refer Section 3.3.3.5) by incentivizing industries (usually in the form of manufacturing businesses) to move away from leading regions and relocate in lagging regions and by restricting such businesses to expand in leading regions (Todes & Turok, 2015:7).

This approach was criticized for failing to promote self-sustaining growth as the new economic activities were not anchored in the lagging region. The newly created jobs were only secure in the lagging regions if the new industries could operate efficiently and/or for as long as subsidies could be sustained, but such firms often struggled as their marketing and research operations were still retained in the core regions (Todes & Turok, 2015:8). These initiatives were generally regarded as being expensive mistakes that diverted a substantial amount of public financial capital from areas where they could have been more successful. Public funds were usually allocated towards lagging regions based on the severity of the lagging regions' problems, usually gaining momentum after outbreaks of social disorder while giving very little to no consideration towards the economic potential of the lagging regions (Todes & Turok, 2015:8) and were subsequently criticized for being fragmented, reactionary and generally unsuccessful. An approach that can be accepted, according to Todes and Turok (2015:8), is in such cases where governments target specific industries within lagging regions to initiate economic growth and spread by means of backward and forward linkages (refer Section 3.3.3.4) and create positive multipliers (refer Section 3.3.3.7), which is seen as the basis of the 'growth pole' (refer Section 3.4.2) concept. However, it must be noted that many growth pole initiatives have failed in their attempt to grow economies in lagging regions (Dawkins, 2003:140).

4.5.1.2 Place-neutral

Place-neutral (space-neutral) policies came as a result of the challenges that governments faced when attempting to apply redistributive policies due to a more competitive global economic environment where labour and capital can move more freely, making it more difficult to anchor investments within a particular area that was exacerbated by the ever-present threat that public funds may be wasted in unsuitable locations (Todes & Turok, 2015:11). Some

economists perceive balanced development policies (place-neutral) to be ineffective, as they argue that market forces are so powerful that they naturally create unbalanced development that cannot be reversed (Streeten, 1959: 168).

According to the World Bank (2009), spatial targeting policies focusing on lagging regions should be avoided at all costs; however, through their World Development Report (WDR) proposed a clear alternative to spatial targeting policies in the form of a place-neutral approach where the focus lies on the basic needs of households such as health and education arguing that if individuals are equipped with the necessary skills, they would be able to leave the lagging region and acquire better employment opportunities in leading regions, thus minimizing unemployment in the lagging region, while simultaneously satisfying the labour demand in the leading regions (World Bank, 2009:22-26). The space-neutral approach as promoted by the World Bank is not without flaws, as there are certain underlying assumptions that must be disclosed. Firstly, natural market forces will naturally converge in large cities, but the environmental impacts thereof are not addressed in the space-neutral policies which may negate the very growth objectives they support (Todes & Turok, 2015:13). Secondly, the space-neutral approach aims to integrate institutional capacity as opposed to building capacity in local institutions (Todes & Turok, 2015:13). Thirdly, the space-neutral approach supports economic integration between regions, regardless of their level of development, naturally assuming that integration will benefit all the regions involved and finally, the WDR assumes that equilibrium occurs faster in poor regions based on the belief that urbanization causes industrialization (Todes & Turok, 2015:14).

4.5.1.3 Spatial targeting

The difficulty that some national governments, as well as multinational organizations such as the European Union (EU) and Organization for Economic Co-operation and Development (OECD) experienced by relying on market forces, foreign direct investments and resource redistribution to direct development as proposed by the space-neutral approach, led to a major policy overhaul based on spatial targeting (OECD, 2009:5). Such place-based policies were designed to deliberately contrast the space-neutral policies that support non-interventionist relying on external investment (Todes & Turok, 2015:15). These place-based policies were additionally spurred on by new growth theories such as endogenous growth and the importance of human capital and institutional coordination (Barca *et al.*, 2012:136). One of the most important principles of place-based policies is that development strategies must be intimately linked to their local context built largely upon local knowledge, institutional capacity, and resources (OECD, 2009:6). This means that development strategies must seek to exploit particular local assets such as resources and be tailored designed for the specific local context,

but at the same time broad enough to cover essential characteristics of the economic environment. Each location has something unique to offer, which can be exploited more effectively and can be in the form of natural resources or labour, among others.

Spatial targeting policies should be based on a sound strategic framework that binds various local and national policies and departments together in such a manner that they reinforce one another to form a coherent unit (Todes & Turok, 2015:17). Place-based policy strategies from a national government level must be explicit to exclude the possibility of those with vested interests and narrow agendas to benefit from such initiatives (Barca *et al.,* 2012:138). The most efficient frameworks are those with a multi-level approach where local, regional, and national perspectives are factored in, ideally in such a faction that the national government provides the necessary resources and support to local governments (Todes & Turok, 2015:17). Such development frameworks can set parameters and conditions for how public funds are spent to prevent wasteful spending and malpractice (Boschma, 2015:740).

An alternative place-based approach that rivals the growth pole concept is the one of Special Economic Zones (SEZs), where industries of all kinds are incentivized to locate in one specific area (as opposed to hand-selecting industries and targeting a whole region as in the case of growth poles) to initiate growth (Todes & Turok, 2015:9). Such SEZs operate under different sets of public policy compared to the rest of the country, in addition to receiving public investment in infrastructure specifically aimed to enhance the ability of industries to operate and grow. This concept was first used successfully in China to support a much larger economic outcome and was later applied in other parts of the world with varying levels of success (OECD, 2017:14).

4.6 Measuring development

Earlier in this chapter, the various growth and development theories were discussed to gain more insight into how regional growth can occur. However, such theories rarely translate very well into practice, due to their relative simplicity, combined with the unknown factors of the real world. For this reason, theories should preferably only be used as a baseline or starting point when it comes to policy formulation. The next section will discuss some of the basic tools (or techniques) policymakers can use to measure regional development in practice. The tools to be discussed are relatively simple and can therefore be used by analysts and planners to make sound policy decisions, even in areas where data acquisition may be problematic, or where analytical capacity may be limited.

4.6.1 Interregional trade multipliers

This technique for measuring regional growth has been developed to negate the critique of simplicity levelled against the export-base theory (refer Section 4.3.2) (Glasson, 1974:69). The interregional trade multiplier technique does so by making the process slightly more complicated, but more realistic at the same time in acknowledging that regional economies do not merely export, but also receive imports, in addition to considering other variables such as foreign direct investment that can boost income, while leakages such as taxation will lower demand (Glasson, 1974:70). This technique additionally works on a monetary scale, as opposed to employment, as in the case of the export-base theory employment multiplier.

The premise of the technique critiques the notion that should every unit of money received through investment be invested back into the same regional economy, the multiplier effect (refer Section 3.3.3.7) will continue indefinitely. However, this is not possible in practice, as consumers generally tend to spend less than what they receive, or what is generally referred to as savings; consumers are also taxed by the government in order to receive an income for public spending, known as taxation; and lastly, consumers tend to spend money on goods and services outside their own region as well, referred to as imports (Glasson, 1974:70). Taxation, savings, and imports are referred to as leakages that decrease the amount of money available for local investment. The multiplier can be calculated as follows: X = I/L, where (X) represents the multiplier; (I) represents the initial investment; and (L) represents the leakages. For example, should a region receive R1 million in initial investment, and the general savings rate is 10% (R100 000), the rate of taxation is 15% (R150 000) and imports account for 25% (R250 000), the multiplier would be R1 million/R500 000 = 2. In practice, the multiplier tends to be 1 > 2 (Glasson, 1974:72).

4.6.2 Shift/share analysis

The shift/share analysis tool can be used for measuring changes in the economic performance of a region and to identify leading and/or declining sectors in that economy by using employment as the unit of measurement (Glasson, 1974:92). The model does so by establishing the national employment growth rate to use as the baseline (the national share component) and measures regional growth in employment (the shift component) against the national average (Glasson, 1974:92). Should the regional average growth rate be slower than the national growth rate it is denoted as negative, and should the growth rate be higher than the national average it is denoted as positive (Glasson & Marshall 2007:65).

The shift component can additionally be divided into the ‘proportionality shift component’ and the ‘differential shift component’, where the former refers to industries and sectors that influence

the regional shift component which can be found in other parts of the country (in order to establish what proportion of regional growth can be attributed to national growth), and the latter refers to local attributes that can influence the shift component such as skilled labour, local natural resources and/or transportation infrastructure, for example (Glasson & Marshall, 2007:65). The difference between the national share component and the regional shift component that can be attributed to local economic influences is also known as the 'local industry mix' (Blair, 1995:148).

In order to use this technique, one must have data for both national and local economic performance, and while the national figures may be readily available, the local figures may not be so easy to obtain and may in some cases even rely on expensive surveys. While the results of the shift/share analysis may shed some light on the local economy, it cannot be used to make accurate predictions, nor can it provide reasons for the observed changes and should therefore be supported by other methods in order to be used for policy formulation purposes.

4.6.3 Regional input/output model

The input-output model was developed by Wassily Leontief in the 1930s. In its simplest form, the model provides a method for describing the industrial structure of an economy (Blair 1995:163; Glasson, 1974:51; Górska, 2015:31). However, Richard Stone later adapted the original model, extending its practical application also to make short-term predictions possible (Górska, 2015:31). The first practical use of the model happened in the late 1950s to identify key (or leading) industries in economic sectors (Górska, 2015:31). In practice, however, it can be extremely difficult to obtain accurate numbers in addition to needing a large study area to be effective, which only increases the complexity of the process (Nel, 1999:31). Another drawback is that, according to this model, regional growth is entirely dependent on demand channelled through backward linkages (refer Section 3.3.3.4), which is not realistic, as in practice, growth can stem from an increase in demand from forward linkages as well (Nel, 1999:31). For the purpose of this study, the descriptive and predictive functionality of the input-output model (i.e. illustrating the structure of a regional economy and making short-term predictions, respectively) will be described in the following section.

The most basic input-output model (refer Table 4.1) consists of a single region containing four sectors. Sector 1 is the largest and represents the local market between industries; Sector 2 represents the local industries sales to the export and/or household market; Sector 3 represents the imports and household supply market; and Sector 4 represents the sales between external market role-players (Glasson, 1974:52). As per the example presented by Table 4.1, Industry 1 sold R50 000 worth of goods to Industry 2; R20 000 worth of goods to Industry 3; and R40 000 worth of goods to the export and/or household market, with a total income of R110 000. During

the same time, Industry 1 bought R20 000 worth of goods from Industry 2; R40 000 from Industry 3; R40 000 from the household market (labour); and R10 000 from the import market, with a total expenditure of R110 000. It is worth noting that according to the descriptive model, inputs always equal outputs.

Table 4.1: Single region input/output table

Inputs from: \ Output to:	Industry 1	Industry 2	Industry 3	Final Demand	Total Outputs
Sector 1 / Industry 1	-	50	20	40	110
Sector 2 / Industry 2	20	-	80	110	210
Sector 3 / Industry 3	40	50	-	60	150
Household Inputs	40	100	50	-	190
Sector 4 / Imports	10	10	-	20	40
(ZAR 1 000) / Total Inputs	110	210	150	230	700

Source: Glasson (1974:52)

Table 4.1 is the simplest input-output model, only accommodating one region, relegating the sales from other regions and the sales to other regions to a single column (final demand) and row (imports), respectively. A slightly more complicated input-output model can accommodate a primary as well as a secondary region (refer Table 4.2), divided into four matrices (as opposed to the single matrix of Table 4.1) wherein the sales from both regions' industries can be seen explicitly, negating the need for a final demand column, but instead makes provision for both households' sales and incomes from both regions to be illustrated. The number of regions that the input-output model can accommodate is limitless; however, the complexity increases exponentially with each region added. Table 4.1 can only be used as a descriptive tool, meaning that it is only possible to determine the industrial structure of any given region at any given time.

In order to use the input-output model as a predictive tool, one must first compile a descriptive model (refer Table 4.2), then convert the input variables (items in the demand column) into a percentage of total inputs known as the supply coefficient (refer Table 4.3) (Glasson, 1974:76). The one concern is that, for prediction purposes, the input coefficient is assumed to stay unchanged over the prediction period, which in practice is not always the case, due to advances in technology, political and socio-economic conditions, etc. (Blair 1995:163; Glasson, 1974:77). There are, however, methods that one can use to adjust (or predict) the changes in the input coefficients to adapt to market fluctuations, whereafter the predictive input-output model can be

used to predict the changes in output for various industries based on various real-world changes, or to estimate income and employment multipliers for each industrial sector (Glasson, 1974:78).

Table 4.2: Descriptive inter-regional input-output table

Inputs from: \ Output to:		Region A Industry 1	Region A Industry 2	Region A Industry 3	Region B Industry 1	Region B Industry 2	Region B Industry 3	Households A	Households B	Total Output
Region A Industry	1	-	-	10	-	50	10	30	-	100
	2	-	-	-	-	-	-	-	-	-
	3	20	-	-	-	-	-	30	-	50
Region B Industry	1	-	-	-	-	-	-	-	-	-
	2	20	-	20	-	-	60	20	80	200
	3	20	-	-	-	50	-	-	30	100
Households A		40	-	20	-	20	-	-	-	80
Households B		-	-	-	-	80	30	-	-	110
Total Inputs		100	-	50	-	200	100	80	110	640

Source: Glasson (1974:74)

Table 4.3: Predictive inter-regional input/output table

Inputs from: \ Output to:		Region A Industry 1	Region A Industry 2	Region A Industry 3	Region B Industry 1	Region B Industry 2	Region B Industry 3	Final Demand A	Final Demand B
Region A Industry	1	-	-	0.20	-	0.25	0.10	0.37	-
	2	-	-	-	-	-	-	-	-
	3	0.20	-	-	-	-	-	0.38	-
Region B Industry	1	-	-	-	-	-	-	-	-
	2	0.20	-	0.40	-	-	0.60	0.25	0.73
	3	0.20	-	-	-	0.25	-	-	0.27
Households A		0.40	-	0.40	-	0.10	-	-	-
Households B		-	-	-	-	0.40	0.30	-	-
Total Inputs		1.00	-	1.00	-	1.00	1.00	1.00	1.00

Source: Glasson (1974:75)

4.7 Conclusion

This chapter commenced by explaining that the traditional neoclassical theories of growth and development propose that growth comes from exogenous (outside) factors. However, since the 1980s, the new growth theory has taken precedence and advocates that growth arises from

endogenous factors, allowing for both regional divergence and convergence, as opposed to the perpetual cycle of convergence as advocated by the neoclassical exogenous growth theories. The new growth theory highlights the importance of technology and exploits local resource endowments through entrepreneurship, labour, and institutional support in achieving regional development by using policy instruments as the driving force. Some theories propose that should economic markets be left to their own devices, a state of equilibrium will occur, while the cumulative causation theory proposes that perpetual divergence is the natural effect of the free-market system. The export-base theory is one of the most influential theories in economic development literature and identifies exports to be the main driver behind regional growth and development.

Structuralist theories such as the Marxist theory describe countries as moving through stages of development, where each stage has a greater capital-to-labour ratio than the one before, commencing with a pre-industrial society, then moving on to a capitalist society, then to a socialist society, and finally to a communist society. Rostow's stages of development theory also see societies as moving through phases with a greater capital-to-labour ratio. However, where Marxist theory relates to socio-political themes, Rostow uses purely economic themes describing society's move from a primary-sector economy through a secondary-sector economy and ending up with a tertiary-sector economy. Waves of development theory describe the world economy moving through phases lasting between 50 to 60 years. The waves theory also underlines the importance of innovation in economic development.

Modernist theories reveal that growth in industrialized countries can be attributed to the application of new technology. It should, however, be noted that the introduction of new technology does not always translate into development, as the implementation thereof and its acceptance into the market (demand) play an important role in its ultimate success. The need for sustainable development has increased in the recent past. Sustainable development should encompass environmental, social, and economic goals, preferably by means of appropriate techniques for energy use and natural resource use, among others. It is commonly accepted that a holistic approach needs to be undertaken wherein natural resources are used more efficiently and responsibly using regional planning instruments such as policies and development plans. Furthermore, the region is the most appropriate scale on which to achieve sustainable development according to many experts.

When it comes to policy formulation, it is important to remember that local context matters, and that policy should enhance endogenous, naturally comparative advantages. The place-neutral approach is criticized for neglecting natural market forces' tendency to create divergence; thus governments should rather focus on local capacity building. Spatial targeting advocates that

development strategies must seek to exploit particular local assets such as resources and be tailor designed for the specific local context. Spatial targeting policies should preferably be integrated into a larger framework that binds various local, regional, and national policies into a cohesive unit, as opposed to standing alone.

As insightful as development theories may be, they do tend to lack ‘real-world’ applicability, due to their simplicity and should therefore only be used as a starting point for policy formulation. Development in the ‘real world’ can be measured more effectively by means of specialized techniques. The interregional trade multipliers technique does so by using the export-base theory but acknowledges leakages such as imports, savings, and taxation. Shift/share analysis uses the national average employment rate (the national share component) as a base, and calculates regional growth or decline based on the regional employment rate compared to that of the national rate (the regional shift component). The shift can then be attributed to either local or nationally established industries. The regional input-output model was used in the late 1950s to identify key (or leading) industries in economic sectors and can be used to make short-term predictions.

Now that the theoretical causes of regional growth have been discussed, it is important for the context of this study to determine whether or not renewable energy deployment can cause regional growth, which will be done in the following chapter.

CHAPTER 5: RENEWABLE ENERGY AND REGIONAL DEVELOPMENT

5.1 Introduction

In the previous chapter of this study, regional development was discussed from a theoretical point of view, illustrating how important public policies aimed at creating an environment for economic growth can be to achieve regional development. As this study's main goal is to utilise renewable energy deployment to achieve regional development, this chapter is aimed towards achieving research objective number three of this study, i.e. **to determine the potential impacts of renewable energy deployment on regional development.** However, to determine the impact that renewable energy deployment may have on regional development effectively, one first must define what exactly is meant by development.

As mentioned in Chapter Four, regional development is particularly subject to economic growth; however, despite much significant devotion towards the topic, there is little agreement as to how economic development outcomes should be measured (Feldman *et al*., 2014:1). Economic development has been defined by several authors and organizations (see Feldman *et al*., 2014:1; Ferroukhi *et al.*, 2016:32; IEDC, 2000:3; IRENA, 2017a:2; Kamdari, 2016:3) with some degree of heterogeneity in terms of specific measurable objectives or outcomes. However, the most common criteria includes economic growth measured in Gross Domestic Product (GDP) per capita, combined with elements that enhance quality of life such as employment, education, and health.

The International Economic Development Council (IEDC, 2000:3) defines economic development as the process that involves economic growth and restructuring aimed at enhancing the welfare of a community. Kamdari (2016:2-3) explains that while economic growth is primarily concerned with an increase in aggregate income, economic development is the increase in the standard of living of a population. According to Feldman *et al.* (2014:1), employment is the main measurement unit; for economic growth, the number of employment opportunities is important, whereas for economic development salaries, career advancement opportunities and working conditions are important. In an attempt to define indicators of human welfare better, the United Nations Development Programme (UNDP) developed the Human Development Index (HDI) in 1990 and included measurements such as income measured in Gross National Income (GNI) per capita, combined with health measured in life expectancy, as well as education measured in mean school years (cited by Klugman, 2009:174). The International Renewable Energy Agency (IRENA, 2017a:2) concurs with the economic and social dimensions as is largely agreed upon. However, they add an environmental component,

which includes a reduction in greenhouse gas emissions and changes in resource consumption patterns.

For ease of reference, in this chapter, the term ‘economic development’ will refer to economic growth measured in an increase in GDP, combined with an increase in welfare measured in employment, education, health, and environmental quality. Unless specifically indicated otherwise, the term ‘development’ will refer to economic development, whereas regional development will refer to economic development linked to a specific geographically defined area. In order to fully grasp the impact that renewable energy deployment may have on regional development, it would be appropriate to begin with examining the relationship between development and energy in general before narrowing the subject down towards renewable energy.

The remainder of this chapter is therefore organized as follows: Section 5.2 will examine the relationship between energy and development by firstly focusing on economic growth and secondly on welfare. Section 5.3 will discuss the environmental considerations that led to the paradigm shift towards renewables; Section 5.4 will discuss the relationship of renewable energy and development, again by firstly focusing on economic growth before moving on to welfare; and finally Section 5.5 will conclude this chapter by highlighting the most important findings and lessons learned.

5.2 Energy and development

The energy sector contributes to development in two ways; firstly, energy is an important factor in production and services, thus enabling economic activities to occur. Secondly, the energy sector creates jobs through manufacturing and services, thus increasing the wellbeing of individuals employed in this sector (Liko, 2019:4). The following section will commence by thoroughly examining the relationship between energy and economic growth, followed by examining the relationship between energy and welfare.

5.2.1 Energy and economic growth

Ferguson *et al.* (2000) use correlation analysis to study the relationship between electrical energy (electricity) consumption per capita and GDP per capita as well as the relationship between total energy supply per capita and GDP per capita in over 100 countries, constituting more than 99 percent of the global economy. The data for each country were analysed in isolation as well as within their various economic and geographic regional contexts.

The results (refer Figure 5.1) illustrate that a very strong positive relationship exists between electricity consumption and economic growth with a coefficient of 0.9 for OECD (Organization for Economic Cooperation and Development) countries and Asian countries and that a strong positive relationship with a coefficient of 0.8 for Latin American countries and Non-OECD European countries exists (Ferguson *et al*., 2000:934). For African countries, there was little to no correlation, and a strong negative relationship with a coefficient of 0.8 exists for the Middle East oil-producing countries (Ferguson *et al*., 2000:934).

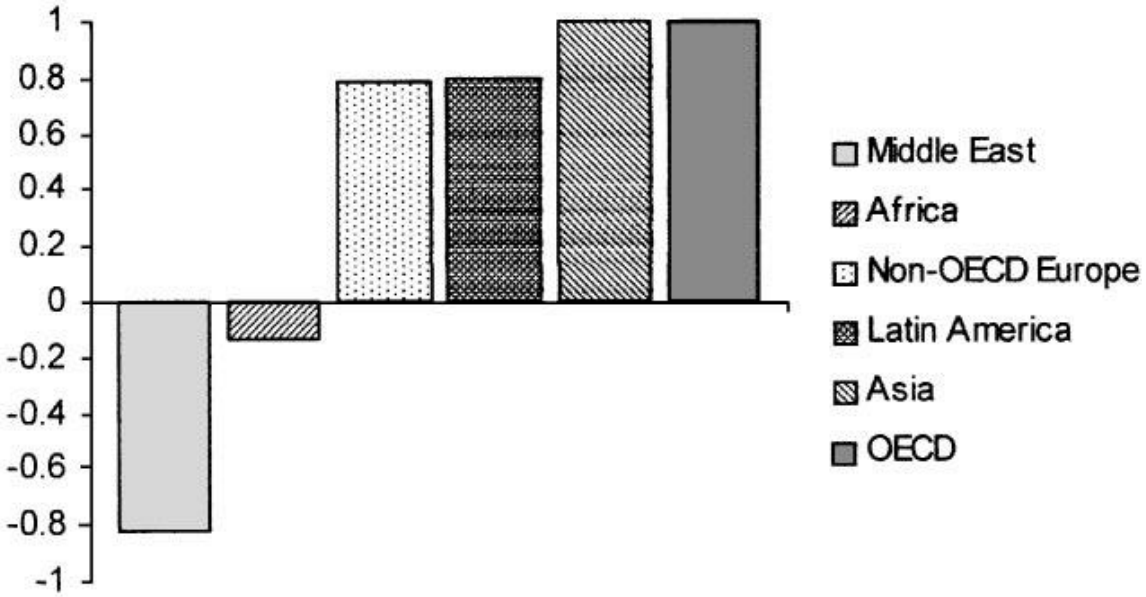

Figure 5.1: Electricity consumption per capita vs. GDP per capita

Source: Ferguson *et al.* (2000:934)

Figure 5.2 illustrates the results for total energy consumption and economic growth. A similar pattern for the various regions exists; however, with a noticeably smaller positive correlation coefficient for OECD countries. It must be noted that the above-mentioned results do not prove causality, but merely illustrate that in wealthier countries economic development and an increase in energy consumption have occurred simultaneously, in particular energy that comes in the form of electricity (Ferguson *et al*., 2000:934). The relationship as presented by Hirsh and Koomey (2015) in their study between electricity use and economic activity in the USA between 1949–2014 shows a similar pattern. Again, it must be noted that Hirsh and Koomey (2015) did not test for causality, but merely compared the data between the two variables (refer Figure 5.3), showing that there is a correlation.

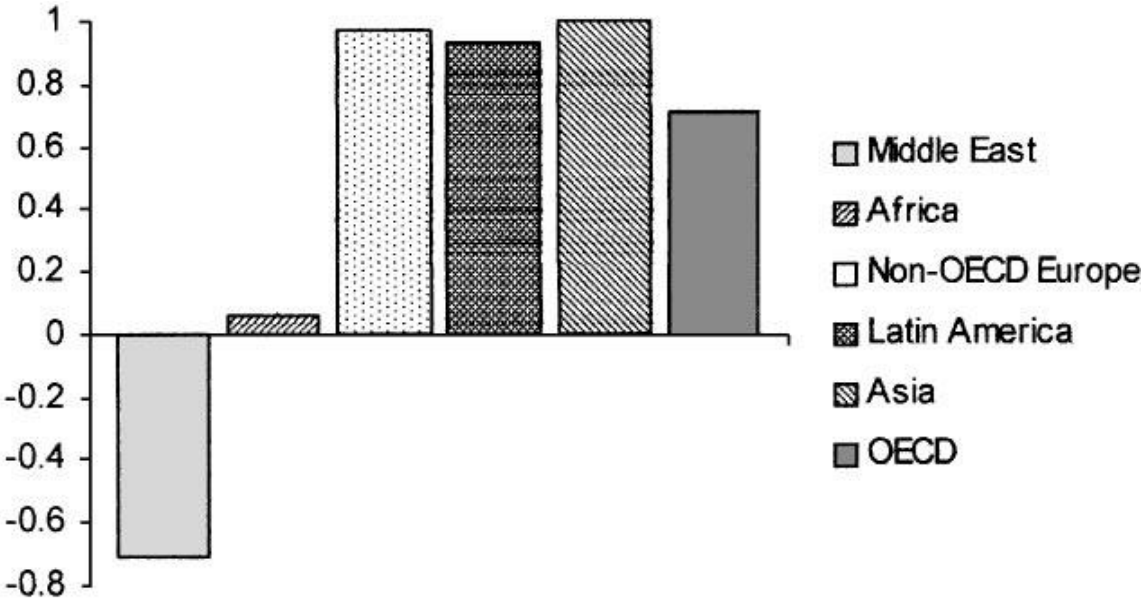

Figure 5.2: Total energy supply per capita vs. GDP per capita

Source: Ferguson *et al*. (2000:934)

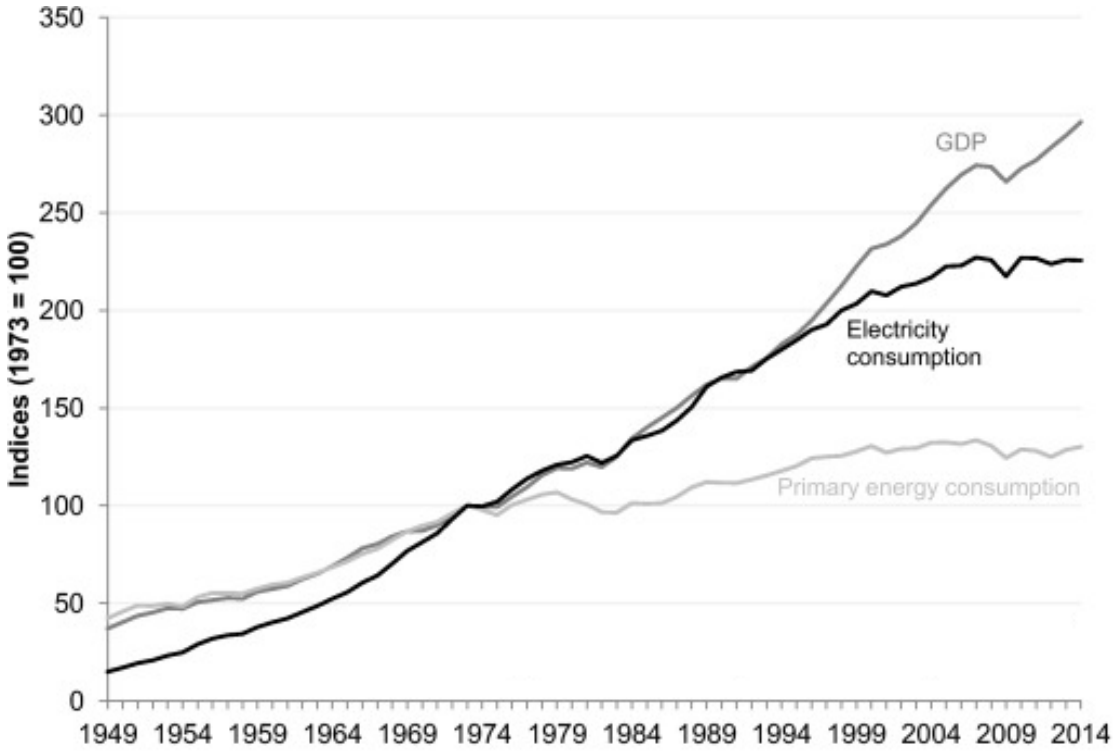

Figure 5.3: Energy, electricity, and GDP

Source: Hirsh and Koomey (2015:75)

5.2.1.1 Causality

There is, however, a general belief that energy consumption and economic growth do have a causal relationship and data from graph 5.3 do indicate that there is some sort of cointegration

between the two variables. However, it is important to determine the merits of this belief before making policy recommendations on its basis. This can be achieved by establishing cointegration via a cointegration test, which would prove that the two variables have a causal relationship (Hjalmarsson & Österholm, 2007:3).

Should the belief that cointegration (a causal relationship) between energy consumption and economic growth exist holds true, the crucial question in for study still remains: What is the causal effect; i.e. does an increase in energy consumption cause economic growth; does economic growth cause an increase in energy consumption; or do the two variables have the same positive effect on each other? Determining the direction of causality is significant, as a positive unidirectional (one-way) causality flowing from energy consumption towards economic growth (known as the growth hypothesis) means that policies supporting energy generation can influence economic growth positively. However, should a positive unidirectional causality flowing from economic growth towards energy consumption exist (known as the conservation hypothesis), policies supporting energy generation may have no influence on economic growth, and should a positive bidirectional (two-way) causality exist (known as the feedback hypothesis), policies supporting energy generation can again have a positive influence on economic growth (Bayraktutan *et al.*, 2011:60; Narayan & Smith, 2005:1109). To establish the direction of causality between energy and economic growth, a causality test will need to be undertaken.

Numerous studies have been devoted towards examining the causal relationship between energy consumption and economic growth using data as far back as the 1940s (see Ciarreta and Zarraga, 2007; Kraft & Kraft, 1978; Nazlioglu *et al*., 2014; Yu and Hwang, 1984). Some of these studies focus on multiple countries simultaneously, while others only use a single country as the study area. For this chapter, country-specific studies were examined in order to isolate the countries' results with the aim of reducing the number of unknown variables, which will hopefully provide clearer indications for causality prerequisites (should there be any) than would have been the case with multi-country studies.

For ease of reference, the outcomes of the studies will be presented categorically in Table 5.1, indicating the author(s), study area, study period, and methodology used. First, the growth hypothesis outcomes will be presented; secondly, the conservation hypothesis outcomes will be presented; thirdly, the feedback hypothesis outcomes will be presented; and finally, those studies that found no causality (known as the neutrality hypothesis) will be presented, whereafter an analysis will be made based on the findings.

Table 5.1: Energy consumption and economic growth causal relationship

Growth hypothesis			
Study	**Study area**	**Period**	**Methodology**
Atif and Siddiqi (2010)	Country A	1971- 2007	Phillips-Perron test and linear Granger-causality.
Aslan (2014)	Country B	1968- 2008	ARDL test and linear Granger-causality.
Conservation hypothesis			
Study	**Study area**	**Period**	**Methodology**
Kraft and Kraft (1978)	Country C	1947 - 1974	Linear Sims-causality spurious
Ciarreta and Zarraga (2007)	Country D	1971 - 2005	VAR & linear Granger-causality.
Hye and Riaz (2008)	Country A	1971- 2007	ARDL test & linear Granger-causality.
Aktaş and Yılmaz (2008) (long-run)	Country B	1970- 2004	ADF cointegration & linear Granger-causality.
Feedback hypothesis			
Study	**Study area**	**Period**	**Methodology**
Shahbaz *et al.* (2012)	Country A	1972-2011	ARDL test and linear Granger-causality
Aktaş and Yılmaz (2008) (short-run)	Country B	1970- 2004	ADF cointegration & linear Granger-causality.
Nazlioglu *et al.* (2014)	Country B	1967-2007	Bounds cointegration & Nonlinear Granger-causality
Yapraklı ve Yurttançıkmaz (2012)	Country B	1970-2010	Johansen cointegration & linear Granger-causality
Neutrality hypothesis			
Study	**Study area**	**Period**	**Methodology**
Yu and Hwang (1984)	Country C	1947 - 1979	Sims-causality

Ciarreta and Zarraga (2007)	Country D	1971 - 2005	VAR & nonlinear Granger- causality
Nazlioglu *et al.* (2014)	Country B	1967-2007	Bounds cointegration & Nonlinear Granger-causality

Source: Own compilation from literature (2020)

From the above findings, several observations can be made:

- The nonlinear causality test seems to create a statistical environment that favours the Neutrality hypothesis, possibly due to the lack of variable isolation. This can be seen in the studies done in Country D between 1971 and 2005, where Ciarreta and Zarraga (2007) performed the same cointegration test (VAR), one followed by a linear and another by a nonlinear Granger-causality test. The former proved the Conservation hypothesis, meaning that economic growth caused an increase in energy consumption, and the latter proving the Neutrality hypothesis, meaning that there is no causal relationship at all. The same phenomenon can be observed in Country B between 1967 and 2007, where Nazlioglu *et al*. (2014) used the Bounds cointegration test before using a linear and nonlinear Granger-causality test; the former showed bidirectional causality, meaning that the two variables positively influenced each other, whereas the latter showed no causality.
- The causality test results additionally appear to be extremely sensitive and subject to small differences in input variables. This can be seen as the same causality test was used in four different studies between roughly the same period in Country B (see Aktaş & Yılmaz, 2008; Aslan, 2014; Nazlioglu *et al*., 2014; Yapraklı & Yurttançıkmaz, 2012), resulting in four different outcomes. The same phenomenon can be observed in Country A, where the same causality test was used during roughly the same period in three separate studies (see Atif & Siddiqi, 2010; Hye & Riaz, 2008; Shahbaz *et al*., 2012) resulting in three different hypotheses, and also in Country C, where Kraft and Kraft (1978) proved the Growth hypothesis during roughly the same period, using the same causality test as Yu and Hwang (1984), which proved the Neutrality hypothesis.

It would appear from the above analysis that a causal relationship between energy use and economic growth is very likely to exist; however, the general direction of causality seems difficult to prove with certainty and may, as Ferguson *et al*. (2000:934) suggest, not being possible at all. In addition to causality tests, basic principles of energy and economics may be able to guide policy formulation. The next section will discuss some of these principles, hopefully to gain more clarity on the subject.

5.2.1.2 Economic principles

The previous section aimed to establish the direction of causality between energy consumption and economic growth for energy policy formulation purposes. However, this proved to be more difficult than anticipated, which is why this section will look at some basic principles relating to energy consumption and economic growth in an attempt to gain more clarity on the subject. As Stern *et al.* (2017:4) point out, energy is an essential factor in the production of goods, as well as in the transport of said goods to the marketplace. From the beginning of the industrial revolution, factories have used energy to manufacture materials and maintain equipment, proving that a continuous supply of energy is needed to maintain and expand economic activity (Bayraktutan *et al.*, 2011:59). The reliable supply of energy is essential for all economies and sectors (Girouard *et al*., 2011:10). Edenhofer *et al.* (2011:120) share this sentiment by stating that energy consumption and economic growth are interdependent and a continuous and stable supply of energy is therefore essential for economic growth in both developed and developing countries. He *et al*. (2015:17) argue that for this reason, high energy prices can also have a negative impact on economic growth as high energy prices, especially electrical energy, will increase the production cost and therefore the price of the final product, making it less accessible to poor communities. This is especially true for poor countries where the cost of energy can be high relative to wealthy countries, which will lead to less energy being used, indicating that high energy prices can be more detrimental in developing economies than in developed economies (Stern *et al*., 2017:6).

One way to circumvent the lack of energy, whether it be due to supply constraints or energy prices, is to use energy more efficiently with technology (Stern & Kander, 2012:127). Stern *et al.* (2017:7) argue that reducing energy intensity is an alternative to increasing the supply of energy. Pakina and Karnaushenko (2017:146) use this argument to explain that the reason why causality test results should be considered with caution is due to a decrease in energy intensity in developed economies as a result of technological innovation, in addition to developed economies increasing their share in the service sector, compared to the manufacturing sector, resulting in less energy consumed for the same level of economic output. This is consistent with the stages of development theory presented by Rostow (1985) (refer Section 4.3.2) and explains why energy intensity is one of the most important indicators of the sustainability of national and regional economies (Pakina & Karnaushenko, 2017:146).

As illustrated by Hirsh and Koomey (2015:75) earlier in this chapter (see Figure 5.3), energy use and economic growth have had a strong correlation since the 1940s, especially energy that comes in the form of electricity. Stern *et al.* (2017:3) point out that as income per capita increases on a national scale, there is an upward shift in the proportion of energy use that

comes in the form of electricity. This may be the result of many factors. However, there is a general belief that electricity is more productive and efficient than other forms of energy in manufacturing due to technological applications (Stern *et al*., 2017:3). Electricity is a high-quality energy carrier with far superior thermodynamic efficiency in applications such as lighting, compared to other forms of energy with less, if not zero, pollution at the point of use and in applications such as computing and telecommunication, electricity has no substitutes, illustrating its potential in both developed and underdeveloped regions (Stern *et al.*, 2017:8). Electricity has proved to be more efficient ever, since the electric motors outperformed the steam engines, revolutionizing the industrial sector (Stern *et al.*, 2017:8). It is therefore not surprising that per capita electricity consumption is used as an indicator of how developed a country is (Bayraktutan *et al.*, 2011:65).

From the above, it can be safely assumed that [electrical] energy is vital for economic growth. However, as pointed out earlier in this chapter, development is not only measured in terms of economic growth, but includes important elements of welfare such as job availability, education, and healthcare. The next section will discuss the relationship between energy and welfare.

5.2.2 Energy and welfare

In the previous section, the role that energy plays in economic growth was discussed. However, it is known that economic growth alone cannot be used to determine economic development, as it includes elements of welfare such as employment, health, education and an increase in environmental quality (Ferroukhi *et al.*, 2016:32; IRENA, 2017:2). The picture of someone living in darkness without electrical light sources, cooking food by burning wood, and having no electronic communication equipment is someone who completely lacks access to modern energy. This is endemic to most developing countries, and as the Centre for Global Development (CGDEV) (2016:5) points out, the lack of access to modern forms of energy is both a symptom as well as a cause of underdevelopment.

Development can be seen as commencing with economic growth, which raises the level of income per capita via job creation, which in turn increases tax revenue, enabling countries to spend more resources on social infrastructures such as schools and hospitals, raising the health and education of the citizens (Ferroukhi *et al.*, 2016:35). It is therefore obvious that jobs are crucial for economic development and globally, and the energy sector has played an important role in job creation (Ferroukhi *et al.*, 2016:38). On a macroeconomic level, energy shortages place a large damper on both economic growth as well as job creation (CGDEV, 2016:6). Energy contributes to welfare in other ways as well, including enabling people to work, eat, travel, and communicate (CGDEV, 2016:3). In recent years, the focus on the role of energy in development has urged governments, business leaders and ordinary people to join hands in

ensuring that access to energy becomes a top priority, as this can have a positive effect on the welfare of all by improving health, education, and job creation (CGDEV, 2016:9).

The agenda for sustainable development has become central to policy formulation in many countries around the world, especially since the United Nations (UN) General Assembly brought forth a set of global Sustainable Development Goals (SDGs) in 2015, aimed to be in place by the year 2030, and which includes 17 goals and 169 outcomes (UN, 2019:3-57). The SDGs differ to some extent from the Millennium Development Goals (MDGs) presented by the UN in 2000, especially in placing a greater demand on the scientific community to reach the proposed goals (Owusa & Asumadu-Sarkodie, 2016:3). Whereas the MDGs only acknowledged energy's role in development and left the objective of access as implicit, the UN Sustainable Development Goal seven (SDG-7) specifies that universal access to sustainable, reliable, modern and affordable energy for all by the year 2030 must be achieved by utilizing renewable energy sources, and has subsequently launched the Sustainable Energy for All (SE4All) initiative in partnership with the World Bank (CGDEV, 2016:9).

Energy consumption is connected to development outcomes such as health, environmental quality, and education as well as to the more commonly known outcome in the form of economic growth (Ferroukhi *et al.*, 2016:32). It can more easily be quantified in terms of the United Nations Development Programme's Human Development Index (HDI), which measures the development of a country based on the life expectancy of citizens at birth, the average number of years for education, combined with GNI per capita. This has been in use since 1990, often featuring in development statistics measuring welfare (CGDEV, 2016:19).

The developmental contributions of energy do, however, come at a price, since a large portion of the global energy supply is generated from air-polluting fossil fuels (Hirsh & Koomey, 2015:72; UN, 2019:36), which negates one of the development outcomes (environmental quality) as listed above. This is exacerbated by the increase in energy demand across the globe, which is what prompted governments to seek alternative forms of energy generation aimed at minimizing the environmental impacts (Ferroukhi *et al.,* 2016:13). The next section will look at how environmental damage relates to the development discussion.

5.3 Environmental considerations

Overwhelming evidence points to the fact that the continuous burning of fossil fuels for energy generation is one of the main contributors to greenhouse gas emissions, which have been linked positively to climate change (Stern, 2006:1). Ayres and Ayres (2009:157) warn that even though climate change has been widely discussed in academic literature publications, the

general public is still not fully aware of its consequences and what it could mean for civilization in the coming years. A warmer world could well result in more intense water cycles and rising sea levels, which will have a detrimental effect on many key determinants of welfare, including, but not limited to, environmental degradation, and climatic changes, resulting in a shortage of water supply, which can result in a food scarcity, affecting human health negatively (Stern, 2006:84). Climate change can also cause economic output to drop as a result of a diminished labour force not healthy enough to work, as well as the loss of fertile agricultural land (Stern, 2006:107).

Environmental management has become one of the most important considerations on both national and regional scales in recent years through the implementation of environmental policies and, according to Pakina and Karnaushenko (2017:151), policies at regional level must aim not only to foster economic growth, but take into consideration the environmental and social effects as well by achieving economic growth via a low-carbon and resource-efficient manner, also referred to as the 'green economy'. Ferroukhi *et al.* (2016:35) suggest that the environmental effects are currently not priced into global economic systems, and as a result, welfare is being compromised. According to Stern (2006:17), climate change can affect the economies of developing countries negatively by several percentage points of GDP.

Climate change affects another aspect of welfare and development in the form of human health negatively as, according to the World Health Organisation (WHO, 2018), over 250 000 deaths per year can be attributed to climate change-related illnesses such as diarrhoea and malnutrition. Education is another welfare indicator that can be affected negatively by climate change as schools and related infrastructure can be damaged through climate disasters, making it more difficult for children to go to school, or education can become financially out of reach for individuals whose finances were affected by climate-induced changes (Stern, 2006:114).

Although fossil fuel-based energy has duly contributed to development as pointed out in Section 5.2, several authors and researchers (see Bayraktutan *et al*., 2011:59; Girouard *et al*., 2011: 24; Perera, 2018:3; Sharma *et al.*, 2012:35) report that these forms of energy are steadily being replaced by renewable sources of energy by governments around the world, due to the associated negative environmental impacts such as air pollution and climate change. It can be assumed that replacing the old fossil fuel-based energy sources with renewable forms of energy such as solar, wind and hydro (which includes ocean-current and ocean-wave energy) will achieve a similar level of development as energy in general, while minimizing the negative environmental impacts, thus helping to achieve truly sustainable development (Owusa & Asumadu-Sarkodie, 2016:3).

Since the global economic recession of 2008/9, many countries have been faced with the challenge of boosting economic output in challenging economic conditions while at the same time being urged by international policies to decarbonize their economies Subsequently, they have turned to renewable energy technologies (refer Section 4.4.1) to achieve the above-mentioned targets and, according to Ferroukhi *et al.* (2016:23), they are now beginning to see the returns on investment in terms of capital, but also in terms of improving the environmental quality. This is what the green growth objectives aim for and shows that economic growth does not have to come at the price of the environment (Ferroukhi *et al*., 2016:23).

The appropriate question that can now be asked is: To what extent can the reduction of greenhouse gas emissions and environmental resource conservation contribute towards economic growth and development. It has been suggested that the Environmental Kuznets Curve (EKC) can be used, as this model postulates that during the initial stage of economic growth within any given region, the environment is damaged before a threshold is reached, and after a certain point, the quality of the environment increases alongside economic growth (Dinda, 2004:434) as depicted in Figure 5.4 below.

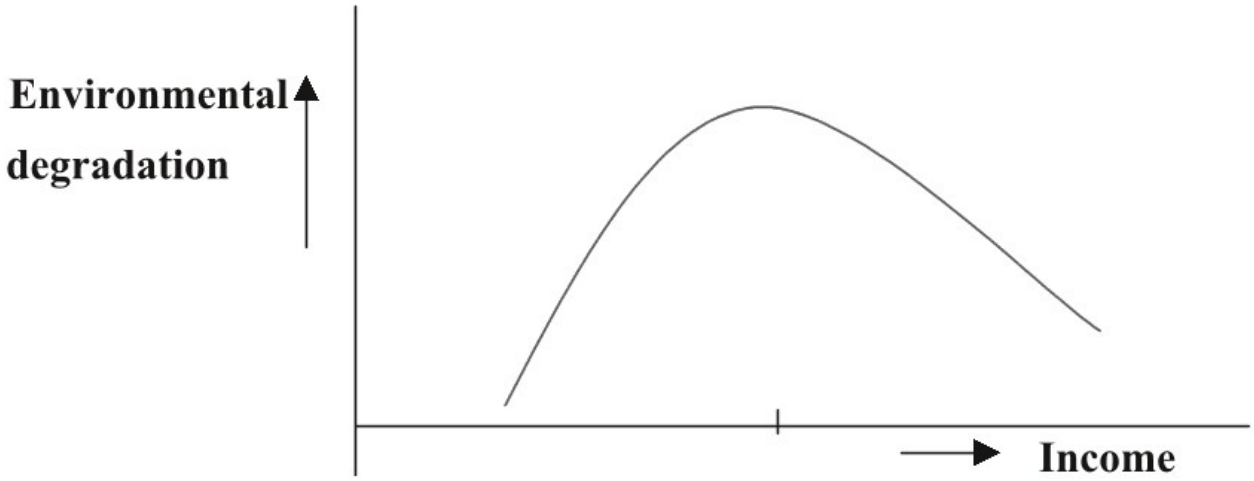

Figure 5.4: EKC Model

Source: Dinda (2004:434)

The EKC is based on a combination of theories, including that some pollution control technologies become financially viable with increasing economies of scale in addition to inefficient industries shifting to a more environmentally friendly way of doing business to using fewer polluting materials as inputs.

5.4 Renewable energy and development

The U.S. Energy Information Administration (EIA, 2019) defines renewable energy resources as *"*energy resources that are naturally replenishing but flow-limited; inexhaustible in duration but

limited in the amount of energy available per unit of time". It is expected that the demand for energy will continue to increase across the globe; however, there still remains the legitimate concerns over the damage conventional energy generation methods will have on the environment, bringing into question whether or not policy with effects lasting for decades should allow these sources to be continuously used to achieve economic growth and development (Ferroukhi *et al*., 2016:13). It has been pointed out that renewable energy can have a positive impact not only on the environment as is commonly agreed, but on the actual economic output of a country as well (Pakina & Karnaushenko, 2017:149).

The adoption of the SDGs in 2015 and the Paris Agreement in 2016 made it clear to the global community that the transition towards renewable forms of energy generation is central to meeting the climate objectives (Ferroukhi *et al*., 2016:9). According to the International Renewable Energy Agency (IRENA), doubling the share of renewables by 2030 will impact economic development positively in relation to economic growth, social welfare, job creation, and overall trade (IRENA, 2017:2). Making the energy supply more environmentally sustainable, cost-effective and reliable (as will be the case if renewable energy is increased) will contribute towards long-term economic development (Ferroukhi *et al.*, 2016:13).

As described earlier in this chapter, in addition to economic growth, economic development can be measured in terms of an increase in the standard of living of a population and typically includes higher levels of income per capita, as well as in increase in the general quality of life. This section will discuss the role that renewable energy plays in economic growth, followed by indicators that relate to the quality of life such as employment, health, education and environmental quality in order to reach research objective number three of this study.

5.4.1 Renewable energy and economic growth

The relationship between renewable energy and economic growth will once again be divided into two sections, as was the case for energy in general. Firstly, causality tests will be examined to determine whether a general direction of causality exists, whereafter general principles will be examined.

5.4.1.1 Causality

Several studies have examined the causal relationship between renewable energy and economic growth in recent years (see Bowden & Payne, 2010; Khobai & Le Roux., 2017; Pau & Fu, 2013; Yildirim *et al*., 2012). As in Section 5.2, only single-country studies were examined to isolate each country's results, which will hopefully provide clearer indications for causal relationship determinants. The studies' results are summarized in Table 5.2 below:

Table 5.2: Renewable energy and economic growth causal relationship

Growth hypothesis			
Study	**Study area**	**Period**	**Methodology**
Bowden & Payne (2010)	Country A (Residential)	1949-2006	Toda–Yamamoto causality
Yildirim *et al*. (2012)	Country A (Biomass only)	Not specified	Toda–Yamamoto causality
Pau & Fu (2013)	Country B (NHREC)	1980-2010	Augmented Dickey–Fuller, Johansen cointegration & Vector error correction model (VECM)
Khobai & Le Roux (2017)	Country C (Long-run)	1990-2014	ARDL & Vector Error Correction Model (VECM)
Conservation hypothesis			
Study	**Study area**	**Period**	**Methodology**
Khobai & Le Roux (2017)	Country C (Short run)	1990-2014	ARDL & Vector Error Correction Model (VECM)
Feedback hypothesis			
Study	**Study area**	**Period**	**Methodology**
Pau & Fu (2013)	Country B (TREC)	1980-2010	Granger-causality
Neutrality hypothesis			
Study	**Study area**	**Period**	**Methodology**
Bowden & Payne (2010)	Country A (Industrial & Commercial)	1949-2006	Toda–Yamamoto causality
Yildirim *et al*. (2012)	Country A (Total RE)	Not specified	Toda–Yamamoto causality

Source: Own compilation from literature (2020)

From the above findings, the following observations can be made:

- The variety of different renewable energy sources have a significant effect on the causality test results when compared to energy in general. This can be seen in the study

done by Pau and Fu (2013) in Country B, where a unidirectional causality flowing from non-hydro renewable energy consumption (NHREC) to economic growth was found, bidirectional causality between total renewable energy consumption (TREC), and economic growth between 1980–2010, indicating that the more the economy grew, the more investment in hydro energy was made. The same phenomenon can be seen in the study done by Yildirim *et al.* (2012) in Country A, where a unidirectional causality from biomass consumption to economic growth was confirmed, but no causality when all the renewable energy sources were combined. The time scales also affect the results, as in Country C, Khobai and Le Roux (2017) found a unidirectional causality flowing from economic growth towards renewable energy consumption in the short-run during 1990–2014, and a unidirectional causality flowing in the opposite direction in the long run.

- The various sectors can also alter the results, as seen in the study done by Bowden and Payne (2010) during 1949–2006 in Country A, where a unidirectional causal relationship flowing from residential renewable energy use towards economic growth was found, and no causal relationship when commercial and industrial renewable energy consumption was tested.

Again, there does seem to be some sort of cointegration between renewable energy consumption and economic growth. However, the direction of causality is subject to a large variety of factors, making it difficult to determine with absolute certainty. Singh *et al.* (2019:4) came to a similar conclusion, stating that the results differ considerably due to the differences in sample selection, employed variables, and quantitative methods. The next section will examine basic principles relating to renewable energy and economic growth to gain more insight into this relationship.

5.4.1.2 Economic principles

As was the case with energy in general, the causality tests for renewable energy and economic growth do not provide sufficient direction to base sound policy decisions on, which is why this section of the chapter will focus on the basic principles of the relationship between renewable energy and economic growth. Seeing as the basic principles of energy in general have already been discussed (refer Section 5.2.1.2), this section will focus only on renewable, energy-specific impacts.

It is has become clear that governments around the world are increasing their focus on renewable energy production as it has recently been labelled as ‘the fuel of the future’ by scientists and researchers alike. However, according to Singh *et al.* (2019:1), the relationship between renewable energy and its impact on the economy has not been clearly defined in the existing literature. In addition, the literature that does exist focuses almost exclusively on GDP

per capita as the measurement of economic growth and largely ignores factors such as the labour force participation (LF) rate, and gross fixed-capital formation (GFCP), which according to Singh *et al.* (2019:7), is not accurate enough, as the latter two indicators are key macroeconomic variables according to the traditional production function model. Singh *et al.* (2019) conducted a study on the relationship between renewable energy and economic growth that includes LF and GFCF in 20 developed and developing countries, and found that an increase in renewable energy production leads to an increase in economic growth in the long run through the contribution from labour (Singh *et al*., 2019:13).

According to Ferroukhi *et al.* (2016:24), an increase in global GDP can be expected, should the share of renewables increase. Such an increase will largely be due to the increased capital investment needed for renewable energy deployment, which will have a knock-on effect (refer Section 3.3.3.7) to the rest of the economy. Ferroukhi *et al*. (2016:29) continue by stating that even though most economic sectors will increase their output due to renewable energy deployment, the sectors that will see the largest gains are those directly involved in producing goods and services for the renewable energy development. Some of the most obvious examples of the aforementioned statement are the metal and non-metal mineral products (e.g. silicon), which are used in the construction of renewable energy infrastructure and technologies meaning that manufacturing and engineering sectors will benefit most. However, the general service sector will also benefit, whether it be directly or indirectly, as a result of the multiplier effect caused by the primary growth in the economy (Ferroukhi *et al*., 2016:31).

It must be noted that there are circumstances where renewable energy deployment will have a negative impact on the economic growth of a country or region. This is particularly the case in oil-producing countries such as Saudi Arabia, Russia, Nigeria, and Venezuela, where fossil fuels play a significant role in generating revenue (Ferroukhi *et al*., 2016:24). The negative correlation for oil-producing countries is similar to the findings of Ferguson *et al.* (2000) in the Middle East with energy use in general. The economic sectors most negatively affected are the fossil fuel industries such as oil refineries (Ferroukhi *et al.*, 2016:31). One of the more indirect negative impacts that renewable energy can have on economic growth is the intermittent nature thereof, which only allows its use during certain times of the day, resulting in the potential loss of production during certain times (Ayres & Ayres, 2009:147).

Due to the fact that renewable energy is indigenous, the deployment thereof decreases the need to import energy from abroad enhancing energy security which is particularly beneficial in regions where there is no access to the national grid for whatever reason (Edenhofer *et al*., 2011:717; Singh *et al.*, 2019:2). Investing in renewable energy capacity will ensure clean and environmentally friendly electricity generation practices, which will boost economic growth, and

governments are advised to support renewable energy investment strategies, including incentives for developers (Bayraktutan *et al*., 2011:66). According to Bayraktutan *et al.* (2011:61), policies supporting the investment in renewable energy will create an environment where sustainable development can occur (refer Section 4.4.2). Globally, policy options need to be designed not only to generate economic growth but to maximize social benefits such as health, education, employment, and human welfare as well as the matter of sustainability is equally important (Ferroukhi *et al*., 2016:31-33).

The next section will focus on the impact renewable energy deployment will have on the other components of development such as welfare, which includes health, education, and environmental quality.

5.4.2 Renewable energy & welfare

Existing literature categorizes welfare into three distinct dimensions: the economic component, which refers to income and employment; the social component, which refers to investment in human capital such as health and education; and the environmental components, which include natural resource preservation and air quality (Ferroukhi *et al*., 2016:33). According to the UN (2019:37), renewable energy deployment will have a positive impact on global welfare, especially if renewable sources are used to generate electricity, which is then used to power electric heating devices and electric vehicles (EVs), meaning that renewable energy goes beyond the traditional benefits of mere economic growth, but extends to the other dimensions of welfare, as well including the social and environmental spheres by increasing access to energy while reducing greenhouse gas emissions. Access to energy plays an important role in increasing human welfare as this triggers a multiplier effect (refer Section 3.3.3.7), leading to an overall increase in health, improved livelihoods, poverty alleviation, job creation, gender equality and access to food and water, which is the main goal behind the UN SDG-7 (CGDEV, 2016:3; Ferroukhi *et al.*, 2016:36; UN, 2019:36-37).

It is increasingly being recognized that the externalities of deploying renewable energy will diversify a country's skill base and boost industrial development (IRENA, 2017:2). The growth of the renewable energy sector has created many new employment opportunities in various sectors and countries around the globe (Ferroukhi *et al.,* 2016:39). The creation and retention of jobs are some of the most important components of economic development, as this provides an income to many households, who can then go out and purchase goods and services that boost local economies, meaning that the benefits of employment go far beyond the immediate, but ripples out into the rest of the economy (IRENA, 2017:2). Another externality of renewable energy deployment that is not fully reflected in conventional economic accounting systems is the health and environmental benefits, as the better environmental quality that comes from

reducing greenhouse gases has a positive effect on the health of people (Ferroukhi *et al.*, 2016:32; IRENA, 2017:2). It is universally acknowledged that access to energy is a vital component of economic growth and economic development (Ferroukhi *et al*., 2016:37). However, in rural regions around the globe, many people do not have access to the national electricity grid, in particular where renewable energy can provide a significant contribution in the form of distributed mini-grid systems (Edenhofer *et al*., 2011:121).

5.5 Conclusion

Development is not easily measured or defined; however, the International Economic Development Council (IEDC), the United Nations Development Programme (UNDP) and the International Renewable Energy Agency (IRENA) all define development based on their own criteria and when combined can provide a general guideline, which includes two pillars; the first is economic growth measured in GNI per capita or GDP per capita, and the second is an increase in welfare measured in factors such as education, employment, health and environmental quality. This chapter sought to establish the relationship between renewable energy and [regional] development as per research objective number three of this study. This was carried out by firstly exploring the relationship between energy (in general) and development, and secondly by exploring the relationship between renewable energy and development. Each of these two steps was additionally divided into two sections; the first focusing on economic growth (as the first determinant of development) and the second focusing on welfare (as the second determinant of development).

When attempting to determine the relationship between energy and economic growth, an important lesson was learned that greatly affects policy decisions. It was learned that there is a significant difference between correlation and cointegration. Correlation means that the distance between two variables or time series remains constant over time, thus behaving as if they influence each other. However, their relative movement may merely be coincidental, unrelated, or a cause of a secondary influence, meaning that even though they appear to have a causal relationship, this may not necessarily be the case. Cointegration, on the other hand, reveals that the two variables or time series have an influence over each other and therefore have a causal relationship in either one direction or both.

However, establishing that there is a causal relationship between energy and economic growth is not sufficient for policy formulation purposes, as the direction of causality will determine whether directives supporting energy generation will affect economic output positively. For instance, should a unidirectional causal relationship between energy and economic growth exist flowing from energy towards growth, policies supporting energy production will influence growth

positively; however, should the same causal relationship exist in the opposite direction, such policies may have no influence on growth. Even though numerous studies have been devoted to determining the causal relationship between energy and economic growth, the number of known and unknown variables makes it near impossible to reach a general conclusion as to the direction of causality.

This was reflected in the studies presented for both energy and renewable energy, where different results were found for studies using the same study area, period, and methodology. Minute differences such as adding or discarding one particular source of renewable energy proved to be sufficient in two studies to reach different outcomes, and the timeframe proved to be the difference in another study. It was further established that in developed economies, technological innovation can create a scenario where energy consumption decreases while economic output increases. A similar trend is found when an economy has developed to a point where the service sector (which is less energy intensive) is the main contributor to growth. For this reason, researchers caution against the use of causality test results, which is why this study additionally examined general principles relating to energy and growth.

It would therefore be advisable to use causality test results within the correct context for policy formulation purposes. Further investigation, however, does point to the high probability of the existence of a bidirectional causal relationship between energy and economic growth. This was seen as energy is an important factor in production, thus enabling economic activities to occur, highlighting the importance of energy availability, which goes hand in hand with the price of energy. Renewable energy had similar economic benefits. It was further established that energy in the form of electricity seems to be more effective in achieving economic growth than is the case for energy in general, especially in applications such as computing and telecommunication.

As highlighted throughout the chapter, economic development includes both economic growth as well as an increase in welfare. Energy also impacted positively on welfare in that it enabled people to keep warm, communicate with one another, and enjoy certain types of entertainment. Energy also enables schools and hospitals to function which, according to the HDI, are vital for wellbeing. The developmental contributions of energy do, however, come at a price, since a large portion of the global energy supply is generated from air-polluting fossil fuels, which negates one of the development outcomes, i.e. environmental quality. It can be assumed that by replacing the old fossil fuel-based energy sources with renewable forms of energy such as solar, wind and hydro (which includes ocean-current and ocean-wave energy, among others) a similar level of development will be achieved while minimizing the negative environmental impacts, thus helping to achieve truly sustainable development. Many countries have

subsequently turned to renewable energy technologies and are now beginning to see the returns on investment in terms of capital, but also in terms of improving environmental quality. According to the International Renewable Energy Agency (IRENA), doubling the share of renewables by 2030 will have a positive impact on economic development in relation to economic growth, social welfare, job creation, and overall trade. According to researchers, policies supporting the investment in renewable energy will create an environment where sustainable economic development can occur.

The following chapter will look at renewable energy sources and technologies in more detail to determine how one can apply them to achieve regional development.

CHAPTER 6: RENEWABLE ENERGY PRINCIPLES AND TECHNOLOGIES

6.1 Introduction

As was established in the previous chapter, [electrical] energy generally plays an important role in the development of countries by contributing to economic growth as a factor in production, and to human welfare by enabling people to receive an income, communicate with one another, cook food and to keep warm, among others. Renewable energy is the energy that derives from naturally occurring resources such as wind, sunlight, ocean waves, and ocean currents, among others (Sharma *et al*., 2012:36). It provides the same development assistance as conventional energy; however, with the added advantage of being environmentally sustainable. Recent international initiatives such as the Sustainable Development Goals and the Paris Agreement have made it clear that energy cannot continue to be generated at the expense of the environment and has subsequently urged countries to explore renewable energy options.

This chapter is aimed towards achieving research objective number four of this study, i.e. **to gain a broad understanding of the relevant renewable energy sources and technologies and how they relate to spatial and infrastructure planning.** For this study, only renewable energy sources applicable to the South African context will be discussed as not to confuse or overwhelm the reader with unnecessary information. The rest of this chapter will be organized as follows: Section 6.2 will discuss basic principles relating to [electrical] energy, electricity infrastructure, and renewable energy. Section 6.3 will discuss the basic principles relating to renewable energy sources and the technologies used for converting the natural energy sources into electrical energy. Section 6.4 will discuss the spatial and infrastructure planning considerations that are applicable to renewable energy developments, and Section 6.5 will conclude this chapter with a discussion on the lessons learned.

6.2 General principles of electricity

A complex variety of infrastructure is needed to deliver electricity to end-users from where it is generated and is commonly known as an electrical grid (OSPE, 2015:6). A typical electrical grid consists of three sections: generation, transmission, and distribution, where the generation section refers to the power plants where electricity is generated; the transmission section refers to the power lines that transport generated electricity from the power stations to where it is needed in other parts of the country; and the distribution section refers to the power lines that service individual end-users (OSPE, 2015:7). Electrical grids are physical structures that occupy space along the surface of the earth, and its presence not only affects the land-use of any given

area, but the spatial layout as well. Physical infrastructure has had an even more profound impact on spatial outcomes in certain areas than spatial planning policies itself (Todes, 2008:4), highlighting the need for careful planning.

To fully understand the spatial implications of electricity infrastructure, the characteristics of electrical energy need to be understood first. Electricity can be likened to a stream of water flowing through a pipe, where the diameter of the pipe represents the electrical current measured in amps (A), the pressure of the water inside the pipe represents the voltage measured in volts (V), and the amount of water that flows through the pipe at any given moment represents the power, measured in watts (W); therefore V x A = W (Bird, 2007:5). To transmit a fixed level of electrical energy over a long distance, one needs to increase the voltage level while equally decreasing the amperage level (similar to squeezing the end of a water pipe) until the energy has the necessary velocity to reach the desired destination, whereafter the voltage needs to be reduced again making the electricity safe to use for end-users (OSPE, 2015:41). The voltage of electricity can be increased and decreased by feeding the electricity through a step-up transformer and step-down transformer, respectively (OSPE, 2015:41). The placement of electrical substations (which generally house transformers among other equipment) in relation to where energy is extracted and where the energy will be consumed is therefore an important consideration for spatial and infrastructure planners.

Figure 6.1 illustrates the typical varying electrical voltages at each phase (i.e. generation, transmission, and distribution) of the process. Electricity is generally generated at 25 000 V (or 25 kV), and is then fed through a step-up transformer to increase the voltage to 500 kV before being transmitted over long distances, and 69 kV for shorter distances (Karady, 2006:4). When the electricity reaches the desired destination, the voltage is reduced at the distribution substation to approximately 12 kV before it is fed through the distribution lines (Karady, 2006:4).

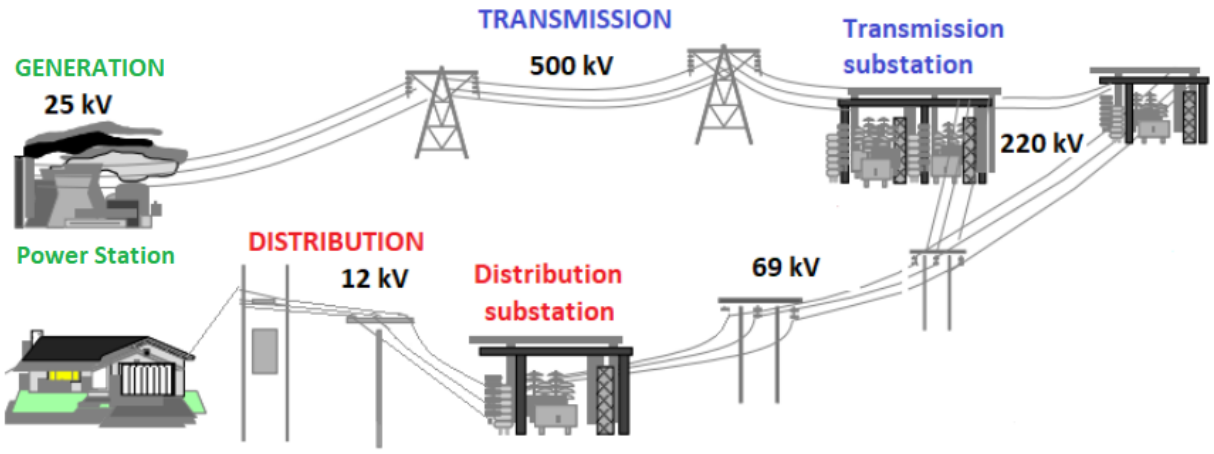

Figure 6.1: Typical electricity grid

Source: Own compilation (2020)

The first law of thermodynamics is a principle of the conservation of energy, which states that energy can neither be created nor destroyed (Mayer, 1862:371). This principle also applies to electrical energy and creates certain challenges for the electricity sector. Seeing as the electricity that has been generated cannot be destroyed, and demand is not unlimited, the electricity needs to be generated at the most appropriate times in order to prevent the collapse of the system due to an over-supply of electricity while avoiding an under-supply, resulting in socio-economic losses (Stern *et al.*, 2017:9). The important function of grid management is done by what is commonly referred to as the system operators (OSPE, 2015: 37). In addition to ensuring that generation output and load demand are in balance, the system operators must ensure that the electricity frequency is held constant ,as well as that the voltage levels are adjusted as required (OSPE, 2015:37).

There are certain measures that can be taken to balance the supply and demand of electricity. Such measures include the temporary ceasing of generation (also known as curtailment), exporting excess electricity to neighbouring countries or finding new applications for fluctuating electricity in heating and cooling systems (Maegaard, 2012:28). In the case of the latter, excess wind and solar power can also be used in electric boilers and heat pumps at combined heat and power (CHP) stations. Electric boilers have proven to be a cost-effective solution to capturing excess energy (Maegaard, 2012:31). By integrating CHP with electric boilers, heat pumps, and hot water storage, it will be possible to incorporate a larger share of wind and solar in the energy structure without causing instability in the power system.

As established in Chapter Five, renewable energy sources can have a positive impact on regional development by providing a more diversified, balanced, and stable pool of energy sources while making industries more competitive over the long run (Bassam, 2012:5). Renewable energy sources such as wind, solar, and hydro have enormous potential as they can meet the world's energy demand in a sustainable manner without the risk of running out of supply (Sharma *et al*., 2012:35). Even though renewable energy sources are plentiful around the world and can in principle supply the world with sufficient electricity, in most cases it is necessary to combine and integrate technologies due to the fluctuating nature of energy demand as well as the intermittent nature of many of these renewable sources, especially wind and solar (Maegaard, 2012:31). Adding wind and solar power to an existing grid can be managed effectively without much difficulty, as long as the additional wind and solar power does not exceed 20 percent of grid capacity, and in regions with a high concentration of wind power installations, the baseload can be effectively covered (Maegaard, 2012:28). Ocean-based hydro energy such as ocean currents provide a more stable and predictable source of energy which can work well for covering base-load energy demand (REN21, 2020:104).

6.3 Renewable energy sources and technologies

Possessing basic knowledge of principles relating to electricity, the energy sector as well as where renewable energy fits in as discussed in the previous section is important for being able to make sound spatial and infrastructure-planning policy decisions. However, it is also important to understand the basic principles relating to the various renewable energy sources themselves, as well as how electricity can be generated from each using the various technologies in practice today.

The following section will discuss and illustrate the various renewable energy sources and technologies that are relevant to South Africa on a macro- or regional scale to answer research question number 4 of this study.

6.3.1 Wind energy

The wind is a free and inexhaustible source of energy that has been used by mankind for many centuries (Banks & Schäffler, 2006:22). Unlike many fossil fuels used for electricity generation where the resource is transportable from the place of origin to the place of energy extraction, wind energy needs to be harvested at the location of origin. The original source of energy contained within the earth's wind is the sun (Banks & Schäffler, 2006:22). Global winds are a result of differences in air pressure caused by the uneven heating of the earth's surface by solar radiation (Manwell *et al*., 2010:24). Earth's proximity to the sun naturally means that the surface of the earth near the equator receives more direct solar radiation than the surface near the poles, which creates a low pressure (or rising air) at the equator and high pressure (or sinking air) at the poles (Manwell *et al.,* 2010:24). The uneven heating of air is further exacerbated by the frictional forces at the earth's surface as well as the rotation of the earth on its own axes known as the Coriolis force. Air will naturally flow from a point of high pressure to a point of low pressure due to gravity, and it is this horizontal flowing air that is experienced as wind, containing within it kinetic energy (Manwell *et al*., 2010:24).

Seeing as the phenomenon of the wind is a result of differences in air pressure caused by the sun's uneven heating of the earth's surface due to the different angles of radiation, as well as the rotation of the earth on its own axes, thus fixed in nature, it creates a scenario where winds will change on time scales ranging between interannual, annual, diurnal and short-term (Manwell *et al*., 2010:28). Interannual wind changes refer to changes in wind speeds and direction over a period that stretches over longer than one year. Annual wind changes are caused by the changing seasons and occur on a time scale of less than one year, but typically longer than one month. Diurnal wind changes are caused by the different radiation levels during

a 24-hour period because of the rising and setting sun. Short-term wind speed variations refer to turbulence and gusts and typically lasts ten minutes or less (Manwell *et al.*, 2010:29).

6.3.1.1 Wind energy technologies

Wind turbines convert the kinetic energy contained within wind into electrical energy by first creating mechanical energy (Tawfiq *et al.*, 2019:40). The wind blows through the blades of the turbine, spinning the rotor (mechanical energy has been created at this point), which is connected to a low-speed shaft (Tawfiq *et al.*, 2019:40). The low-speed shaft is connected to a gearbox at the front, which is connected to a high-speed shaft at the rear (Tawfiq *et al.*, 2019:40). The high-speed shaft powers a generator, which converts the mechanical energy into electrical energy, which is then fed into a transformer to increase the voltage ready to be transported via the electricity grid (Tawfiq *et al.*, 2019:40).

There are two main types of wind turbines; the first is the Horizontal Axis Wind Turbine (HAWT), and the second the Vertical Axis Wind Turbine (VAWT). Both technologies will be discussed briefly in the following section.

6.3.1.1.1 Horizontal axis wind turbine (HAWT)

The most common turbine design used today is the horizontal wind axis turbine (HAWT), which means that the axis of rotation is parallel to the ground (refer Figure 6.2) (Ferry & Monoian, 2020: 76). The HAWT can be used both on-shore as well as off-shore (Ferry & Monoian, 2020: 78).

Figure 6.2: Horizontal Axis Wind Turbine (HAWT)

Source: Ferry & Monoian (2020: 77)

6.3.1.1.2 Vertical axis wind turbine (VAWT)

Although less common than the HAWT, the Vertical Axis Wind Turbine (VAWT) generates electricity using the same principles as the HAWT, except for the fact that there are no blades and their axis rotate vertically (refer Figure 6.3) (Ferry & Monoian, 2020: 80). The applications do differ to some extent, as the HAWTs typically have larger generation capacity and are predominantly used for utility-scale purposes, where the VAWTs are smaller in terms of generation capacity and are more ideal for smaller-scale applications, due to them having lower cut-in speeds, and their ability to be effective while being positioned lower to the ground (Ferry & Monoian, 2020: 80).

Figure 6.3: Vertical Axis Wind Turbine (VAWT)
Source: Ferry & Monoian (2020: 79)

6.3.2 Solar energy

Solar energy, as the name suggests, derives from the sun, which in its simplest form is a nuclear reactor fusing atoms together through extreme heat and pressure that exist in the sun's core (GENI, 2014:6). Utilizing solar energy dates back to the ancient Greeks and Romans who used mirrors to concentrate the incoming solar radiation onto a small area to light fires (GENI, 2014:6). However, it was only in the 19th century when Auguste Mouchout realized the potential of solar energy and resulted in Scottish minister Robert Stirling patenting what was to become the first solar-powered generator. However, due to the discovery of fossil fuels such as oil, which was subsequently favoured for power production, the commercialization of solar thermal power was stymied (Ferry & Monoian, 2020:6). The photo-electric effect was discovered by Alexandre-Edmond Becquerel in 1839 and was illustrated throughout the 19th century, but only became commercially available in the latter part of the 20th century (Ferry & Monoian, 2020:24). The first commercial solar PV applications came in 1964 when NASA used solar PV in the aerospace industry to power satellites and became more popular for domestic use in the late 20th century (GENI, 2014:8).

6.3.2.1 Solar energy technologies

As mentioned before, solar energy is energy derived from the sun and is converted into electricity by means of two main types of technology; the first being solar thermal (sometimes referred to as concentrated solar power – CSP), and the second being solar photovoltaic (PV) technology (Ferry & Monoian, 2020:23-61). These technologies will be discussed briefly in the following section to provide clarity and context for solar power applications on a regional scale.

6.3.2.1.1 Solar thermal

Solar thermal energy refers to technologies that utilize solar radiation to heat a medium that can retain the heat for extended periods of time such as oil, which is then used either directly as heat energy, or the heat is used to create steam, which is pumped through a turbine and generator to generate electricity (Ferry & Monoian, 2020:5). In some cases, mirrors are used to concentrate solar radiation towards one central point atop a tower where the heat is absorbed by molten salt (refer Figure 6.4) (Ferry & Monoian, 2020:16). The principle of storing heat for energy purposes as opposed to generating electricity from the onset means that the energy can be stored more easily and for longer periods, making this type of energy more suitable for covering base loads in national electrical grids (Ferry & Monoian, 2020:16). Solar thermal plants can vary in size, but are typically scaled up for utility-scale purposes where they can produce several megawatts at a time capable of servicing entire regions (GENI, 2014:25; Banks & Schäffler, 2006:18; Ferry & Monoian, 2020:16).

Figure 6.4: Solar Thermal Tower

Source: Ferry & Monoian (2020:15)

6.3.2.1.2 Solar photovoltaic (PV)

Photovoltaic (PV) technology (refer Figure 6.5) is vastly different from solar thermal. Where the latter uses the energy contained within the heat of solar radiation, PV technology uses semiconductor materials such as silicon to create electricity directly from solar radiation by means of the photoelectric effect (GENI, 2014:25). A solar PV cell consists of two semiconductor materials (one saturated with electrons and therefore negatively charged, and the other deprived of electrons; therefore positively charged) separated by an insulator or junction (GENI, 2014:27). The photoelectric effect refers to an electric charge that occurs due to the flow of electrons between two differently charged semiconductor materials (Augustyn *et al.,* 2020). When particles of sunlight (or photons) come into contact with a PV cell, one of the existing negatively charged electrons surrounding the nucleus of the atom of the semiconductor material gets replaced by a photon, which then flows towards the positively charged semiconductor, which creates an electrical current (Augustyn *et al.,* 2020).

Figure 6.5: Solar photovoltaic (PV) array

Source: Ferry & Monoian (2020:35)

PV technology can be applied on various scales, ranging from individual private use to large utility-scale applications, where hundreds of PV panels are connected (alternatively known as solar farms) to the national utility grid (GENI, 2014:28; Piyatadsananon, 2016:79). PV cells are

particularly useful in remote areas disconnected from the grid where there is sufficient sunlight. This is arguably the easiest method to use for off-grid applications and distributed generation (GENI, 2014:28).

6.3.3 Hydro energy

Hydro energy derives from harnessing the kinetic energy contained within moving water and is the most advanced form of renewable energy in the world considered in terms of installed capacity, as it accounts for more than 71 percent of all renewable energy to date and accounts for almost 16 percent of the world's total electrical energy (Ferry & Monoian, 2020:98). Due to South Africa being a water-scarce country, conventional hydro-energy technologies such as dammed reservoirs and run-of-the river systems will not be discussed.

6.3.3.1 Hydro-energy technologies

There are a vast number of hydro-energy technologies available today that are able to extract the kinetic energy from moving water within the world's oceans (Ferry & Monoian, 2020). The following section will briefly discuss each of the main hydro-energy technologies in practice today (relevant to the South African context) as well as the scales applicable to each in order to provide context for their importance on a regional scale.

6.3.3.1.1 Ocean current turbines

Ocean current energy refers to the energy contained within vast and powerful streams of moving water within the world's oceans such as the Agulhas current in the Indian Ocean (Ferry & Monoian, 2020:110). To harness the energy within ocean currents, turbine-driven generators would need to be anchored in place inside the current stream to capture the kinetic energy, allowing the moving water to flow through the turbine blades (similar to the wind moving wind-turbine blades) creating mechanical energy, which would then drive a generator to convert the mechanical energy into electrical energy (refer Figure 6.6) (Banks & Schäffler, 2006:32). Currently, three types of current energy technologies are tested; the first type is fixed to the seabed, but needs to be mounted in shallow water where ocean currents are relatively weak. The second is a floating system with much higher energy potential, but this type needs further engineering solutions. The third is a hybrid between the previously mentioned two systems (Ferry & Monoian, 2020:110).

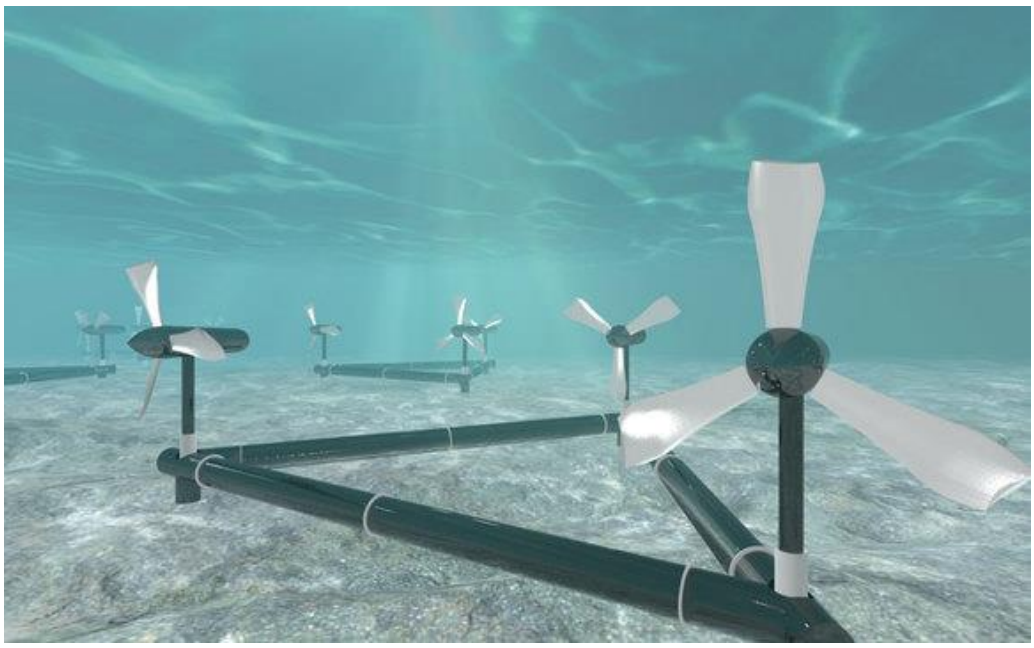

Figure 6.6: Underwater current turbine

Source: Ferry & Monoian (2020:110)

6.3.3.1.2 Ocean-wave energy converters

There are a variety of wave-energy technologies available today due to the complexity of harnessing energy from waves and the various operating principles (REN21, 2020:103). Wave energy refers to the kinetic energy contained within undulating water. Waves in the ocean are generally formed due to wind passing over the water surface, which can travel enormous distances, with little to no energy loss (Ferry & Monoian, 2020:112). This means that regional wind energy is often out of phase with wave energy for that particular region, resulting in a complementary scenario between the two sources of energy within that region (Ferry & Monoian, 2020:112). Capturing wave energy can be achieved by means of using a long, hinged, serpentine-like device that floats along the surface of the water (refer Figure 6.7) containing oil-filled chambers that build pressure due to the changes in orientation between the chambers caused by the action of the waves (Ferry & Monoian, 2020:112). The release in oil pressure drives hydraulic motors capable of generating 750 kW of energy (Ferry & Monoian, 2020:112).

Figure 6.7: Wave energy converter (WEC)

Source: Ferry & Monoian (2020:111)

6.4 Spatial planning considerations for renewable energy development

6.4.1 Preamble

Renewable energy development is highly subject to spatial or locational considerations, primarily due to the resources' natural uneven distribution across the world in what Hebertson (1905) refers to as “natural regions” (refer Section 3.2.2). There are several factors that must be taken into account when formulating an implementation strategy for renewable energy. However, for the purpose of this study, the focus will be on spatial considerations in determining the locality of a generation plant, and will be discussed in the following section. It was found that for the resources and technologies discussed in the previous section, there are four main areas of concern that will determine where a renewable energy generation plant can ultimately be located. The considerations are (1) resource availability, (2) ecosystem and natural environment, (3) grid access, and (4) spatial planning and land use. The following section will discuss each of these considerations in more detail.

6.4.2 Resource availability

6.4.2.1 Wind energy

As pointed out earlier in this chapter, wind energy needs to be harvested in the area where it occurs naturally as it cannot be transported from the place of origin to a place of extraction like for instance coal (Manwell *et al*., 2010:3). Therefore, to maximize the effectiveness of wind energy developments, the most appropriate location must be determined (Baseer *et al*., 2017:2; Manwell *et al.*, 2010:408). The main objective for determining the best location for wind turbine citing is to maximize revenue while minimizing environmental impacts (Baseer *et al.*, 2017:2; Manwell *et al.*, 2010:408). Firstly, this means identifying regions where wind generally has sufficient meteorological (kinetic energy) potential, which are regions with high average wind speeds and which can be identified using a wind atlas (Baffoe & Sarpong, 2016:11). Using resources such as wind atlases and geographic information systems (GIS) to illustrate the wind energy potential of regions can provide the necessary guidance for wind energy developers and policymakers alike (Baseer *et al*., 2017:2).

The average wind speed is the primary consideration when determining the location for a wind farm, and the highest weight is attached to this outcome in a multi-criteria decision-making (MCDM) analysis (refer Krewitt & Nitsch, 2003; Siyal *et al*., 2015; Sliz-Szkliniarz & Vogt, 2011). As weather stations are located far apart, an interpolated technique is used to measure or calculate the wind speed between weather stations (Baseer *et al*., 2017:7). According to experts in the field such as wind planners, an average wind speed of 6 metres per second (m/s) or more is optimal and can be considered the entry speed as regions with an average wind speed of 5 m/s or less is less suited for utility-scale wind farms (Baseer *et al.*, 2017:11). This being said, technology is evolving rapidly; hence, the average wind speed of a region is used together with technology efficiencies in order to determine the expected energy output for that region (Baseer *et al*., 2017:4). The energy output is used to calculate the potential economic output by taking factors such as operational costs, constraints, and incentives into account (Baffoe & Sarpong, 2016:11).

6.4.2.2 Solar energy

Solar farm feasibility studies will be based on existing and newly gathered solar resource data both satellite and meteorologically derived, as well as land-based measurements, where the latter can be used to calibrate the findings of the former in order to improve the accuracy of the findings (Miller & Lumby, 2012:5; Piyatadsananon, 2016:81). Solar resource potential is usually defined in terms of four different solar irradiation categories, including the Direct Normal Irradiation (DNI), the Global Horizontal Irradiation (GHI), the Diffuse Horizontal Irradiance (DHI),

and the Global Tilted Irradiation (GTI) (Lubmy, 2015:42; Piyatadsananon, 2016:81). DNI is particularly important for solar thermal technologies such as Concentrated Solar Plants (CSP) (Lubmy, 2015:43), whereas GHI is the most basic consideration for developing a solar PV project (Piyatadsananon, 2016:81). For a utility scale solar PV plant, a minimum of 2 000 kilowatt hours per square metre (kWh/m²) per annum is necessary and measurements should ideally be taken over a twelve-month period in order to capture seasonal variations and, if possible, for at least ten continuous years in order to account for climate variability (Lubmy, 2015:44-45).

6.4.2.3 Hydro energy

Harvesting hydropower from within the ocean such as wave energy needs to begin with the identification of spatially dispersed energy sites by using criteria such as wave height, wave period as well as the general wave direction (Uihlein & Magagna, 2016:1071). Wave energy potential has been measured in various places around the world on a global, regional and local scale, initially using buoy data that could only provide information relating to local conditions, which was followed up with buoy data, combined with hydrological models capable of simulating wave energy potential in deep ocean waters. More recently, radar measurements have been used (Uihlein & Magagna, 2016:1072). According to Van Niekerk (2013:2), 30 kW/m or more is generally regarded as sufficient for wave energy exploitation. Ocean tidal current energy has also been measured in various places around the world for several years using two-dimensional (2D) and three-dimensional (3D) modelling techniques (Uihlein & Magagna, 2016:1072). Due to water's high density, a velocity of 1 metre per second (m/s) is sufficient to generate electricity (Husseini, 2018).

6.4.3 Ecosystem and natural environment

6.4.3.1 Wind energy

The location of onshore wind farms needs to be accessible to vehicles, practical for construction in terms of geology and topography, and has as little environmental impact as possible (Baseer *et al*., 2017:9). Such locations are identified by isolating areas within the regions where resource potential is sufficient into sites that are geographically suited for wind-energy production. If the natural landscape of the region varies significantly, a detailed study should be undertaken to determine constraints relating to topographical, ecological, and geological issues. Wind farms cannot be constructed on slopes greater than 30 °, nor in protected areas such as game reserves (Baseer *et al.*, 2017:4). In order to diminish the cost of wind farms, their locations need to be as close to an established road network as possible. However, it has also been proposed by regional planning authorities that they must not be too close in order to make way for a buffer

zone (refer Krewitt & Nitsch, 2003; Siyal *et al.*, 2015; Sliz-Szkliniarz & Vogt, 2011). Wind turbines can cause harm or even death to migrating birds due to them colliding with the turbine rotors and blades, thus ruling out areas where migratory birds generally fly (Baseer *et al.*, 2017:9). Off-shore wind farms may not be burdened with issues such as topography, but are subject to several other site specific considerations including issues such as shipping lanes, fishing activities, existing underwater communication infrastructure, tides, and currents among others (Manwell *et al.*, 2010:477). In addition to the above environmental considerations, practical viability also plays an important role and includes matters relating to distance from the shore and ocean depth, among others (Manwell *et al.*, 2010:477).

6.4.3.2 Solar energy

In addition to sufficient solar resources, climate conditions for a solar farm should ideally be mild and not extreme (Miller & Lumby, 2012:56). Areas prone to flooding should be avoided as far as possible due to the potential damage water can cause to electrical equipment, and areas where with high wind speeds are prevalent should also be used with caution, as high wind speeds can damage structures (Lubmy, 2015:59-60). Areas where snow is a regular occurrence in winter should be used with caution, but if unavoidable, the necessary mitigation measures should be in place, as is the case in areas where extremely high temperatures in summer can occur (Lubmy, 2015:60). Places where air pollution is prevalent should be avoided as far as possible, as air quality affects the effectiveness of solar modules (Lubmy, 2015:60).

Ecologically and archeologically sensitive areas with high biodiversity such as natural forests, wetlands, and wildlife corridors should be avoided and barren areas such as semi-deserts should be pursued for solar farms (Lubmy, 2015:61). Taking the above into consideration, it must be noted that any form of shading will have a negative effect on production and it may be necessary for trees to be removed (Miller & Lumby, 2012:56). In certain areas, a geotechnical study should be undertaken in order to ensure that the ground conditions are favourable for construction, with little to no seismic activity or low resistive and erosion-prone soil (Lubmy, 2015:62; Miller & Lumby, 2012:7). Ideally, the site should be flat in order not to complicate the construction of infrastructure. However, a slight tilt towards the north (in the southern hemisphere) or even steep slopes exposed to the sun can be an added advantage, as solar modules will face in that direction (Lubmy, 2015:60; Miller & Lumby, 2012:128). Access to clean, low mineral-content water is important for cleaning solar modules, as dirty water can stain the outside surface, thus minimizing their effectiveness (Lubmy, 2015:63).

6.4.3.3 Hydro energy

Where ocean energy is concerned, there is an increasing need for governments, policymakers, and society at large to gain a deeper sense of understanding towards the environmental implications that are applicable before any deployment takes place. This includes both Environmental Impact Assessments (EIAs) and Life Cycle Assessments (LCA) (Uihlein & Magagna, 2016:1073). Due to the nature of ocean energy infrastructure, it is important to identify the effects such infrastructure can have on the benthic community such as fish, marine mammals, and turtles (Uihlein & Magagna, 2016:1073). In general, benthic regions are affected by tidal current energy infrastructure due to the altered direction and velocity in the flow of water, as well as the changes that occur to the seabed sediment, not to mention direct physical impacts between ocean living organisms and the infrastructure, which can cause injury or death (Uihlein & Magagna, 2016:1074). Studies such as by Neill *et al.* (2017) have shown that wave energy infrastructure can have environmental impacts such as competition for space, vibration, electromagnetic fields and pollution (Uihlein & Magagna, 2016:1075).

6.4.4 Grid access

It goes without saying that power generation plants need to be able to transport the generated electricity to end-users and must therefore have access to the national transmission and distribution grid. The further away the generation plant is located from the existing grid, the more expensive the electricity produced by the power plant becomes, as long cables will have to be laid (Baseer *et al.*, 2017:7). The viability of the grid connection will depend on the proximity, availability, and capacity of the grid (Lubmy, 2015:62). Proximity refers to the distance between the power plant and the distribution or transmission network (Lubmy, 2015:62). Grid availability refers to the amount of time the grid can accept outside power. This is oftentimes more favourable in developed areas, as opposed to rural areas (Lubmy, 2015:62). The capacity of the grid will depend on the network and loading ratio of the grid, which will need to be aligned with the capacity of the power plant (Miller & Lumby, 2012:64).

Ocean-based energy is more complicated and expensive to connect to the national grid, as specialized infrastructure needs to be constructed, such as subsea electrical systems and a submarine cable connection to the shore, among others, which is why grid access and grid availability are a prerequisite for any ocean-energy powerplant (Uihlein & Magana, 2016:1075). Ocean energy such as wave or current energy is oftentimes located in regions with a low population density that is far away from existing grids, or have weak grids, which then require the construction of new or upgraded infrastructure, adding to the cost of generation and ultimately the cost of the electricity produced (Uihlein & Magana, 2016:1076). Another complexity is the fact that offshore wind energy is cyclical and variable, which can lead to other

problems with grid stability, grid congestion, and problems related to technological development (Uihlein & Magagna, 2016:1076).

6.4.5 Zoning and land-use

Planning policy and legislation will differ from region to region. However, this should be considered beforehand, as in most cases land will have to be owned by the developer (Lubmy, 2015:61; Miller & Lumby, 2012:64). In addition to tenure, land also needs to be appropriately zoned for the intended use meaning that spatial planning systems should take all the necessary information into consideration when zoning schemes are developed in order to reduce potential conflicts of uses (Vanderkamp, 2016:20). Power plants generally need to be zoned for industrial purposes (Lubmy, 2015:61). As highlighted in Section 6.4.3, proximity to distribution and transmission infrastructure should also be taken into consideration when identifying potential areas for energy generation in zoning schemes, with the aim of streamlining proposed and existing energy infrastructure (Vanderkamp, 2016:21).

As mentioned in Section 6.4.2, generation plants often have buffer zones to limit the negative effects such as noise, nuisance, etc., which must be determined and defined beforehand and is especially important for wind farms (Baseer *et al.*, 2017:8). The distance between wind farms and their surroundings differs from region to region and the buffer zones are oftentimes determined and justified on a case-by-case basis by the national, provincial, or local planning authorities (Baseer *et al.,* 2017:8). Solar farms have their challenges, as sites should be large enough to allow for the required capacity to be installed without having to alter the pitch, to the extent that yield loss becomes a reality (Lubmy, 2015:59). Solar plants should ideally be constructed on low-value land and the use of highly fertile agricultural land should be avoided as far as possible. However, there are agricultural activities that will not be affected, such as livestock (sheep and cattle) and grazing (Lubmy, 2015:61). It is also important to adopt an enabling approach, as opposed to a prescriptive planning approach when planning for large-scale wind and solar farms, while exploring the option of adopting separate policies for small-scale energy production to reduce regulatory constraints (Vanderkamp, 2016:20).

Solutions such as marine spatial planning have been proposed to overcome problems with overlapping jurisdiction in oceans and to support the full potential of ocean energy in addition to avoiding user conflicts, improve the management of marine spatial claims and to sustain ecosystem-based management of ocean and seas (Uihlein & Magagna, 2016:1075). It has been proven in case studies (refer Azzellino *et al.*, 2013; Galparsoro *et al.*, 2012) that marine spatial planning can manage marine resource use successfully in addition to offering the potential to optimize the siting of ocean power plants. Marine spatial planning is the process of

regulating human activities' Exclusive Economic Zones (EEZs) to ensure the sustainable use of marine resources, including renewable energy resources (UNESCO, 2017:2).

6.5 Conclusion

This chapter commenced by highlighting the various components and technical aspects applicable to an electrical grid from where the energy is harvested (or generated), to the transmission lines that carry the electricity to where it is needed, and finally, the distribution lines that feed individual properties. It is important to recognize that electricity grids are physical structures that influence not only the land use of any given area, but can also affect the spatial layout of an area as well, thus necessitating careful spatial planning.

As energy cannot be destroyed, it is important to generate the correct amounts of electricity at the appropriate times, which is why electricity grids are constantly being monitored and managed to ensure that there is sufficient power to support economic development; yet, not so much that the infrastructure can be harmed. The vast spatial distribution and intermittency of most renewable energy sources do add to the complexity of grid management. However, this can be overcome by employing various techniques such as temporary ceasing of generation (or what is known as curtailment), finding new applications for fluctuating electricity, exporting excess electricity to other countries, or combining two or more energy sources typically one source to cover the baseload (such as ocean currents) and another to cover peak demand.

Renewable energy technologies have come a long way in terms of sophistication over the past couple of decades, and each has the potential to provide valuable energy at little to no environmental costs. Renewable energy sources also have enormous potential for distributed generation. Distributed generation plants can make use of wind, solar and ocean-based energy sources to supply electricity to regions where access to the national grid is not feasible, or as part of the electricity grid network to service end-users in close proximity from where the energy is generated.

The wind is essentially horizontally moving air flowing from areas with high pressure to areas of low pressure due to gravity, exacerbated by the rotation of the earth on its own axes. This moving air contains kinetic energy, which can be captured and converted into other forms of energy. Wind turbines are used for this purpose and work as follows: Wind flows through long blades that are located on top of a tall structure known as a tower. The blades are fixed to a rotor, which spins when the blades move, due to the passing wind. At this point, the kinetic energy of the wind has been converted into mechanical energy. The spinning rotor is connected to a low-speed shaft, which spins at the same revolution as the rotor. The low-speed shaft is

connected to a gearbox that increases the speed of rotation, which is then transferred to the high-speed shaft. The high-speed shaft is connected to a generator that converts the mechanical energy into electrical energy. Currently, there are two main types of wind turbines: (1) a horizontal axis wind turbine; and (2) a vertical axis wind turbine. Both turbines use the same mechanical process to convert kinetic energy into electrical energy. However, horizontal axis wind turbines have larger generation capacities compared to vertical axis wind turbines, making them ideal for utility-scale purposes and can additionally be located both on- and off-shore.

Solar energy derives from the sun's solar radiation, which we experience as heat energy and light energy. There are currently two types of solar energy technologies, namely (1) solar thermal energy, and (2) solar photovoltaic (PV) energy. There are a variety of solar thermal energy technologies. However, they all convert the heat energy from the sun into electrical energy by heating a substance such as oil, normally by concentrating mirrors onto a single spot. The heated substance can then be used to heat water to create steam, which can flow through a turbine and generator to create electrical energy, or the heat energy can be stored for later use. Solar PV technology uses semiconductor materials to convert light energy from the sun directly into electrical energy by means of the photoelectric effect. This is an atomic reaction where photons (light particles) replace negatively charged electrons around the nucleus of a semiconductor material to create a positive electrical charge. Both of these technologies can be used for utility-scale applications; however, this normally requires a large area of land.

Ocean currents are vast underwater streams of water located in the world's oceans containing within them kinetic energy that can be converted into electrical energy by means of specialized turbines and generators. There are a variety of ocean current technologies, each tailored to the strength and depth of these currents. Ocean waves are a result of wind passing over ocean waters and contain within them kinetic energy. Wave energy technologies can take the form of long serpent-like devices that float on the surface of the water, filled with oil-filled chambers that build up pressure due to the undulating motion of waves. When the pressure is released, hydraulic motors are driven, which generates electrical energy.

When determining where a renewable energy generation plant can be located, there are four main factors that must be taken into consideration. The first and arguably the most important consideration relates to the availability of the particular energy source. As highlighted in this chapter, renewable energy cannot be transported and must therefore be harvested in the area where it occurs naturally. For wind energy sites to be successful, a minimum average wind speed of 6 metres per second (m/s) is generally necessary whereas, for solar PV sites, a minimum solar radiation of 2 000 kWh/m² per annum is generally required. Wave energy is

measured by taking into consideration wave height, wave period as well as the general direction, measured in kilowatts per metre (kW/m). For wave energy extraction, sites with an output of 30 kW/m or more are generally regarded as exploitable, whereas a velocity of 1 m/s is sufficient for generating electricity from ocean currents.

The second consideration relates to the ecosystem and the natural environment, and prescribes that generation sites be accessible to vehicles, practical for construction in terms of geology and topography, and have as little environmental impact as possible. Onshore wind farms cannot be constructed on slopes greater than 30 ° and should take into consideration bird migratory patterns, whereas off-shore wind farms need to take into consideration shipping lanes, fishing activities and ocean-based infrastructure, among others. Solar PV sites should ideally be constructed in less fertile land such as semi-deserts while avoiding areas prone to flooding, soil erosion, natural shade, and air pollution, among others. Ocean current turbines must take into consideration seabed stability as well as oceanic creatures.

The third consideration relates to grid infrastructure access and applies equally to all the above-mentioned energy sources and technologies. Grid access consists of three components. Firstly, grid proximity refers to the distance between the generation plant and the existing grid, which needs to be as short as possible. This is because the further the generation plant is located from existing grid infrastructure, the more expensive the electricity becomes to cover the cost of laying long electrical cables. Secondly, grid availability refers to the amount of time the grid can accept newly generated electricity, which needs to be as high as possible, and thirdly, grid capacity refers to the loading ratio of the existing grid, which needs to be aligned with that of the generation plant.

The fourth and final consideration relates to statutory planning requirements such as zoning and land-use management. Although statutory planning requirements will differ from place to place, energy generation plans generally need to be constructed on land that is zoned for industrial purposes and in some cases, a buffer zone between the generation plant and neighbouring uses will need to be in place as to minimise any potential negative impacts. What ocean-based technologies are concerned, marine spatial planning provides a framework wherein the necessary regulations and prescriptions can be formalized.

The intended objective of gaining a broad understanding of renewable energy sources and technologies as well as how they relate to spatial and infrastructure planning has therefore been achieved in this chapter. The following chapter will investigate cases of successful implementation of applicable renewable energy sources in practice to gain best-practice guideline knowledge.

CHAPTER 7: EMPIRICAL STUDY: INTERNATIONAL PERSPECTIVES

7.1 Introduction

In the previous four chapters, the theoretical foundation was laid, highlighting that regional planning should be aimed towards achieving regional development by means of contextually appropriate policy formulation and implementation, that regional development can be achieved by exploiting endogenous factors through technology, and that renewable energy deployment can affect regional development positively if spatial and infrastructure planning are done correctly. To fully grasp how planning policy can be used to achieve regional development through renewable energy deployment, it is necessary to look at successfully executed practical examples. This chapter is therefore aimed towards achieving research objective number five of this study, i.e. **to evaluate best-practice policy frameworks for renewable energy planning and implementation on a regional planning level.** The chapter begins with discussing global policy perspectives to provide context for the rest of the chapter. Evaluating best practices regarding renewable energy development from leading countries is enriched when seen against the backdrop of global policies and programmes.

Once a global perspective has been gained, the chapter will then move on to focus on individual countries from which to draw meaningful conclusions. Due to the lessons learnt ultimately being applied in South African, study areas were chosen based on their ability to provide guidance for renewable energy most relevant to South Africa, i.e. (1) onshore wind and solar energy as well as (2) ocean-based renewable energy, including off-shore wind, wave, and current energy. The above-mentioned criteria lend itself to a purposive case selection technique using deviant case studies. Purposive sample selection allows the researcher to apply his/her own judgement to select cases based on particular qualities or attributes they possess (thus a non-random selection technique) and the deviant (which is a type of purposive sampling) cases are called thus because they are normally experts or world leaders, indicating that they can provide a unique level of insight into the particular phenomenon being studied (refer Section 2.7), making them ideal for best-practice observation.

For onshore wind and solar energy policy evaluation, this study will focus on China due to their world-leading wind and solar energy industries (refer Section 7.3.2) and for ocean-based renewable energy policy evaluation, this study will focus on Scotland due to their proven track record in ocean-based spatial planning policy applications and world-leading off-shore wind and marine renewables industry (refer Section 7.3.1). The selected countries will be evaluated by firstly gathering general background information relating to climate, topography, and economics, among others, whereafter the details revealing their world-leading status in the aforementioned

industries will be highlighted. Once the necessary context has been provided, the chapter will examine the selected countries in terms of their renewable energy potential, as this forms the basis of their industry success. The chapter will then evaluate the selected country's renewable energy policies to identify the best-practice policies that have resulted in their world-leading status before ending with a brief conclusion summarizing the most important findings.

7.2 Global policy perspectives

Renewable energy development on a global scale did not merely come to be but was rather driven by policies, programmes, and treaties aimed at reducing Greenhouse Gas (GHG) emissions to combat climate change and enhance the general quality of life of people in all countries (see UN, 1998; UN, 2015). The following section will discuss the most relevant policies on a global scale that gave rise to and supports the global renewable energy industry before narrowing the focus of the study to individual countries.

7.2.1 Kyoto Protocol

In 1997, global concerns regarding the amount of greenhouse gasses (GHG) such as Carbon Dioxide (CO2) that was being emitted into the earth's atmosphere led to the adoption of an international treaty known as the Kyoto Protocol (Cirman *et al.*, 2009:31). The Kyoto Protocol was adopted by the Conference of the Parties (COP) at the United Nations Framework Convention on Climate Change (UNFCCC) and simply aimed to limit GHG emissions to a level that would prevent any adverse changes to the global climate system (Cirman *et al.,* 2009:29; UN, 1998:2). The objectives included; to reduce global GHG emissions by 5 percent (compared to 1990 levels) by 2012, to promote energy efficiency, and to increase the number of renewable energy sources as part of the overall energy mix, among others (Cirman *et al.,* 2009:30; UN, 1998:3). Given the fact that industrialized countries were the largest emitters of GHG, the Kyoto Protocol placed a heavier burden on developed economies based on the principle of "common but different responsibilities" (Cirman *et al.,* 36; UN, 1998:9).

The Kyoto Protocol introduced three instruments to assist countries in achieving their targets (UN, 1998:5-15), namely (1) joint implementation, (2) the clean development mechanism (CDM), and (3) emissions trading. Joint implementation is described under Article 6 and is defined as a mechanism by which countries that ratified the Kyoto Protocol can earn emission reduction units separately or combined with another country with emission reduction commitments under the Protocol by joining together (UN, 1998:6). The clean development mechanism is defined under Article 12 and aims to support emission reduction projects such as renewable energy among others (UN, 1998:11), while missions trading is defined under Article

17 and allows countries to sell their ‘spare’ emissions to other countries that have exceeded their limits (UN, 1998:15).

7.2.2 Paris Agreement

The COP adopted the Paris Agreement during the UNFCCC held in Paris France on 12 December 2015, aimed at strengthening the global effort towards eradicating the threat of climate change (UN, 2015:2-3). The Paris Agreement replaces the Kyoto Protocol and provides a framework for guiding international efforts beyond 2020 to limit GHG emissions in order to limit the increase in global temperature below 2 °C from pre-industrial levels (UN, 2015:2). To achieve the above-mentioned goal, countries that are Parties to the Agreement will have to make significant changes to the way in which their economies function. Unlike the Kyoto Protocol, the Paris Agreement does not provide country-specific goals, but rather prescribes that countries work together to develop strategies towards climate change mitigation by communicating their voluntary Nationally Determined Contributions (NDCs) to the Secretariat of the UNFCCC (Clémençon, 2016:4). Renewable energy development has been one of the main strategies used by countries to combat climate change as by 2017, 145 countries referred to renewable energy actions as part of their NDCs of which 109 countries referred to specific measurable renewable energy targets (IRENA, 2017:7).

7.2.3 Sustainable Development Goals (SDGs)

The agenda for sustainable development has become central to policy formulation in many countries around the world, especially since 2015, when the United Nations (UN) General Assembly brought forth a set of global Sustainable Development Goals (SDGs) which includes 17 goals and 169 outcomes, replacing the Millennium Development Goals (MDGs) presented by the UN in 2000, and is aimed to be in place by the year 2030 (UN, 2019:3-57). The SDGs differ from the MDGs, as the former includes more goals and is more specific in terms of desired outcomes (UN, 2019:59). Whereas the MDGs only acknowledged energy’s role in development and left the objective of access as implicit, Sustainable Development Goal Seven (SDG-7) explicitly states that there should be universal access to modern, reliable, and affordable energy by 2030, citing the significant increase in renewable energy produced on a global scale as a means to achieve this goal (CGDEV, 2016:9; UN, 2018:6). SDG-7 has subsequently led to the Sustainable Energy for All (SE4All) initiative in partnership with the World Bank (CGDEV, 2016:9). Access to energy plays an important role in increasing human welfare leading to an overall increase in health, improved livelihoods, poverty alleviation, job creation, gender equality and access to food and water, which is the main goal behind the UN SDG-7 (CGDEV, 2016:3; UN, 2019:36-37).

7.2.4 Global regulatory and fiscal policies

SDG-7 has illustrated that renewable energy deployment on a global scale can be spurred on either directly or indirectly by means of policies aimed to combat climate change. Policies mandating a reduction or even an elimination of GHG emissions in energy generation will create a shift away from fossil fuel-based energy towards clean and ideally renewable forms of energy (REN21, 2020:58). In addition to the SDG-7, the NDCs as prescribed by the Paris Agreement can foster an environment where renewable energy technologies become a logical alternative to GHG emitting technologies (REN21, 2020:59). Another policy mechanism that has the potential to increase the uptake of renewable energy is by placing a price on carbon emissions, as a form of carbon tax, which increases the cost of fossil fuel-based energy relative to renewable energy (REN21, 2020:59).

The aforementioned renewable energy incentive schemes have seemingly been effective given that the number of countries that have formulated renewable energy policies has continued to increase over the past decade as 166 countries have set renewable energy targets, and 151 countries have introduced renewable energy supporting policies by the end of 2019 (REN21, 2020:70). The question, therefore, is no longer whether renewable energy should play a part in the energy sector, but rather how to do so more efficiently using the available policy mechanisms. The policies currently being used can be divided into two main clusters, namely (1) regulatory policies and (2) fiscal policies, where the former relates to the framework within which renewable energy development can be facilitated, and the latter relates to a financial incentive to entice developers to invest in renewable energy projects (REN21, 2020:75-79). Regulatory policies aimed at facilitating utility-scale renewable energy programmes include among others Feed-In-Tariffs (FITs), renewable energy auctions and tenders, Renewable Portfolio Standards (RPS), and related renewable energy quota obligations, whereas fiscal policies include among others tax credits, rebates, and grants (REN21, 2020:71). Renewable energy infrastructure and spatial planning policies will normally fall within the regulatory policy cluster. However, on a global scale, these policies are not frequently discussed in detail, due to the large variability in planning policies between regions and countries.

With regard to other regulatory policies, in 2017 it became clear that the relevance of FITs will decrease in favour of tenders and auctions whereas the fiscal policies showed little in terms of frontrunners, again due to regional differences (IEA, 2018:18; REN21, 2017:84). Additionally, it became clear that grid planning should receive more attention and some experts voiced their support of mandatory grid connections (REN21, 2017:84). According to the National Renewable Energy Laboratory (NREL), policies aimed to support the improvement of grid infrastructure can lead to the increased facilitation of renewable energy (NREL, 2015:2). In 2019, the shift away

from FITs towards auctions and tenders continued and most renewable energy projects came in the form of large- or utility-scale centralized projects (REN21, 2020:70-71). Most of the new auctioned projects around the globe focused on solar PV and/or wind power (REN21, 2020:72). Figure 7.1 illustrates that not only has renewable energy capacity continued to increase globally since 2015, but that additional wind and solar power for 2019 far outperformed other forms of renewable energy such as bioenergy, hydro energy, and geothermal energy.

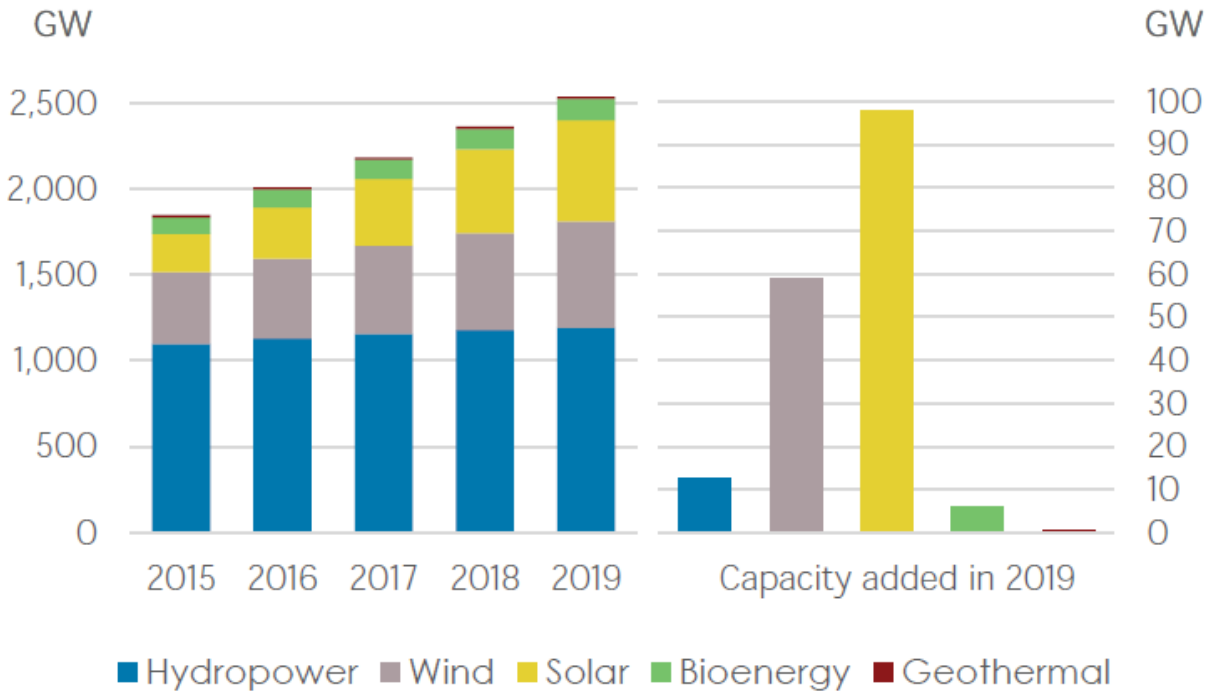

Figure 7.1: Global renewable energy installed capacity.

Source: IRENA (2020a:1)

7.2.5 Global wind energy trends

The global wind energy market grew by approximately 10 percent in 2019, with close to 60 GW of newly installed capacity added to electricity grids around the globe (IRENA, 2020b:14). Off-shore wind energy projects are becoming increasingly more relevant in the global market accounting for one-tenth of newly installed capacity in 2019, which is the largest portion to date (GWEC, 2019:10). The rapidly falling costs of wind energy technologies have made it possible for both on- and off-shore wind energy projects to keep expanding and to become price competitive with even fossil fuel-based generation in many parts of the world, in many cases even without the assistance of financial support (IRENA, 2019:11). The favourable economics of wind energy have been the primary driving force behind the growth in the industry and have become one of the most economical ways in which to add new generating capacity (FS-UNEP, 2020:29; IRENA, 2019:16). The falling prices are largely due to the shift away from regulatory policies such as FITs towards auctions and tenders, which brought intense price competition

into the market. It is noteworthy that should one not include China (which still uses FITs for wind energy to a degree) and the United States of America (USA) (which use RPS for wind energy), wind energy projects around the world have largely been driven by auctions and tenders (GWEC, 2019:18).

7.2.6 Global solar PV energy trends

The global solar PV market increased by an estimated 21 percent in 2019, accounting for nearly 100 GW of newly installed capacity (IRENA, 2020b:25). Solar PV is already playing an increasing role in electricity generation and the demand for solar PV energy is continuously growing, as it has become the most cost-effective option for adding new capacity in a growing number of locations around the world (IEA, 2018:80; REN21, 2020:107). This can be confirmed as by the end of 2019, 39 countries around the world had a cumulative installed capacity of 1 GW or more, up from 31 countries in 2018 (REN21, 2020:107). There are however, a number of challenges that still need to be addressed before solar PV can become a universal source of electricity around the globe and includes among others the lack of regulatory stability and grid infrastructure challenges (IEA, 2018:80).

In the majority of countries, solar PV energy still needs adjusted regulatory and grid connection policy frameworks. Traditional FITs continue to drive the global market with tenders and auctions only now starting to become relevant (IEA, 2018:80; REN21, 2020:108). Globally, despite a rise in distributed generation for commercial and industrial-scale applications, large utility-scale projects continue to dominate the solar PV market (IEA, 2019:9). The global rise in large-scale solar PV projects is partly due to the slowly shifting policies away from FITs towards auctions and tenders (IEA, 2020:11). Auctions and tenders have started to drive solar PV prices downward in 2019, to the point where in some countries, solar PV energy prices are now lower than the average wholesale price for electricity (IEA, 2020:15).

7.2.7 Global ocean energy trends

Ocean energy constitutes the smallest portion of global energy installed capacity and even though the potential for ocean energy is substantial, ocean energy technologies are still relatively underdeveloped (REN21, 2020:103). Tidal current and wave energy receive the majority of research and development efforts around the globe, especially in European countries such as the United Kingdom (UK). However, countries such as Canada, the USA, and China are also making headway in this area (OEE, 2019:16).

Modern ocean energy devices are a result of new innovation and advances in technology. However, the first ocean-based energy devices were developed as far as 200 years ago with the earliest patent dating back to the late 1700s, and the first operational ocean energy device harvested energy in the early 1900s (REN21, 2020:104). The UK alone granted over 300 patents for ocean energy devices during the years 1855 to 1973 (REN21, 2020:104). In the early 2000s, ocean energy experienced a resurgence driven by global concerns over climate change and subsequent policies such as the Paris Agreement and SDGs, as well as the establishment of the Ocean Energy Systems (OES) programme in 2001, with help from the International Energy Agency (IEA) (REN21, 2020:104). In 2003, the European Marine Energy Centre (EMEC) was established and has become an essential testing facility allowing for grid-connected ocean energy applications (REN21, 2020:104). In 2016, MeyGen launched the first tidal stream turbine in the Pentland Firth, Scotland (REN21, 2020:104). Overall, ocean energy's outlook seems to be positive as costs are declining and capital expenditure is even lower than what was expected at this stage (REN21, 2020:104).

7.2.8 Global renewable energy and spatial planning

Spatial planners need to possess the correct set of skills to meet the challenges of climate change as they have an important role to play in developing energy strategies (refer Section 6.4). Planners across Europe are leading the way towards a low carbon future as, according to Vanderkamp *et al.* (2016:3), spatial planning is the profession with the greatest ability to coordinate the variety of interchangeable linkages that make up energy planning in such a way that mitigates the adverse effects of climate change. Planning departments should be involved in developing and implementing energy plans at local and regional levels by promoting environmentally friendly and sustainable energy solutions (Vanderkamp *et al.,* 2016:6). In order for spatial planning as a profession to aid in advancing renewable forms of energy generation, all scales need to be taken into consideration as spatial planning policies are relevant to energy planning at both micro- and macro-scales, ranging from national and regional, to local level (Vanderkamp *et al*., 2016:6). It must be noted, however, that spatial planning policies and regulatory systems differ substantially across the globe and each unique set of policies must be utilized effectively in order to ensure effective energy planning (Vanderkamp *et al.,* 2016:7).

Marine Spatial Planning (MSP) is governed by a number of international marine management policies including among others the Water Framework Directive (WFD), the Marine Strategy Framework Directive (MSFD), the Common Fisheries Policy as well as the United Nations Convention on the Law of the Sea (UNCLOS) (Scottish Government, 2015:8). In 2007, the European Commission published a 'blue paper' which sought to provide the foundation for an integrated marine policy framework that makes use of MSP as the implementation mechanism

(UNESCO, 2017:4). Prior to this, only seven countries were experimenting with MSP, but it has since matured into a mechanism with the potential to achieve sustainable ocean development by utilizing instruments such as Marine Spatial Plans (MSPs) (UNESCO, 2017:4). In 2014, the EU passed the MSP Directive, which mandated EU Member states with marine waters to develop approved MSPs by 2021. By 2016, approximately 20 countries around the globe have started to implement MSPs, meaning that, should the current rate of development in this regard continue, a third of the world's exclusive economic zones (EEZs) can have government-approved MSPs by 2030 (UNESCO, 2017:4). It is noteworthy that, similar to terrestrial spatial plans, the MSPs that have been developed are also divided into either statutory and/or strategic plans (UNESCO, 2017:4).

Many countries and regions around the globe (especially EU Member States) are rethinking their approach to their ocean-based economies in light of the fact that MSP can provide stability, transparency, and predictability for investors (UNESCO, 2017:37). Given the fact that there are no physical boundaries between the EEZs of neighbouring countries, planning at the regional sea scale must be a coherent effort between countries and must be based on achieving and maintaining environmental quality (UNESCO, 2017:38). In order to achieve the aforementioned coherent ecosystem-based MSP in the world's oceans, better mutual understanding needs to be obtained as to what MSP entails by learning from each other's experiences to extract the common best practices (UNESCO, 2017:39).

The global policy perspectives as discussed in this section has provided useful context for this study, however, in order to achieve this chapter's objective i.e. to evaluate best-practice policy frameworks for renewable energy planning and implementation on a regional level, it is necessary to evaluate policies from individual countries which will be the focus of the following section.

7.3 Renewable-energy leading countries

As explained in Section 7.1, the countries to be evaluated were selected based on their ability to provide best-practice policy guidance for renewable energy planning and implementation, especially with regard to renewable energy sources that are applicable to South Africa.

Scotland is a suitable case study from which to draw meaningful insight based on Scotland's speciality in offshore wind energy and marine renewables (ocean tidal current- and ocean-wave energy). Scotland as a case was therefore chosen by means of a purposive sampling technique (refer Section 2.7 & 7.1) due to Scotland being a world leader (making this a deviant case) in ocean-based renewable energy applications (EMEC, 2018). Approaches to regional marine

planning have been spearheaded by the Scottish Government who have voiced their commitment to further support and develop regional marine planning by means of providing guidance (Scottish Government, 2015:5). The Scottish government has done more towards the support of marine renewables than any other nation on earth, as Scotland's exceptional offshore renewable energy sources, combined with decades of engineering experience, have made Scotland a world-leader in the marine renewables industry (Scottish Government, 2017:78).

Scotland is part of the United Kingdom (UK) situated within the island of Great Britain, bordering with England to the southeast, is surrounded by the North Sea to the northeast and the Irish Sea to the south, and the Atlantic Ocean to the north and west (refer Figure 7.2). The Scottish economy has traditionally relied heavily on the North Sea for revenue by extracting oil for the export market, but has become more de-industrialized since the 1980s, with a growing tertiary sector (Neill *et al.*, 2017:1). Scotland's climate is temperate and oceanic; the west of Scotland tends to be warmer than the east due to the gulf stream in the Atlantic, bringing with it warmer air from the equator (Neill *et al.*, 2017:4).

China as a case study was also chosen by means of a purposive sampling technique (refer Section 2.7 & 7.1) based on China being a world leader (making this a deviant case) in solar- and wind-energy implementation (REN21, 2020:205). China can additionally boast with the world's largest installed capacity of renewable energy and has the world's largest renewable energy industry (Wang *et al.*, 2019:166). For the past decade, China has established and continues to lead the world in newly installed renewable energy (and in particular wind and solar PV) projects (Hove, 2020:2; REN21, 2020:205). In 2016, the total renewable energy capacity in China reached 570 GW, which not only made China the largest single country in terms of capacity, but equated to approximately one-third of the world's total installed capacity (Wang *et al.,* 2019:162). In 2018 alone, China added a total of 66 GW of newly installed wind- and solar-energy capacity, adding another 52 GW in 2019 (China Energy Portal, 2020).

China is located in the southeast of the Eurasian landmass, between 4 ° and 53 ° north latitude and between 73 ° and 135 ° east longitude, covering an area of approximately 9.6 million km² (refer Figure 7.2) and is featured with mountains, plateaux, valleys, and plains (Zhang *et al*., 2017:867). The altitudes in China vary significantly, ranging from 100 m above sea level in the east to over 4 000 m in the west (FAO, 2011:1). China's climate also varies, with only the southern parts of the country experiencing a monsoon climate, due to mountains preventing the monsoons from crossing over into the northern parts, resulting in a dryer climate in these areas (FAO, 2011:1). Average rainfall ranges from below 700 mm per annum in the northern regions

to more than 2 000 mm per annum in the southwest and coastal regions (FAO, 2011:1). According to Wang *et al*., 1999 (in FAO, 2011:1), China can be divided into four climatic zones:

1. The arid zone in the west and northwestern part of the country.
2. The semi-arid zone in the central part of the country.
3. The semi-humid zone in the northeastern part of the country.
4. The humid zone in the south and southwestern part of the country.

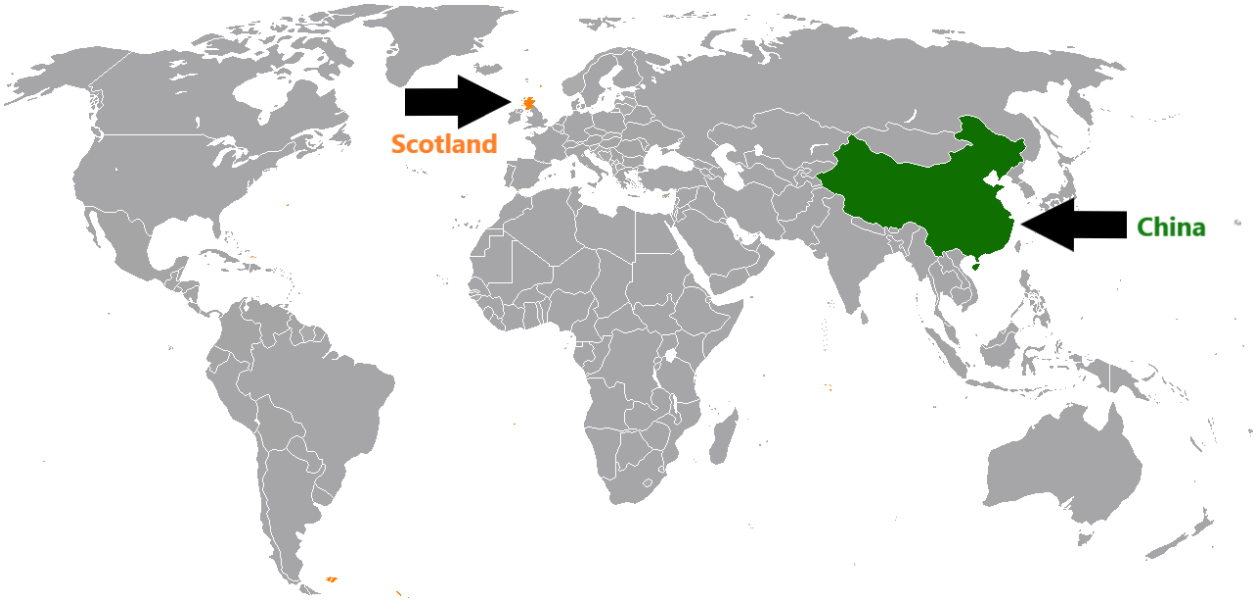

Figure 7. 2: Locality map of Scotland and China
Source: Own compilation (2020)

7.3.1 Renewable energy planning in Scotland

7.3.1.1 Introduction

Scotland has set one of the most ambitious renewable energy targets of any country on the planet by aiming to generate virtually 100 percent of Scotland's total electrical energy demand from renewable sources by as early as 2020, in addition to reducing the country's greenhouse gas (GHG) emissions by 80 percent by the year 2050 (Scottish Government, 2015:81).

The Orkney Islands off the northeast coast of Scotland are home to the world's first grid-connected tidal and wave test centre known as the European Marine Energy Centre (EMEC), as well as the world's largest tidal-current turbine (Scottish Government, 2017:78). The flagship Orkney-based EMEC was launched in 2003 and has deployed more grid-connected marine energy infrastructure than any other place in the world and is the only accredited marine energy laboratory in the world (EMEC, 2020). The Pentland Firth and Orkney Waters (PFOW) region

hosted the world's first commercial-scale wave and tidal energy lease (Scottish Government, 2015:82) while the world's first floating wind farm was commissioned off the east coast of Scotland in 2017 (ORE, 2018:8). Further north, Nova Innovation successfully deployed a third tidal turbine along the coast of the Shetland Islands in 2017 and the MeyGen tidal project has become operational with a capacity of 6 MW (Scottish Government, 2017:46). The tidal current array was developed by Scotrenewables and has already exported a significant amount of electrical energy to the Orkney grid (Scottish Government, 2017:46). Orkney also boasts the UK's first smart-grid, which connects renewable energy from the PFOW to the Orkney Islands distribution grid at a substantially lower cost than ordinary grid connections (Scottish Government, 2017:55).

Scotland will continue to build a world-leading offshore wind and marine renewables industry to not only secure supply of energy for the Scottish economy, but also to transition to a low-carbon economy (Scottish Government, 2015:81). According to the Scottish government, offshore wind and marine renewables will continue to increase beyond the year 2020 and is set to contribute to the aforementioned targets in a significant way (Scottish Government, 2015:81). However, this cannot be accomplished without a sound implementation policy framework. Marine spatial planning will play a central role in ensuring the delivery of offshore wind and marine renewables by guiding among others the provision of suitable infrastructure and offshore facilities in an organized manner (Scottish Government, 2015:83). However, to fully grasp the implementation policies, the renewable energy resource potential on which these policies are based needs to be examined.

7.3.1.2 Scottish renewable energy resource potential

It has been estimated that the oceans surrounding Scotland possess approximately 25 percent of Europe's offshore wind and tidal energy potential, and approximately 10 percent of Europe's wave energy potential (Scottish Government, 2015:82; Scottish Government, 2018:4). Within Scotland's marine area, there are a number of planned development sites (refer Figure 7.3) for both offshore wind and marine renewables including the following (Scottish Government, 2015:82):

- The Crown Estate 'Round 3' Offshore Wind Sites;
- The Scottish Territorial Waters Offshore Wind Sites;
- The Pentland Firth strategic wave and tidal energy lease area; and
- The Saltire Prize lease sites.

It is important to note that planned developments are those that have been granted consent for development and/or those which have already been given agreements for lease by the Crown Estate (Scottish Government, 2015:82).

Scotland has a comparative advantage (refer Section 3.3.3.2) in offshore wind due to a combination of high wind speeds and availability of deep-water sites (Scottish Government, 2019:9). Around Scotland, there are several offshore wind energy locations to the east, north, and west of the country, with a combined potential capacity of more than 100 GW (Scottish Government, 2018:9). Since 2016, Scottish Ministers have consented to various prototypes and demonstration-scale off-shore wind projects in Scottish waters with the intention of becoming commercially operational, and include the following (Scottish Government, 2018:5):

- The 30 MW Hywind Scotland Pilot Park;
- The 50 MW Kincardine Offshore Wind Farm; and
- The 12 MW Dounreay Tri-floating Wind Demonstration Project.

In May 2018, Scotland had 217 MW of installed offshore wind capacity with an additional 4.2 GW in the construction phase (Scottish Government, 2018:5). Scotland is a prime location for the development of marine renewables technology as this part of the world has significant tidal current and wave energy resources. The UK Wave and Tidal Key Resource Areas Project determined that the waters surrounding Scotland can offer up to 4 Terawatt hours per year (TWh/year) of wave energy, and up to 32 TWh/year of tidal current energy (Scottish Government, 2015:82). Scotland's tides originate from the North Atlantic with an average tidal range of between 3–4 metres, but can exceed 7 metres in the northern Irish sea *(*Neill *et al.*, 2017:2). Tidal currents in general travel at a velocity of approximately 1 metre per second (m/s) but within the channels around Scotland, tides generally travel at 2.5–3 m/s (Neill *et al*., 2017:3) and can reach a velocity of up to 4 m/s around the Orkney Islands (Neill *et al.*, 2014:346). When power density was measured, it was found that the Pentland Firth, the channel that separates the Orkney Islands from mainland Scotland and links the northeast Atlantic to the North Sea has the highest power density and is arguably the most concentrated tidal energy resource on the planet with energy measurements of 16 kW/m^2, translating into 8 GW for this small area alone (Neill *et al*., 2017:5-6).

As in the case with tidal energy, the majority of Scotland's wave energy can also be found in the North Atlantic (Neill & Hashemi, 2013:32). The west coast of Scotland as well as the Orkney Islands are the regions most exposed to the Atlantic and where wave resources have the most potential (Neill *et al*., 2017:3). The region with both a high wave-energy potential as well as being relatively close to shore is at the Hebrides islands to the west of mainland Scotland,

where the average wave energy potential has been measured to be between 50 kW/m and 130 kW/m (Neill *et al.*, 2017:10). The Orkney Islands and Northern Isles have shown to have sufficient (albeit less than the Hebrides Islands) wave potential for harvesting, ranging between 30 kW/m and 40 kW/m under normal circumstances, but have been measured to reach 100 kW/m to the West of the Shetland Islands (Neill *et al*., 2017:10).

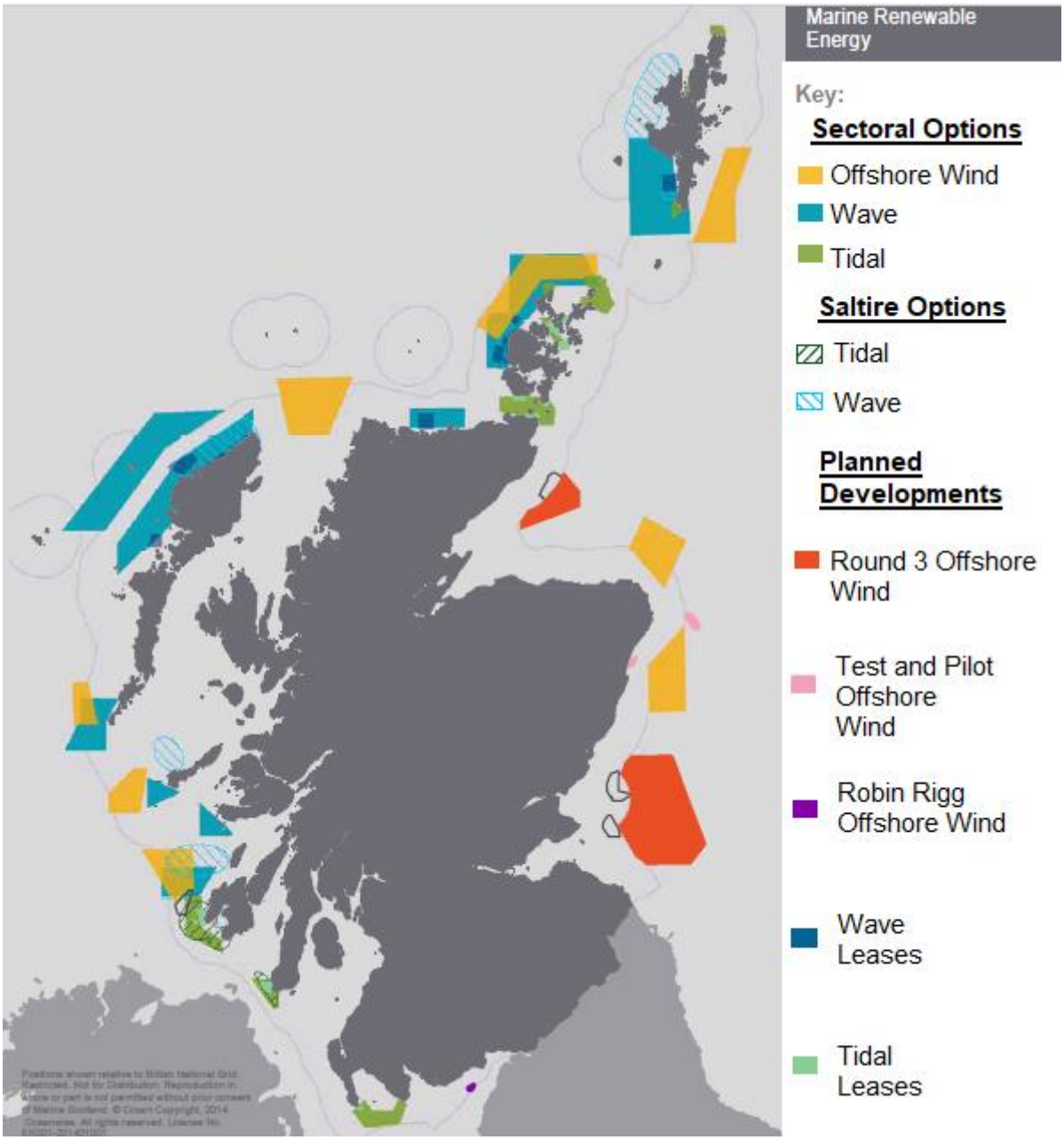

Figure 7.3: Scotland marine renewable energy map

Source: Scottish Government (2015:88)

Now that it is clear which renewable energy sources have exploitable potential and where such sources are naturally located, the energy, infrastructure, and spatial planning policy mechanisms used to exploit these sources can be discussed.

7.3.1.3 Scottish renewable energy policy

The Scottish National Planning Framework (SNPF) and related planning policy acknowledge the importance of place (the placement of functions), as well as the transition towards a low-carbon economy to create sustainable and well-designed places (Scottish Government, 2017:53). Renewable energy, therefore, forms an important part of Scottish spatial planning policy as the successful placement and subsequent implementation thereof have been proven to reduce greenhouse gas emissions in addition to providing significant economic opportunities (Scottish Government, 2017:53). Scottish spatial planning supports energy planning by locating renewable energy developments in appropriate locations as well as by encouraging grid connections to decentralize the Scottish power system (Scottish Government, 2017:53). The Scottish Parliament approved an amended version of the Scottish Planning Bill in June 2019, which aims to provide guidance for the planning and delivery of onshore infrastructure, whereas applications for marine energy infrastructure such as offshore wind and marine renewables are reviewed and approved by Marine Scotland in accordance with the Marine Act of 2010 and Marine and Coastal Access Act of 2009, combined known as the Marine Acts (Scottish Government, 2015:1).

The Marine and Coastal Access Act (2009) prescribes Scottish Ministers to ensure that a National Marine Plan (NMP) is in place to govern both Scottish inshore and offshore waters, which was subsequently approved and published in 2015 (Scottish Government, 2015:1). A software-based plan was developed to assess the condition of the Scottish marine area known as the Marine Atlas and is accessible to any interested party via the interactive GIS portal known as the National Marine Plan Interactive (NMPi) (Scottish Government, 2015:2). In addition to the NMP, marine planning at a more local level is done through the various Regional Marine Plans (RMPs) (refer Figure 7.4) applicable to Scottish marine regions up to 12 nautical miles (22 km) from the shore, the boundaries of which are set by secondary legislation (Scottish Government, 2019:13).

RMPs are to be adopted by Scottish Ministers and take cognizance of local circumstances within smaller ecosystem units as well as the NMP (except where not feasible or desirable) and the Marine Policy Statement (MPS) in order to ensure compliance with national objectives and strategies. However, unless approved under the Marine Act (2010), RMPs will not alter national priorities (Scottish Government, 2015:4). RMPs must include among others an assessment of the region's physical, environmental, social, cultural, and economic conditions, the purpose for which it is used as well as the infrastructure and natural resources that support said purpose, in addition to objectives that will lead to the sustainable development of the region (Scottish Government, 2015:5).

Among the above-mentioned objectives for sustainable regional marine development is the need to issue licenses for certain activities within the marine area (such as the construction of infrastructure, for example) after due consideration has been given to specific aspects of the proposed development (Scottish Government, 2015:6). Another objective includes the need to align marine and terrestrial spatial planning by means of policy guidance. Terrestrial Scottish Planning Policy such as the National Planning Framework (NPF3) and Local Development Plans (LDPs) will all be consulted during the course of developing RMPs and the opposite applies to terrestrial planning authorities when developing LDPs (Scottish Government, 2015:7).

The system aimed at ensuring the coherence between marine and terrestrial planning called the Planning Circular (refer Figure7.4), deals with the relationship between statutory land use planning and marine planning by considering among others the following (Scottish Government, 2015:7):

- Liaison between marine and terrestrial planning authorities;
- Synchronizing the timing of marine and terrestrial plans;
- Alignment of marine and terrestrial plans;
- Marine licencing; and
- Sector planning (such as renewable energy).

Marine sector planning should be directed towards the sustainable use of marine resources in response to climate change challenges and aimed towards the socio-economic development of Scottish people (Scottish Government, 2015:15-18). Sectoral Marine Plans (SMPs) should therefore consider among others the following (Scottish Government, 2015:18):

- Identifying incompatibilities in areas were different sectors are proposed and make recommendations on how differing sectors can coexist; and
- Identifying areas wherein specific sectors can be given preferential use status.

The above-mentioned considerations can result in proposals for commercial-scale (>100MW) off-shore wind and marine renewable energy developments being sited on the SMP as Plan Options, which translate to preferred sites for specific renewable energy developments (Scottish Government, 2015:79). Renewable energy developments in Scottish seas are planned for in SMPs (which are then included in the NMP and relevant RMP) for each technology, i.e. offshore wind, wave, and tidal energy (Scottish Government, 2019:17). The sector planning process (refer Figure 7.4) is central to the successful delivery of offshore wind and marine renewable energy projects and will therefore be described in more detail in the following section.

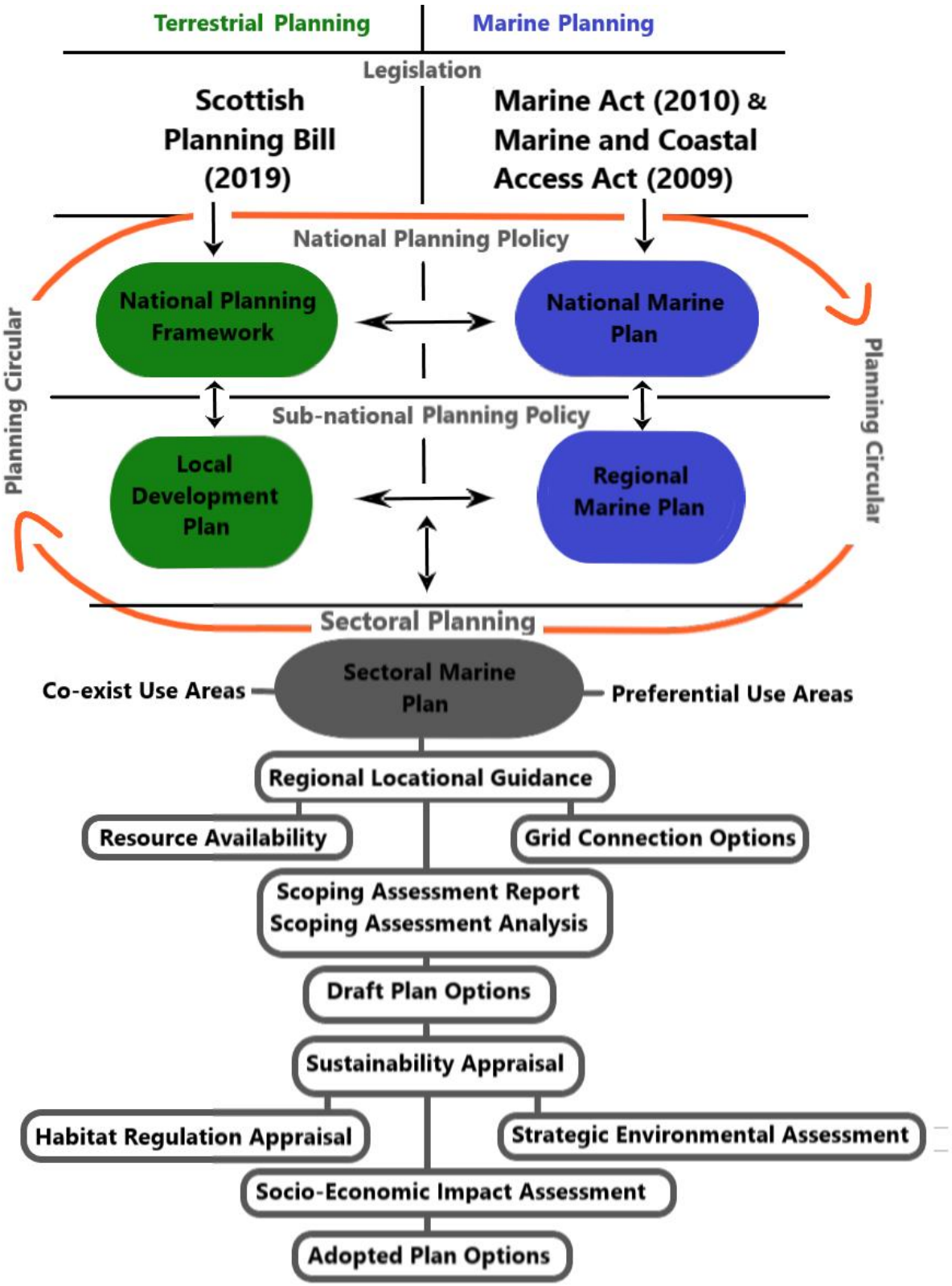

Figure 7.4: Scotland renewable energy planning process

Source: Own Compilation (2020)

As previously stated, planned development areas (or adopted Plan Options) are sites that have been granted consent for commercial-scale renewable energy projects and are identified through a multi-stage process that involves scientific scoping exercises commencing with

Regional Locational Guidance, which details the relevant information applicable to each specific type of renewable energy project such as resource availability and grid connection options (refer Section 6.4 & Figure 7.4) and are called Draft Plan Options (Scottish Government, 2019:20). Draft Plan Options then undergo a Sustainability Appraisal (which includes a Strategic Environmental Assessment (SEA), a Habitat Regulation Appraisal, and a Socio-Economic Impact Assessment) prior to adoption (Scottish Government, 2019:20). The Sustainability Appraisal will assess key environmental risks associated with renewable energy development projects (Scottish Government, 2015:86). It is noteworthy that proposals for offshore wind and marine renewable-energy developments within Plan Options are still subject to a licensing and consenting process, during which planners and decision-makers must evaluate each proposal on its own merits (Scottish Government, 2015:83).

While the Scotland case provided useful information regarding marine spatial and energy planning as well as marine and terrestrial planning coordination, little information was provided regarding onshore wind and solar energy planning, which is why the following section will focus on China.

7.3.2 Renewable energy planning in China

7.3.2.1 Introduction

In 2015, China established the Enhanced Actions and Measures on Climate Change which aims to lower the amount of CO2 the economy emits per unit of GDP by 28.6 percent by 2020 (compared to 2010 levels) and increase the share of renewable forms of energy in the overall energy mix from 8.3 percent to 15 percent, necessitating the shift away from coal-based energy systems with renewable energy supportive policies such as power purchase agreements and financial incentives among others (NEA, 2016). In 2016, the Chinese government published their 13th Five Year Plan for Electrical Power Development wherein it is outlined to increase the amount of public funds invested in renewable energy (NEA, 2016).

However, due to double-digit economic growth during the recent past, energy demand in China has reached unprecedented levels and has subsequently forced the Chinese government to increase energy supply with the added requirement of not compromising environmental quality (Zhang *et al.*, 2017:865).

7.3.2.2 Chinese renewable energy resource potential

China is blessed with a high level of renewable energy sources that can be exploited to the benefit of the country and the environment (Liu *et al.,* 2011:218). Based on a resource potential assessment, the sectors with the highest development potential in China are wind and solar

energy (Wang *et al.,* 2019:171). The Wind energy potential is considerable as, according to the third national wind energy survey carried out by the Chinese Meteorological Administration, the exploitable onshore potential ranges between 300–1 000 GW (NDRC, 2007:1). Due to China's geographical characteristics as described in Section 7.3, the wind and solar resources are relatively distributed across the country as wind energy potential is concentrated within two major 'wind belts' in the northwest and northeast, whereas abundant solar energy resources are concentrated in the northern and western parts of the country (see Figure 7.5) (Wang *et al.,* 2019:171). Approximately two-thirds of China receive more than 2 200 hours of sunshine on an annual basis and the western part of the country is extremely suitable for solar energy development (NDRC, 2007:2).

Despite the abundance of wind energy potential, the resources are distributed unevenly across the country, and areas where potential exists, are more often than not areas where economic development lags behind, and vice versa (Zhang *et al*., 2017:867). One of the prime examples of this can be seen in the Inner Mongolia regions where approximately one-third of the cumulative wind capacity is generated but only accounts for approximately 7 percent of total electricity consumption, while the Zhejiang region with a more developed economy accounting for more than 20 percent of total electricity consumption, only produces approximately 5 percent of the cumulative wind energy (Zhang *et al*., 2017:867). It is expected that the wind power industry will continue growing in the future and are projected to exceed 300 GW by 2030 (Zhang *et al*., 2017:870).

Solar energy has grown quickly with installed capacity projected to reach 20 GW in 2020 (in 2010 the installed capacity was a mere 500 MW) (Zhang *et al.,* 2017:870). This projection has materialized as China dominated the solar energy market in 2019, accounting for nearly one third of the year's total global additions (REN21, 2020:108). There are several regions in China that have the potential to generate more than 1 750 kWh/m² and is the reason behind China's rapid growth in the solar industry since 2004 *(*Zhang *et al*., 2017:867).

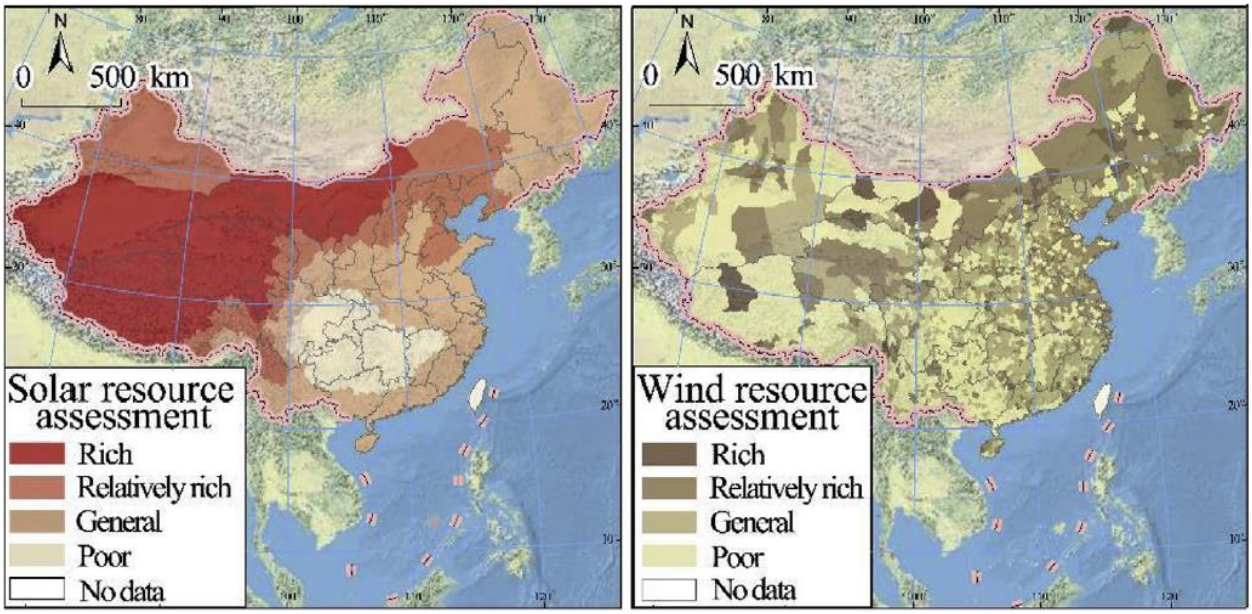

Figure 7.5: China wind and solar resource regions

Source: Wang *et al.* (2019:171)

7.3.2.3 Chinese renewable energy policy

In addition to natural factors such as topography and the availability of energy sources, the availability of renewable energy supporting policy plays a significant role in the location of renewable energy projects in China as well as the scale of these projects (NDRC, 2007:10). What the natural features are concerned, the regions are divided into four categories, ranging from resource rich, to relatively resource rich, to general, and finally resource poor (refer Figure 7.5) and have a direct influence on the spatial distribution of renewable energy developments across China (Wang *et al*., 2019:169). Since 1997, the Chinese government has implemented a variety of policies, laws, and programmes aimed to support renewable energy, consisting mainly of FITs and subsidies in the form of quota obligations prescribing regions in China to deliver a predetermined amount of renewable energy (Wang *et al*., 2019:171).

The policies issued for wind power in the 1990s did not make a significant impact, mainly due to the comparatively high costs for wind power at the time as well as the lack of incentives, which subsequently led to the Chinese government changing their strategy for wind power in 2003 to concession projects, which also addressed large-scale wind farms (GWEC, 2010:31). The concession projects were managed by the National Development and Reform Commission (NDRC) and allowed selected wind farm developers to sell the wind-generated electricity to provincial grid companies via a bidding process resulting in the establishment of a stable local market (GWEC, 2010:31). One of the unique features of the concession projects was that the NDRC required of wind farm developers to purchase at least 70 percent of their wind turbines domestically, and all wind turbines must be assembled within China, otherwise the projects

were not approved (Wang *et al.*, 2009:1873). The aforementioned requirement resulted in an influx of foreign investment establishing a thriving wind turbine manufacturing industry in China (NFTC, 2010:47).

In 2005, the Renewable Energy Law (REL) was adopted by the Chinese government, making way for a new era in renewable energy development, allowing for major renewable energy subsidy schemes. In 2009, the REL was amended to rectify some of its practical shortcomings in terms of implementation (He *et al*., 2016:697). The REL has five core management mechanisms; the first relates to the government's development targets which must be achieved within a certain time period, sending a strong message to the market; the second relates to power grid enterprises' obligation to purchase all the renewable energy available to them; the third relates to different prices developers may charge for different type of renewable energy; the fourth mandates each region to assist developers in carrying the cost of generation; and the fifth relates to financial support to developers and researchers in the form of subsidies and grants, respectively (Qiu & Li, 2012:10680).

The wind energy concession projects initiated in 2003 were used until 2009, whereafter China switched to what was the prevailing global regulatory policy at the time in the form of FITs, which stabilized the market increasing output to 13.6 GW and 16.5 GW in 2009 and 2010, respectively (GWEC, 2010:30). The FITs were also used for solar energy projects (Zhang & He, 2013:393). In early 2010, the Chinese government decided to set up a National Energy Commission (NEC), which included 23 members from various agencies, including the NDRC (NDRC) (Wang *et al.,* 2019:167). The NEC was tasked with the responsibility of drafting a national energy plan, taking into consideration energy security and energy policies, as well as coordinating local energy development with the international market (Wang *et al*., 2019:167).

In 2016, the National Energy Administration (NEA) officially released the 13th Five-Year Plan for Electrical Power Development (2016-2020) wherein it highlights the NEA's role as the responsible department for national power planning under the guidance of the NDRC, with provincial-level energy authorities to take responsibility for provincial-level power planning (NEA, 2016). The 13the Five-Year Plan additionally prescribes that a planning coordination mechanism be established to link national and local planning and that a power operation monitoring and evaluation system be established to ensure the full guaranteed purchase of renewable energy (NEA, 2016).

Due to the dispersed nature of the renewable energy generation plants and transmission grid shortcomings in China, not all the generated renewable energy was reaching end-users and as a result, generation had to be reduced below what the plants were capable of (CNREC, 2019:5). According to China's NEA (cited by Hove, 2020:3), wind curtailment in 2016 reached

17 percent for the entire country, while in some regions, curtailments reached as high as 40 percent. In 2017 curtailment for wind energy continued at a rate of 12 percent and at a rate of 7 percent in 2018 (CNREC, 2019:5). Solar energy curtailment for the year 2017 was approximately 6 percent and in 2018 curtailment was reduced to 3 percent (CNREC, 2019:5).

According to the NDRC and the NEA (cited by Li, 2019), the government placed a mandate on provinces and grid companies in 2018 to start reducing wind and solar energy curtailment with the year 2020 as the target year during which energy curtailment and grid integration issues had to be resolved, aiming for a curtailment rate of less than 5 percent in all provinces. Several new transmission lines were built as a result and, combined with new market regulations such as generation trading rights between provinces as well as the option to bid for curtailed renewable energy from a neighbouring province, this meant that the aforementioned target was achieved by as early as 2019, during which wind curtailment fell below 4 percent and solar PV curtailment was approximately 2 percent (NEA, 2020).

In 2019, however, the renewable energy market in China declined as a result of policy uncertainty brought on by the shift away from high-speed capacity growth through FITs towards a high-quality technology market and subsidy-free auctions for new generation (Haugwitz, 2019). The shift in policy started in 2018 when the NDRC (who sets prices for newly generated renewable energy) and NEA signalled that FITs for wind and solar would be phased out completely and would instead need to participate in tenders from 2019 (CNREC, 2019:6). The Chinese government moved quickly and ceased new subsidized wind and solar projects at the end of May 2018 and in June 2018, reducing the FITs for solar PV (Haugwitz, 2019). The policy changes of 2018 were cited as the main reason for the reduced investment in renewable energy in China (REN21, 2020:71).

7.4 Conclusion

Since the mid-1990s, there have been intensified efforts on a global scale to reduce GHG emissions to combat climate change. The Kyoto Protocol is widely recognized as the first international treaty to focus on this goal. It did so by placing obligations on countries to reduce their GHG emissions based on their level of development, as this normally correlated with GHG emissions. The Kyoto Protocol was replaced with the Paris Agreement in 2015, which aimed to reduce the increase in global temperature below 2 °C from pre-industrial levels. The Paris Agreement did not place a heavier burden on developed countries in terms of their efforts towards the cause as was the case with the Kyoto Protocol, but rather requested countries to work together by means of voluntary Nationally Determined Contributions (NDCs). One of the most popular NDCs used by countries is to increase their renewable energy efforts at the

expense of fossil-fuel generated energy. Also, in 2015, the United Nations developed the Sustainable Development Goals (SDGs) in an effort to enhance people's general quality of life among others. One of the SDGs, i.e. SDG-7, highlights the need for global energy security by means of clean and modern forms of energy. SDG-7 has subsequently contributed to renewable energy policies being adopted by many countries around the world.

Renewable energy policies can be divided into two clusters; the first being regulatory policies aimed at facilitating renewable energy development and the second being fiscal policies aimed at encouraging renewable energy development by means of financial incentives. Renewable energy planning policies will fall within the regulatory policy cluster, but on a global scale, this is not frequently discussed, due to the regional differences in planning policy. Observable regulatory policy trends include the shift away from FITs towards auctions and tenders due to the proven results in driving down the costs for renewable energy as a result of competition. Regardless of the prevailing renewable energy policies being used, it is proposed that professional spatial planners be heavily involved in developing renewable energy strategies as, according to some experts, this profession has the greatest ability to coordinate the complex process of energy infrastructure and spatial planning at national, regional and local scales. Ocean energy is still in the early stages of adoption, but as technology improves, the vast amount of energy contained within the world's oceans will increasingly be harvested, necessitating a relatively new regulatory policy framework that includes what is commonly known as Marine Spatial Planning (MSP).

Scotland can be considered to be the world leaders in ocean-based renewable energy development due to the high potential for wave, tidal current and offshore wind energy in the ocean waters surrounding Scotland, the research and development programmes initiated by the Scottish government as well as Scotland's advanced marine spatial planning system. Scottish spatial planning policy (both terrestrial and marine) acknowledges the importance of 'place', i.e. the placement of functions and therefore plays an important role in renewable energy by placing developments in appropriate locations in addition to encouraging grid connections. Ocean-based and terrestrial renewable energy developments are reviewed and approved by separate government departments, as they are guided by separate legislation and policies, with the two being linked to one another by means of a 'planning circular' policy mechanism. Scotland is one of the few countries in the world to coordinate their world-leading marine energy sector by means of Marine Spatial Planning (MSP). Scotland has in place a National Marine Plan (NMP) that informs all the various uses in Scottish ocean waters, including renewable energy. Marine spatial planning on a smaller scale that allows for more detail is done by means of Regional Marine Plans (RMPs), which take into consideration local physical, environmental, social, cultural, and economic conditions for proposed uses that will lead to the development of the

region. RMPs must be aligned not only with the NMP, but also with terrestrial spatial plans to achieve coherence.

Ocean-based renewable energy developments are planned for in Sectoral Marine Plans (SMPs) that inform the relevant RMPs, the NMP and terrestrial development plans such as Local Development Plans (LDPs). It is important to note that Sector Planning is carried out by the relevant national government sector department for both national and subnational application. Renewable energy developments are prioritized in SMPs as 'Plan Options' indicating preferential and/or coexisting use areas for specific renewable energy projects. Plan Options are identified via a multi-stage process commencing with Regional Locational Guidance, which highlights the potential for a specific type of renewable energy development and related natural and man-made features that can support the envisaged use, followed by a Scoping Assessment Report and Analysis. Once such areas have been identified a Sustainability Appraisal is carried out, which includes a Strategic Environmental Assessment (SEA), a Habitat Regulation Appraisal, and a Socio-Economic Impact Assessment prior to adoption. It is worth noting that proposals for offshore wind and marine renewable energy developments within Plan Options are still subject to a licensing and consenting process during which planners and decision-makers must evaluate each proposal on its own merits

China leads the world in installed renewable energy capacity for wind and solar PV, making China a suitable case study from which to draw meaningful conclusions. China's wind energy potential is concentrated within two major 'wind belts' and wind energy developments are distributed relatively unevenly across the country, whereas solar energy potential is concentrated largely within the western part of the country where the potential is the highest. China has divided the country into four categories relating to renewable energy potential, which has a direct influence on the spatial distribution of renewable energy developments. Unfortunately, this study could not determine how renewable energy and spatial planning is integrated; however, it was established that one of the most influential driving forces behind China's renewable energy industry's success is their attitude towards achieving goals.

From the introduction of concession projects in 2003, the Chinese government has aimed to make renewable energy development as easy for developers as possible through a reduction in red tape by allowing wind farm developers to sell electricity directly to provincial grid companies, while simultaneously focusing on growing the renewable energy manufacturing industry in China by requiring that at least 70 percent of developers' turbines are locally acquired and ensure that all their wind turbines were assembled locally. This facilitating mindset can also be seen in the enactment of the 2005 Renewable Energy Law (REL), which offered financial support for the renewable energy industry by means of research grants and development

subsidies in addition to guaranteeing grid access for developers to sell their generated electricity through Feed-in-Tariffs (FITs) at reasonable prices. In 2010, the National Energy Commission (NEC) was tasked to draft a National Energy Plan to provide a blueprint for the energy market. In 2016, the 13th Five-Year Plan for Electrical Power Development (2016-2020) was adopted wherein provincial-level energy authorities were given the responsibility for provincial-level energy planning in addition to prescribing that a coordination mechanism be established to link national and local energy planning. Another indicator of China's goal-achieving mindset can be seen in their distribution and transmission infrastructure expansion that commenced in 2018 after renewable energy curtailment became a problem.

In the following chapter, South African renewable energy potential as well as infrastructure, energy, and spatial planning policies will be analysed in order to identify a policy framework in which to facilitate renewable energy development to achieve regional economic development.

CHAPTER 8: EMPIRICAL STUDY: SOUTH AFRICAN PERSPECTIVE

8.1 Introduction

In the previous chapter, best-practice examples for solar-, wind- and ocean-based renewable energy planning and implementation were evaluated, providing a sound frame of reference for local application. This chapter is aimed towards achieving research objective number six of this study i.e. **to identify energy, infrastructure and spatial planning policies that can form a framework for renewable energy implementation in South Africa.** The policies will be discussed in a chronological manner to illustrate how energy, infrastructure, and spatial planning policies have evolved over time to provide the necessary context for South Africa's current situation.

Firstly, the renewable energy potential in South Africa will be examined to identify energy sources in which South Africa has a comparative advantage. As established in Section 6.3.1, renewable energy is naturally occurring in nature and can only be harvested in its place of origin. For this reason, it must be established where and what types of energy sources have sufficient potential to be harvested to align and direct the relevant energy, infrastructure, and spatial planning policies to this end. This will be followed by an in-depth policy analysis that is divided into two sections: (1) policy background, and (2) current policies. The chapter then ends with a conclusion highlighting the most important findings.

8.2 Renewable energy potential in South Africa

To utilize renewable energy to achieve regional development, one must first establish what forms of naturally occurring energy is available, as well as where such energy has sufficient potential for exploitation. South Africa has an abundance of naturally occurring renewable energy sources, especially solar and wind energy (Department of Minerals and Energy, 2003:13-20; WWF, 2017:7). Solar energy potential ranks among the highest in the world, especially in the western and central parts of the country, while wind energy potential is largely concentrated within the coastal provinces of the Western and Eastern Cape (refer Figures 8.1 & 8.2) (Department of Minerals and Energy, 2003:13-20). In addition to the level of solar- and wind-energy potential, is their complementary profile, meaning that wind energy tends to be the highest during the evenings, and solar energy is the highest during the days, resulting in a constant flow of energy (WWF, 2017:10). South Africa is a water-scarce country and therefore has limited potential in traditional forms of hydro-energy such as dammed reservoirs and pumped storage (Department of Planning, Monitoring and Evaluation, 2019:54). However,

South Africa has significant potential in ocean energy, especially in the form of wave and current energy, which can provide steady base-load energy due to their relative consistency (Department of Minerals and Energy, 2003:22; Meyer *et al.,* 2013:54). Offshore wind energy (not necessarily classified as ocean derived energy) also has significant potential in South African ocean waters (Inamboa & Cunden, 2019:103-104). Each of the abovementioned energy sources will be discussed in more detail below, commencing with solar energy.

8.2.1 Solar energy

According to Gulati and Scholtz (2017), South Africa has a high radiation area of approximately 194 000 km² and is blessed with some of the highest solar radiation levels on earth i.e. between 4.5 and 6.5 kilowatt hours per square metre (kWh/m²) which equates to roughly 1 640 and 2 370 kWh/m² per annum (refer Figure 8.1), compared with approximately 3.6 kWh/m² for parts of the United States and approximately 2.5 kWh/m² for parts of Europe and the United Kingdom (cited by WWF, 2017:9). The Northern Cape Province alone has a solar thermal potential capacity of approximately 64 GW (Department of Energy, 2016:52).

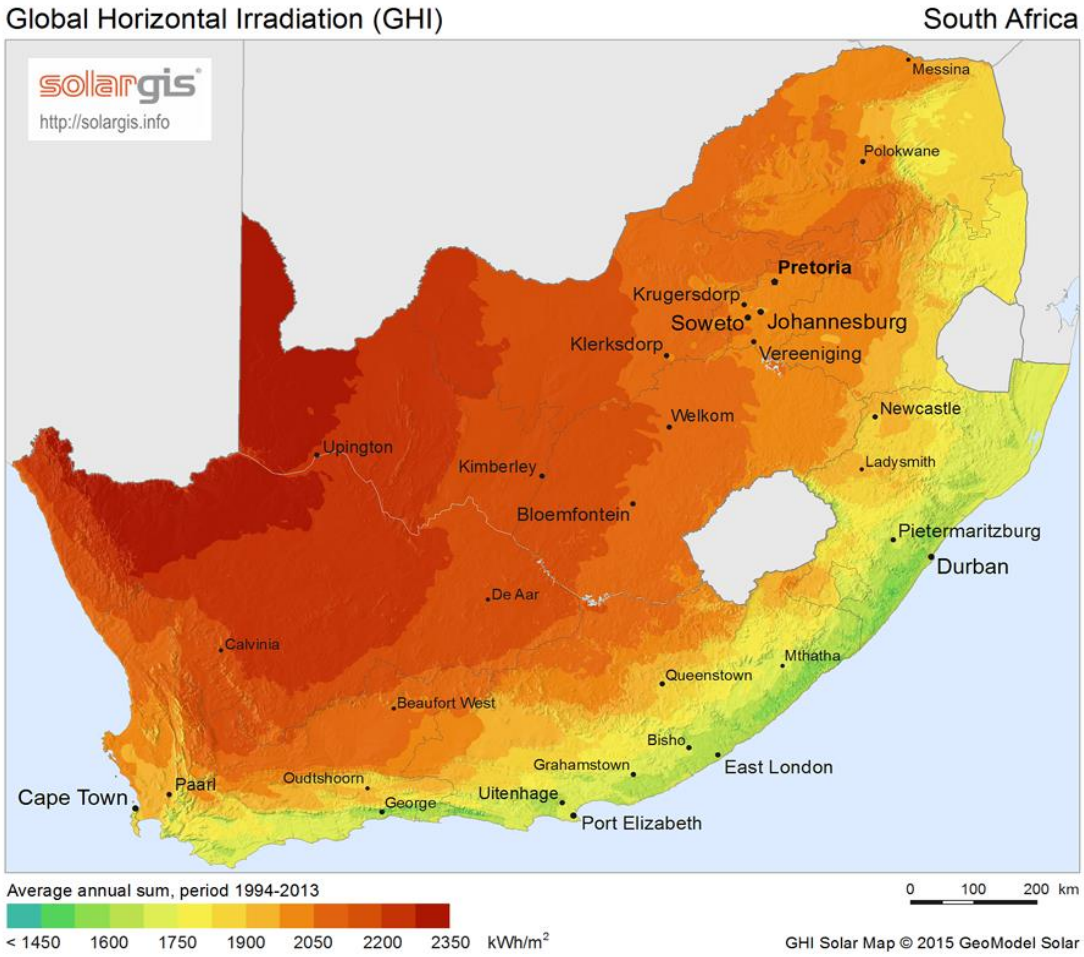

Figure 8.1: Solar GHI energy potential in South Africa

Source: Solar GIS (2015)

South Africa is in such a fortunate position that provinces with the lowest solar-energy potential such as KwaZulu-Natal and Mpumalanga have higher levels of solar irradiation than other industrialized countries that use solar technologies on a larger scale (WWF, 2017:5). Solar technologies also present the greatest potential for job creation; thus the need to explore special focused programmes to promote and develop solar technologies as well as roll-out programmes (Department of Energy, 2016:19).

8.2.2 Wind energy

Professor Roseanne Diab (1995) undertook a study wherein she concluded that wind energy potential along the South African coast is generally good and particularly good at coastal promontories with a potential of over 200 Watt per square metre (W/m²) at a wind speed of approximately 6 metres per second (m/s) (refer Figure 8.2). Minor potential for wind energy also exists inland, especially along the Drakensberg foothills and the Highveld plateau (Department of Energy, 2016:54).

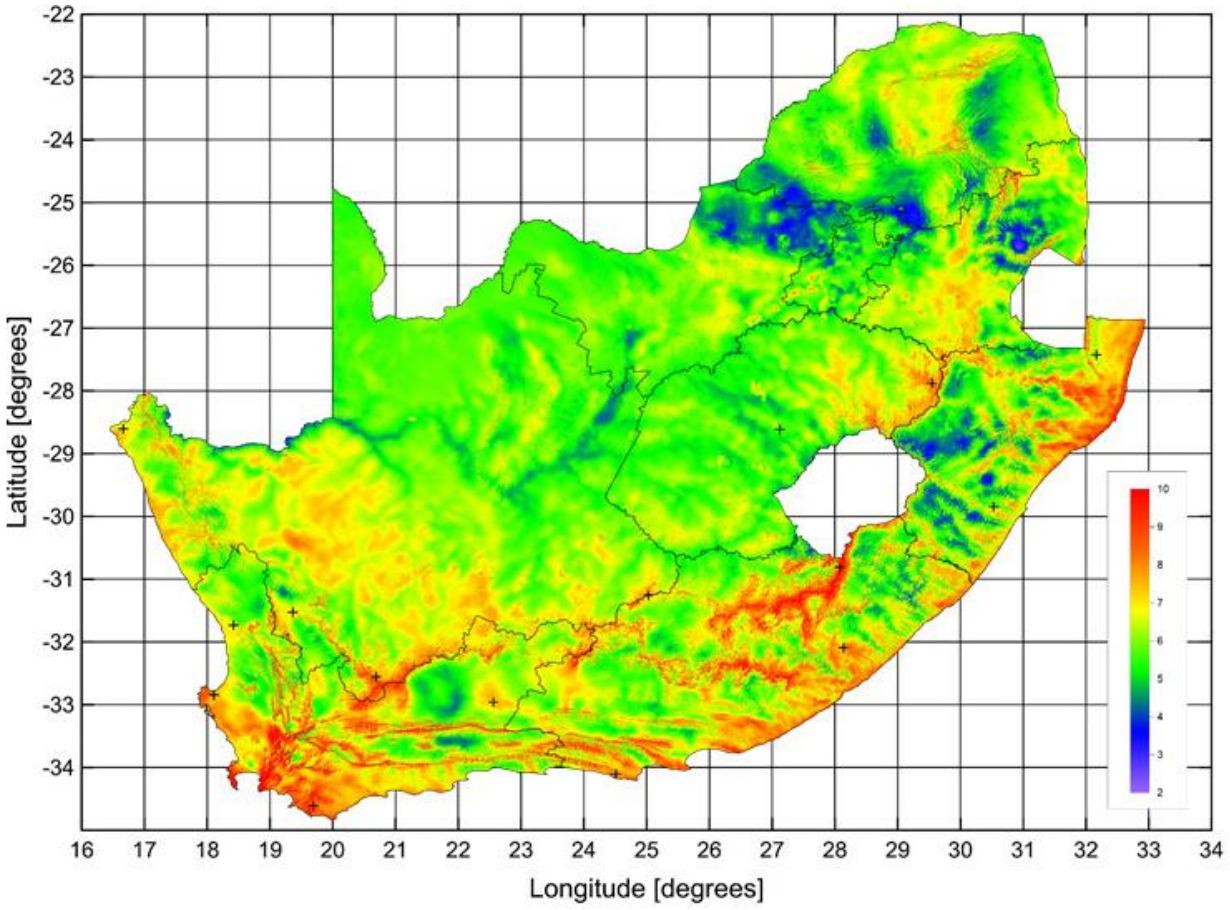

Figure 8.2: Wind energy potential in South Africa

Source: SAWEA (2017)

In 2003, the South African Renewable Energy Strategy Formulation Team conducted a study that concluded that wind energy potential in South Africa is as high as 60 Terawatt-hours (TWh) per year (Banks & Schäffler, 2006:23). It has been estimated by the Council for Scientific and Industrial Research (CSIR) (cited by WWF *et al*., 2017:8) that in order to generate 250 TWh of electricity via wind energy technologies (which is roughly South Africa's electricity demand) only 0.6 percent of the available South African landmass would be needed.

The Department of Energy (DoE) has collaborated with the Global Environmental Facility (GEF) via the United Nations Development Programme (UNDP) as well as the Danish Government to develop the first numerically verified Wind Atlas for South Africa (WASA) (Department of Energy, 2015b:2). The DoE also established the South African Wind Energy Programme (SAWEP), which received funds from the GEF in order to provide support to the wind energy sector by updating South Africa's wind atlas to be used by prospective wind energy developers (Department of Energy, 2016:54).

8.2.3 Hydro Energy

As a water-scarce country, South Africa is unlikely to be able to rely on traditional small-scale hydro-power stations during dry periods (Department of Energy, 2016:55). However, South Africa does have exploitable ocean-based energy potential (Department of Minerals and Energy, 2003:22; Meyer *et al.*, 2013:54).

8.2.3.1 Ocean wave energy

Our planet's oceans possess an enormous amount of energy in the form of ocean waves (Department of Minerals and Energy, 2003:22). Ocean waves crashing onto South Africa's western and southern shores, especially those concentrated around Cape Point have an estimated energy intensity of between 25 and 50 Megawatts per kilometre (MW/km) and present potential for 56 800 MW along the entire coast, which is considered to be sufficient for exploitation (refer Figure 8.3) (Banks & Shaffer, 2006:39; Department of Minerals and Energy, 2003:22).

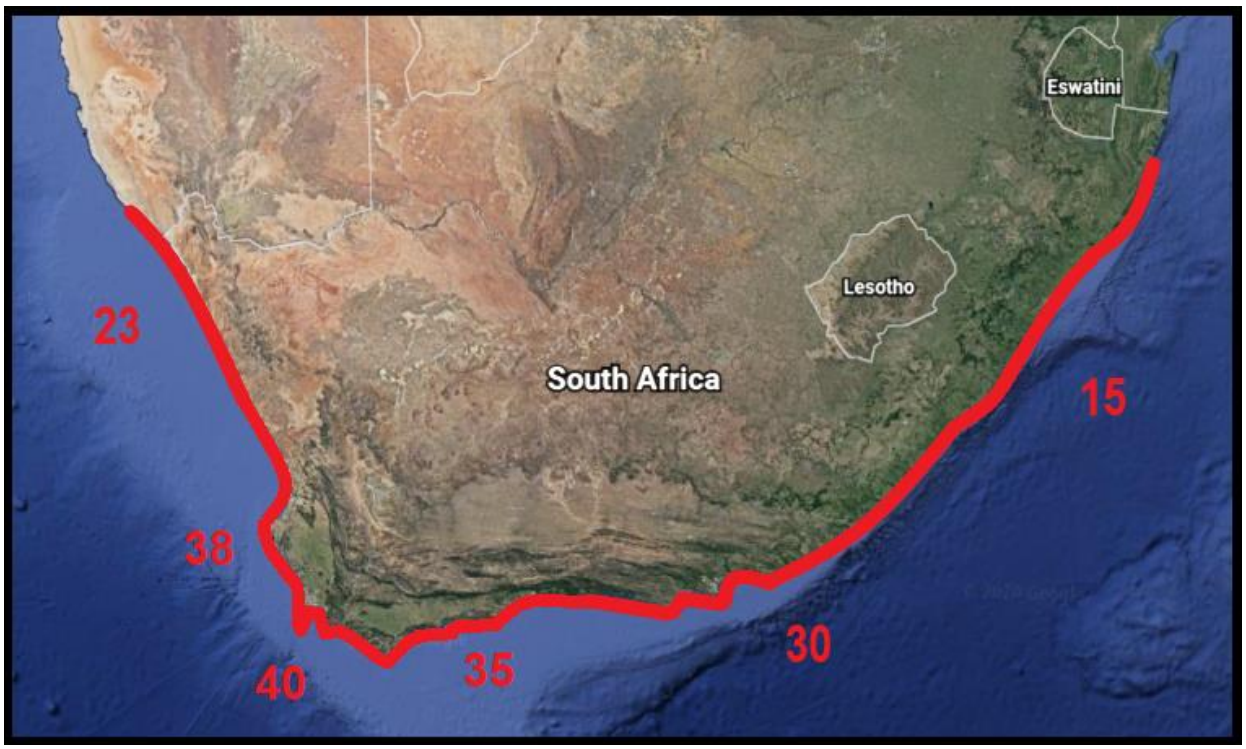

Figure 8.3: Ocean wave energy potential

Source: Van Niekerk (2013:1)

8.2.3.2 Ocean current energy

Ocean currents are streams of fast-moving water located in all the world's oceans and could be used to drive turbines (similar to wind turbines) to generate electricity by converting the kinetic energy in the moving current into mechanical energy and then into electrical energy (Banks & Schäffler, 2006:32). The narrowing of the continental shelf along the east coast of South Africa causes the current to flow close to the coast, and due to the shelf's relative steepness, causes the current to travel at a high velocity (Meyer *et al*., 2013:19). The Agulhas current (refer Figure 8.4) flows at an average velocity of approximately 1.2 metres per second (m/s) and is considered to have sufficient energy potential for exploitation (Van Niekerk, 2013:2; Meyer *et al.*, 2013:28). The majority of the current's energy lies in the upper portion as opposed to the deeper portion, and it has been concluded that the most promising sites for energy extraction are at Cape Morgan and East London (Meyer *et al*., 2013:35-38).

Figure 8.4: Suitable locations for ocean current energy around South Africa
Source: Adapted from Meyer *et al.* (2013:39)

8.2.3.3 Offshore wind energy

Inambao and Cunden (2019:98) conducted a study to determine the potential for offshore wind developments at specific locations around the South African coast. The study took into consideration the average wind speeds, dominant wind direction, shipping routes, environmental conditions and proximity to terrestrial electricity grid infrastructure in South Africa (Inambao & Cunden, 2019:99). The study concluded that four regions are suitable for wind energy extraction (refer Figure 8.5). The first site is located approximately 200 km southeast of Durban harbour and covers an area of approximately 21 000 km² (Inambao & Cunden, 2019:103-104). The second site is located approximately 300 km south of Port Elizabeth and covers an area of approximately 79 000 km² (Inambao & Cunden, 2019:104). The third site is located approximately 290 km south of Cape Town, covering an area of approximately 13 332 km², and the fourth site is located approximately 570 km northwest of Saldanha Bay, covering an area of approximately 37 419 km² (Inambao & Cunden, 2019:105).

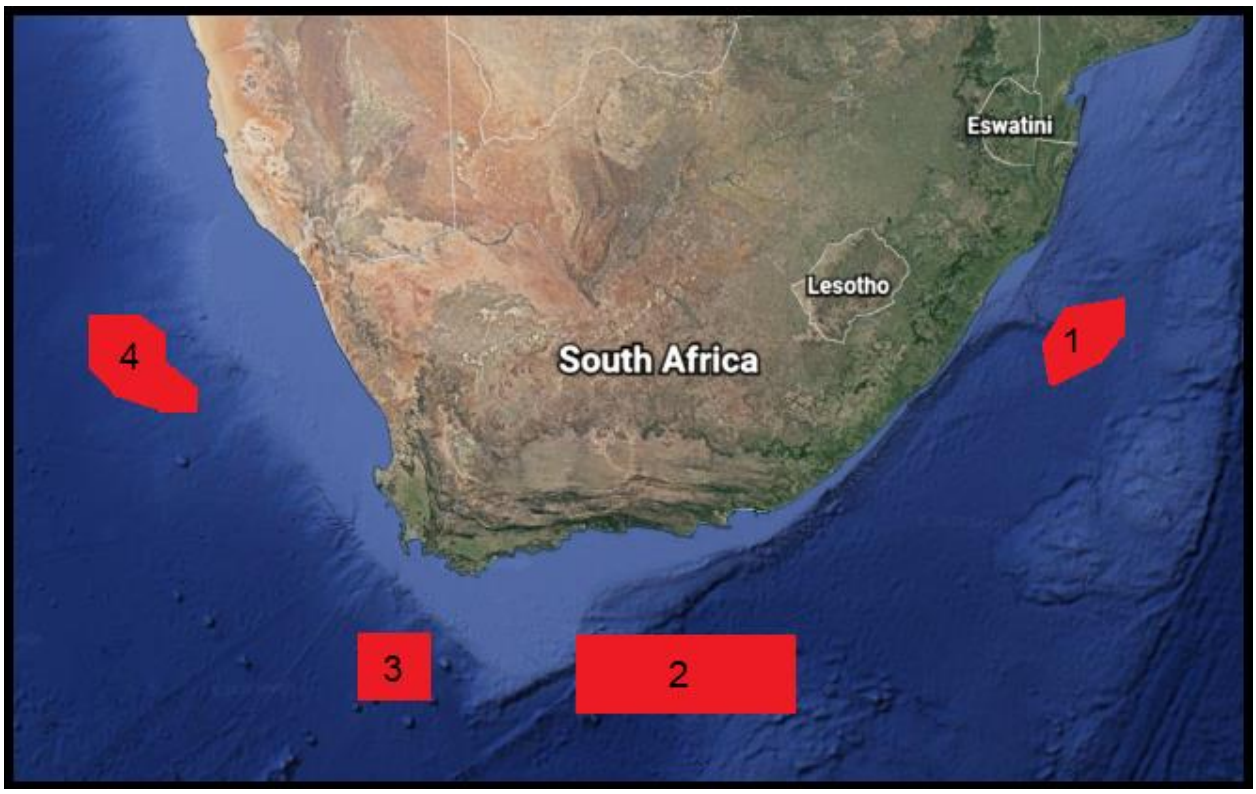

Figure 8.5: Suitable locations for offshore wind energy around South Africa

Source: Adapted from Inambao & Cunden (2019: 103-106).

8.3 Policy overview

The continued use of coal in South Africa will depend on the strength of policy measures that favour lower-emission energy sources (NERSA, 2015:31). The following section will provide an overview of how energy, infrastructure, and spatial planning policies have evolved over the years, as well as how they have been implemented. The policy section will be presented chronologically to enable the reader to witness the progression of policies made, thus illustrating how South Africa got to where it is now and how the current policies can be used.

8.3.1 Energy, infrastructure, and spatial planning policy (1998–2009)

The first piece of legislation that was published by the South African government explicitly mentioning renewable energy was the 1998 White Paper on Energy (Department of Minerals and Energy, 1998). The White Paper on Energy was the primary policy document for the energy sector in South Africa at the time and guided all subsequent energy policies (Department of Energy, 2016:26). In an attempt to establish an environment that is conducive to the development and implementation of renewable energy, the South African government published the White Paper on Renewable Energy in 2003 and was the first policy document wherein a formal national renewable energy production target was set. The target of 1 664 MW (or

10 000GWh) was set to be in place by 2013 (Department of Minerals and Energy, 2003:25). The White Paper highlighted South Africa's potential in ocean-current, ocean-wave, wind, and solar energy (Department of Minerals and Energy, 2003:13-22). The White Paper outlined institutional arrangements for the electricity sector referring to the generation, transmission, and distribution (refer Figure 6.1) of electricity in South Africa, including a National Electrification Programme that makes provision for multiple electricity generators, and a National Energy Regulator (NER) that will have jurisdiction over the entire industry (Department of Minerals and Energy, 2003:30).

During this time the South African government started to adopt an indicative approach to national planning in the form of a Spatial Development Perspective using a multidimensional view of the national space in order to identify areas with potential to be developed over a period of 20 to 30 years and ultimately led to the formulation of the National Spatial Development Perspective (NSDP) in 2003 in an attempt to guide spatial planning and infrastructure investment (The Presidency, 2006). The NSDP focused on the whole of South Africa (albeit without a physical or spatial development plan) and prescribed that infrastructure investments support localities where growth poles (refer Section 3.4.2) can be established to form a gateway to the global economy (Drewes & Van Aswegen 2012:25).

In October 2005, the National Energy Regulator of South Africa (NERSA) was established in terms of Section 3 of the National Energy Regulator Act (NERA) (40 of 2004) as outlined in the White Paper on Renewable Energy, with the mandate to act as a regulator in the electricity sector in terms Section 3 of the Electricity Regulation Act (ERA) (4 of 2006) (NERSA, 2015:3). NERSA's mandate is to issue electricity generation licences and set prices for electricity sold in South Africa (NERSA, 2015:3). NERSA also aims to establish an environment for clean energy development on a national scale (NERSA, 2015:22). In 2006, Cabinet approved a decision allowing the private sector access to the electricity generation sector and the ERA made provision for competitive bidding to the Department of Minerals and Energy (DME) as the purchaser (NERSA, 2015:30). The procurement by the DME took much longer than expected and in 2007 Cabinet decided that Eskom be the sole purchaser of electricity from Independent Power Producers (IPPs) through a Single Buyers Office (SBO) with the responsibility of ensuring that adequate capacity will be available at all times in addition to ensuring that 30 percent of electricity come from IPPs (NERSA, 2015:30). The procurement process was largely unsuccessful, as only a small number of short-term agreements with industrial generators were signed (Eberhard *et al*., 2014:6). Later in 2007, the National Industrial Policy Framework (NIPF) was approved and set out a broad approach to industrial development for South Africa (Department of Trade and Industry, 2007; Drewes & Van Aswegen 2012:25). The NIPF was founded on the belief that the macro-economic policies were in place at the time and

therefore needed to focus on the micro-economic level (Drewes & Van Aswegen 2012:25). The NIPF did not refer to any specific locations, but merely highlighted the importance of infrastructure investments outside traditional growth poles (Robbins, 2008:5).

The White Paper on Energy (1998) was formally enacted by the South African government in 2008. Chapter 2 of The National Energy Act (34 of 2008) specifies that South Africa must seek to minimize the negative environmental impacts associated with energy carriers and ensure universal access to appropriate forms of energy taking into account the available resources and the need for new infrastructure among others. Chapter 3 specifies that the Minister of Minerals and Energy must prepare an Integrated Energy Plan (IEP) with a planning horizon of no less than 20 years considering issues relating to the security of supply, environmental impacts and the optimal use of indigenous energy resources among others.

The first legitimate renewable energy trading platform came in March 2009 when NERSA approved Feed-In-Tariffs (FITs) (NERSA, 2009a:4). Projects needed to produce electricity from naturally occurring and non-depletable sources of energy to qualify for the FIT programme (NERSA, 2009b:10). Costs for connecting to the high voltage grid were borne by the developer in accordance with the Distribution/Transmission Tariff Code (NERSA, 2009a:8). The FITs enabled the Renewable Energy Purchasing Agency (REPA), in this case, the SBO of Eskom to purchase renewable energy from qualifying generators (NERSA, 2009a:8). The National Energy Act (No 34 of 2008) put into effect some of the objectives as outlined in the White Paper on Renewable Energy, particularly those concerned with the management of resources and in March 2011, the Integrated Resource Plan (IRP 2010) was promulgated and set a target of 17 800 MW of renewable energy to be in place by 2030, of which 8 400 MW must come from wind energy, a further 8 400 MW from Solar PV, and the remaining 1 000 MW from Solar Thermal (Lloyd, 2012:12;Department of Energy, 2011:14).

8.3.2 Energy, infrastructure and spatial planning policy (2010–2016)

The expansion of renewable energy technologies was further highlighted to create job opportunities in South Africa when the New Growth Path (NGP) was published on 23 November of 2010 (Department of Economic Development, 2011a:74). The NGP does not have a physical or spatial plan, but does include a Green Economic Accord aimed at mobilizing a strong partnership between the private sector, government, organized labour, and communities to promote the Green Economy. The Green Economy aims to promote the development of renewable energy technologies in South Africa while creating job opportunities in the renewable energy infrastructure manufacturing industry at the same time (Department of Economic Development, 2011b:18).

These commitments were solidified when during the COP17 meeting the DoE and the Department of Trade and Industry (DTI) launched the South African Renewables Initiative (SARi) aimed at establishing financial arrangements necessary for large-scale renewable energy development in South Africa in order to ensure both energy security and economic growth (Department of Trade and Industry, 2011:5). The focus of the initiative was on low-interest loans and financial risk-management strategies, in addition to a funding scheme from both international and domestic sources (Department of Trade and Industry, 2011:10). The aim of the funding scheme was to lower the initial cost of capital for renewable energy developments as well as to assist the FIT programme (Department of Trade and Industry, 2011:11-18).

There was, however, uncertainty as to the nature of the procurement and licensing process of the FIT programme as the legality thereof within the South African public procurement framework was unclear (Eberhard *et al*., 2014:7). In the two years following the launch of the FITs, not a single contract for electricity generation from IPPs was signed, as there was no practical procurement process (Eberhard *et al*., 2014:8). By the end of 2010, a team of consultants looked at possible solutions, but when it became clear that the FIT process could not continue, the external donors opted for a tender-based process as seen successfully implemented by other countries around the world at the time (refer Section 7.2.4) (Eberhard *et al*., 2014:10).

In response to the failure of the FIT programme the DoE, in conjunction with the National Treasury and the Development Bank of Southern Africa (DBSA), launched the Renewable Energy Independent Power Producer Procurement Programme (REI4P) in August 2011 to replace the FIT programme (Eberhard *et al.*, 2014:8). The REI4P's main objective was to provide a platform for private sector investment to develop additional generation capacity whilst diversifying South Africa's energy mix at the same time (Department of Mineral Resources and Energy, 2019a). As per the REI4P, IPPs are expected to bid in order to secure contracts for selling renewable energy in South Africa and bidders are required to bid on tariffs as well as their envisaged contributions towards the identified socio-economic development objectives of the DoE (IPP Office, 2016). Tariffs between the buyer and the IPP are set in the Power Purchase Agreement (PPA) to be entered into between Eskom and the project company of the preferred bidder (IPP Office, 2016). The PPAs are to be signed by the IPP (as the seller of electricity) and Eskom (as the buyer of electricity) and must stipulate that contracts are valid for 20 years from the Commercial Operation Date (COD) (Eberhard *et al*., 2014:11).

The South African government was in a long-term planning phase during this time and subsequently, the National Planning Commission (NPC) was tasked to prepare a long-term plan for South Africa up to 2030. The NPC published a Diagnostic Report in June 2011 and after a

round of public participation, the draft National Development Plan (NDP) was published in November 2011 (The Presidency, 2012a:25). The short time lapse between the NGP (which was released in 2010) and the NDP created some uncertainty as to the significance of each and the relationship between the two strategic plans. The NDP clarifies this by stating that the NDP is a country vision towards the year 2030 whereas the NGP is a government strategy in pursuit of the country's vision and despite the order of coming into being, the NDP has come to take precedence over the NGP (The Presidency, 2012a:117).

One of the NDP's Enabling Milestones for achieving the vision is to produce sufficient electrical energy to support a growing economy while reducing carbon emissions per unit of power by approximately one-third at the same time (The Presidency, 2012a:34). The NDP subsequently prescribes that the constraints on economic growth, energy generation, and distribution should be removed (The Presidency, 2012a:64), off-grid electricity infrastructure should be provided to isolated communities to ensure that 100 percent of South Africans have access to electricity by 2030, at least 20 000 MW of renewable electricity should be procured by 2030, and 11 000 MW of aging coal-fired power stations should be decommissioned by 2030 (The Presidency, 2012a:177). The NDP proposes that power management, procurement and power purchasing be moved from Eskom's Transmission System Market Operator (TSMO) and Single Buyers Office (SBO) to an Independent Systems and Market Operator (ISMO) to eliminate conflicts of interest and to accelerate the procurement and delivery of renewable energy in South Africa (The Presidency, 2012a:66). The NDP does not include a national spatial plan but does propose that a National Spatial Framework (NSF) be developed to unlock development potential and guide infrastructure investment among others (The Presidency, 2012a:277).

In reaction to the NDP targets relating to GHG emissions reduction, the Department of Environmental Affairs (DEA) published the National Climate Change Response White Paper (NCCRWP) in 2012. The South African government through the White Paper aimed to create a policy framework that would assist in reducing the country's carbon footprint by means of prioritizing among others the implementation of the IRP (2010) (Department of Environmental Affairs, 2012:15). The government recognized that the biggest gains would be made by focusing on the largest emitter of GHGs in the country i.e. the energy sector (Department of Environmental Affairs, 2012:26). The NCCRWP also aims to increase the use of renewable energy beyond the 17 800 MW as specified in the IRP (2010) by making use of the South African Renewables Initiative (SARi) led by the Department of Public Enterprise and funded by the dti (Department of Environmental Affairs, 2012:31).

In 2011, Cabinet established the Presidential Infrastructure Coordinating Committee (PICC) to formulate a plan to stimulate job creation based on infrastructure investment (The Presidency,

2012b:7). The PICC's mandate is to do strategic infrastructure planning and ensure the effective implementation of large-scale projects (The Presidency, 2012b:4). The PICC drafted a National Infrastructure Plan (NIP) the was adopted by the South African government in 2012 (The Presidency, 2012b:6). The NIP contained 18 Strategic Integrated Projects (SIPs) of which three relate to energy infrastructure (The Presidency, 2012b:17). SIP 8 sets out support for green energy infrastructure investment on a national scale through a variety of renewable energy options as stipulated in the IRP (2010) (The Presidency, 2012b:20). SIP 9 and SIP 10 propose an increase in electricity generation capacity as well as the expansion of electricity transmission and distribution infrastructure respectively (The Presidency, 2012b:20).

In August 2013, the Spatial Planning and Land Use Management Act (SPLUMA) (16 of 2013) was passed (repealing the PPA and DFA) to provide a framework for spatial planning and land use management in South Africa. Chapter Four of SPLUMA outlines the preparation of Spatial Development Frameworks (SDFs) wherein it states that each of the three spheres (national, provincial, and local) of government must prepare an SDF to interpret and represent the spatial vision for their area of jurisdiction, guide strategic and statutory planning decisions, as well as to indicate desired land-use patterns and priority areas for investment among others. Similar to the Physical Planning Act (PPA), but unlike the Development Facilitation Act (DFA), the regional level is defined as a separate sphere for which an SDF can be prepared i.e. the Regional Spatial Development Framework (RSDF). The term 'region' is defined in SPLUMA as "a circumscribed geographical area characterized by distinctive economic, social or natural features which may or may not correspond to the administrative boundary of a province or provinces or a municipality or municipalities". The Minister of Rural Development and Land Reform may, after consulting with the relevant Premier and Municipal Council, declare any geographic area of the Republic a region for the purpose of adopting an RSDF. It must be noted that while national, provincial, and local SDFs are mandatory, an RSDF is discretionary and only prepared for a specific purpose (Department of Rural Development and Land Reform, 2014:51). As this study will make recommendations [partly] based on an RSDF, the process for preparing an RSDF will be summarized briefly. The process consists of six stages (Department of Rural Development and Land Reform, 2014:54-61): During the first stage the policy context is established; during the second stage the RSDF goals and objectives are formulated; during the third stage the regional context and issues are established; during the fourth stage the spatial proposals are formulated; during the fifth stage the implementation framework is formulated; and during the sixth stage the RSDF is approved.

In addition to the IRP, there is a separate plan directing South Africa's energy sector known as the Integrated Energy Plan (IEP). The IEP was adopted in 2016 and the relationship between the two energy policy documents is complementary in nature and can be described as follows

(Department of Public Enterprises, 2019:8): The IEP is the primary energy plan for South Africa whereas the IRP lays out specific details in terms of how the IEP must be implemented. Both the IRP and the IEP make projections relating to energy supply and demand until 2050 (Department of Public Enterprises, 2019:8). The aim of the IEP is to guide the selection and investment strategies of appropriate technologies (including alternative energy sources) to meet South Africa's current and future energy demand (Department of Energy, 2016:23). It is worth mentioning that while the IEP does briefly mention energy infrastructure, there are no infrastructure plans based on supply and demand or existing infrastructure at specific geographic locations. According to the IEP solar and wind technologies should play a significant role in achieving the IRP targets (Department of Energy, 2016:165-166).

Accordingly, the DEA in collaboration with the Council for Scientific and Industrial Research (CSIR) conducted Strategic Environmental Assessments (SEAs) in terms of the National Environmental Management Act (107 of 1998) to determine the feasibility of wind and solar technologies in South Africa by taking into consideration the economic, social and environmental impacts of wind and solar technologies at specific geographic locations that were labelled as Renewable Energy Development Zones (REDZs) (Department of Environmental Affairs, 2016:75). In February 2016, Cabinet approved eight REDZs and five Power Corridors designated as priority areas for renewable energy investment (Department of Environmental Affairs, 2016:75). The SEAs commenced with positive mapping exercises that included areas with an abundance of existing wind and solar energy sources, close proximity to, and access to Power Corridors in addition to related technical criteria (CSIR, 2019). This was followed by negative mapping exercises that excluded areas with environmental sensitivity and that are prone to possible environmental degradation as a result of constructing large-scale wind and/or solar PV facilities (CSIR, 2019). The second phase of SEAs for Wind and Solar PV was conducted in 2019 resulting in three additional REDZs (see Figure 8.6) in support of the IRP (2019) (CSIR, 2019).

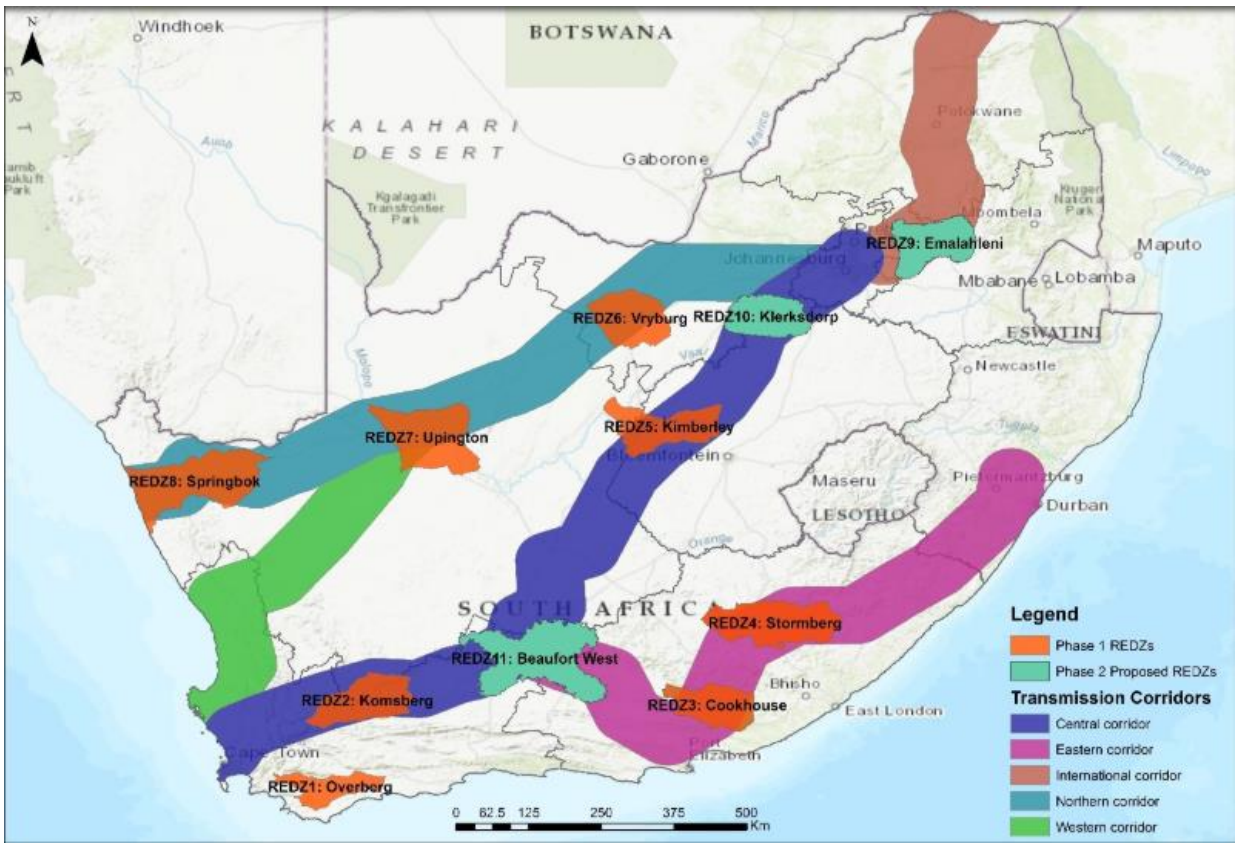

Figure 8.6: Renewable Energy Development Zones (REDZs)

Source: CSIR (2019)

From Figure 8.6 it is clear that no ocean-based energy potential studies were carried out during the preparation of the REDZs, despite the abundance of ocean energy potential as highlighted in the White Paper on Renewable Energy and subsequent research publications (Department of Minerals and Energy, 2003:22). The National Spatial Development Framework (NSDF) (refer Section 8.3.3) also highlights the importance of exploiting the ocean economy to achieve regional and national economic development (Department of Planning, Monitoring and Evaluation, 2019:127). As this study will make recommendations on both terrestrial and marine renewable energy development, it is necessary to clarify the purpose and functionality of South Africa's newly adopted Marine Spatial Planning Framework (MSPF) and Marine Spatial Planning Act (MSPA) (16 of 2018).

8.3.3 Energy, infrastructure and spatial planning policy (2017–2020)

The MSPA (16 of 2018) provides a framework for marine spatial planning via Marine Spatial Plans (MSPs) as well as the institutional arrangements necessary for their implementation. According to the MSPA, South Africa has an Exclusive Economic Zone (EEZ) totalling 1 540 000 km² (refer Figure 8.7), which may be utilized for economic activities such as industrial-scale energy generation, among others. The MSPA specifies that the South African ocean economy must be managed through coordinated and integrated planning guided by

principles such as the sustainable use of ocean resources and the identification of economic opportunities. The marine spatial planning policy formulation process began with the development of an MSPF which will guide the development of Marine Areas Plans (MAPs) to be implemented and evaluated and finally reviewed in terms of Section 14 of the MSPA. According to the MSPF, which was published on 26 May 2017, MAPs may be developed and overseen by the National Working Group on Marine Spatial Planning (NWGMSP) (which consists of competent officials from various state departments) and approved by the Directors General Committee on Marine Spatial Planning (DGCMSP) and the Ministerial Committee on Marine Spatial Planning (MCMSP) (Department of Environmental Affairs, 2017:47). It is important to note that MAPs are integrated sustainable development plans; as such, they are distinct from sectoral development plans (Department of Environmental Affairs, 2019:70).

While the MSPA will pertain to a variety of marine-based economic sectors and uses, the MSPF explicitly highlights that ocean energy derived from waves, tides, currents, and off-shore wind can play a significant role in contributing to South Africa's economy once these technologies become economically viable (Department of Environmental Affairs, 2017:43). In order to simplify the implementation of marine spatial planning, South Africa's ocean space will be divided into smaller geographic areas known as Marine Planning Areas (MPAs) (refer Figure 8.7) (Department of Environmental Affairs, 2019:71) including the following:

1. the Western Marine Planning Area
2. the Southern Marine Planning Area
3. the Eastern Marine Planning Area
4. the Prince Edward Islands Marine Planning Area

For each of the four MPAs, a MAP will be developed for which a spatial management system is proposed consisting of (a) general development guidelines, (b) sectoral development guidelines, and (c) a zoning scheme (Department of Environmental Affairs, 2019:73). The general development guidelines will be broad enough to apply to all MPAs and should be aligned with terrestrial Spatial Development Frameworks (SDFs) and Integrated Development Plans (IDPs), whereas sectoral development guidelines will be more specific to each sectoral marine activity with the aim of achieving the sectoral objectives while promoting the sustainable development of each sector and will apply throughout the specific MPA (Department of Environmental Affairs, 2019:73-74). The zoning schemes are based on terrestrial zoning schemes in that they will permit or prohibit specific uses (Department of Environmental Affairs, 2019:76). Each zoning scheme will achieve this by prioritizing specific uses in terms of three types of uses, namely: (1) primary uses which will be given priority in the zone in question; (2) consent uses which may accompany the primary use should there be no conflict; and (3)

prohibited uses that are not allowed (Department of Environmental Affairs, 2019:76). Zones are delineated based on the natural conditions for economic opportunities and the distribution of key resources among others (Department of Environmental Affairs, 2019:78). As such the following zones are proposed which are applicable to this study (Department of Environmental Affairs, 2019:82-83):

- Mining Zones
- Underwater Infrastructure Zones

The DEA is the lead authority on marine spatial planning and hence the preparation of MAPs (Department of Environmental Affairs, 2017:46). As this study will make recommendations [partly] based on MAPs, the process for preparing a MAP will be summarized briefly. The process for developing a MAP consists of eight stages (Department of Environmental Affairs, 2017:45-51): During the first stage the relevant data are collected; during the second stage the MAP goals and objectives are established; during the third stage the various spatial scenarios are envisaged; during the fourth stage the management actions are established; during the fifth stage the draft MAP is presented; during the sixth stage the MAP is reviewed and approved; during the seventh stage the MAP is implemented; and during the eight stage the implemented MAP is monitored and evaluated.

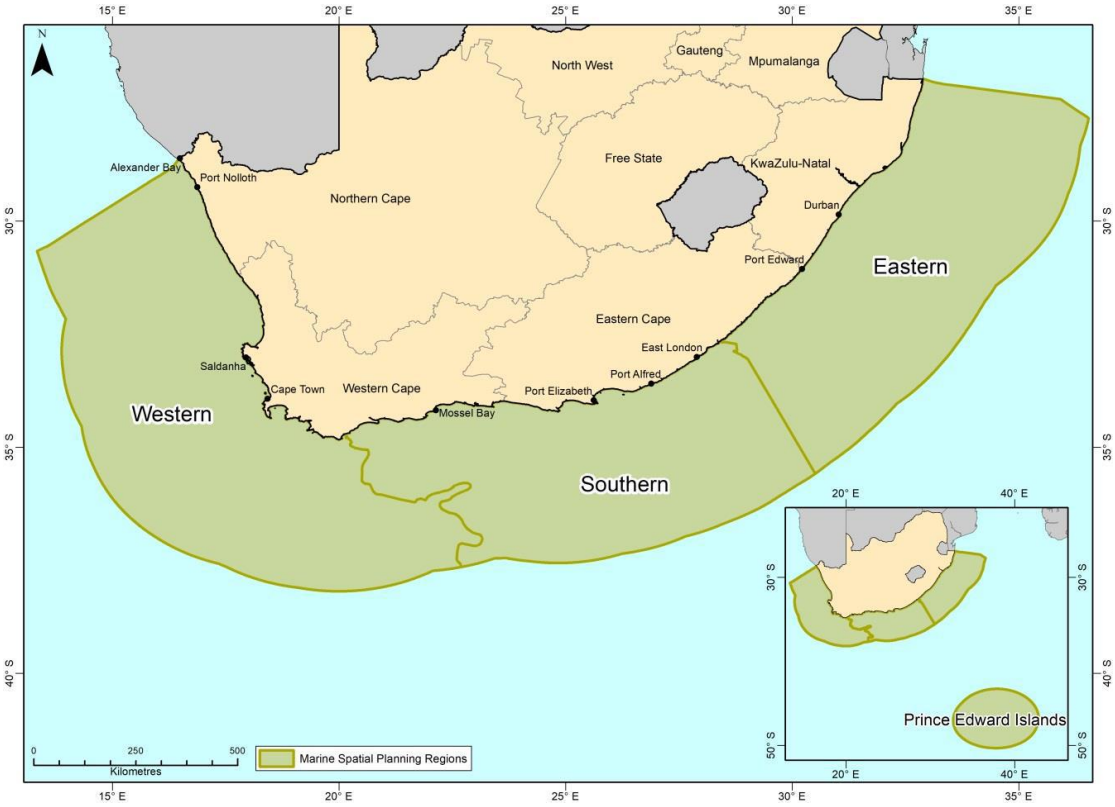

Figure 8.7: South African marine planning areas

Source: Department of Environmental Affairs (2019:72)

To assist the NWGMSP with the preparation of MAPs, a dedicated team known as the Marine Area Planning Group (MAPG) will be established (Department of Environmental Affairs 2017:47). After a round of internal review, the MAP will be presented to the MCMSP via the DGCMSP before the NWGMSP oversees the implementation of the approved MAP (Department of Environmental Affairs, 2017:52).

As called for in chapter 8 of the NDP and provided for in the SPLUMA (16 of 2013), a National Spatial Development Framework (NSDF) was prepared for South Africa by the Department of Planning, Monitoring and Evaluation in collaboration with the Department of Rural Development and Land Reform. Section 12(1) of the SPLUMA (16 of 2013) prescribes that the NSDF must represent the national spatial vision for South Africa; represent the integration of national sector policies and plans; guide planning and development across all sectors of government within the national sphere as well as between the three spheres; and indicate priority areas for investment and land development, among others. Section 12(2)(a) of the SPLUMA (16 of 2013) specifies that the three spheres of government must align their spatial plans to ensure coherent spatial planning. Section 12(3) and (6), Section 13(3) and Section 14 of the SPLUMA (16 of 2013) collectively specify that the NSDF must consider, coordinate, give spatial expression and give effect to national development policies, plans and programmes that impact on spatial planning, land development and land use management, as well as ensuring the implementation of priority spatial areas, including RSDFs.

Part three of the NSDF provides an overview of significant national spatial development opportunities and challenges and acknowledges therein that South Africa is too heavily reliant on coal-based energy generation and subsequently prescribes that long-term spatial and infrastructure planning should be cognisant of where renewable energy has exploitable potential (refer Figure 8.8) and take advantage of the opportunities presented by the Southern African Development Community (SADC) in terms of energy generation and trade (Department of Planning, Monitoring and Evaluation, 2019:65-66, 80).

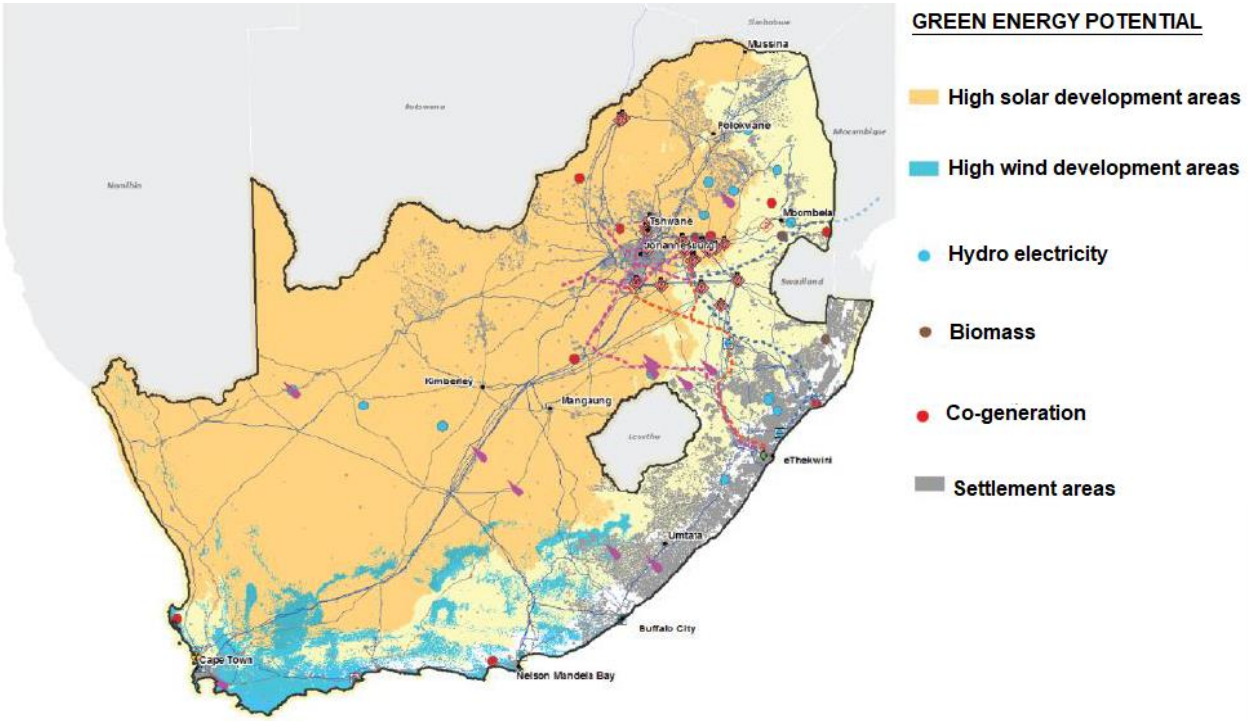

Figure 8.8: Green energy potential South Africa

Source: Department of Planning, Monitoring and Evaluation (2019:70)

Part four represents; the national spatial development vision, the necessary shifts that need to be made in the national spatial development logic based on NDP and SPLUMA principles, puts forward six national spatial development levers to give spatial expression to the spatial development vision, and provides a set of five national spatial outcomes to achieve the NDP and SPLUMA objectives and ultimately realise the national spatial development vision of South Africa. Part five aims to formulate an ideal pattern for national spatial development, commencing with the identification of five NSDF sub-frames, which is followed by five national spatial action areas for government and the private sector in order to achieve the ideal national spatial development pattern. Part six outlines the implementation measures, approach, and actions of the NSDF, as well as the various role-players involved in this process. The following section will discuss the relevant information in parts four, five and six in more detail.

One of the necessary shifts that needs to be made is a greater focus, awareness and quantification of South Africa's natural resource base in order to affect the sustainable use and protection of such resources (Department of Planning, Monitoring and Evaluation, 2019:87). It is also necessary to move away from the use of a finite and ecologically-unfriendly resource extraction economic model and pursue the establishment of regional development anchors in rural areas in order to achieve regional-rural development (Department of Planning, Monitoring and Evaluation, 2019:88). What spatial development planning is concerned, there is a need to ensure greater coordination, collaboration and integration of spatial development planning both within and between spheres and sectors of government by making use of spatial targeting (refer

Section 4.5.1.3) policies based on our natural resource-base to benefit not only the regional economy but also the national economy (Department of Planning, Monitoring and Evaluation, 2019:89).

To support the above-mentioned shifts, a series of national spatial development levers were developed, which are aimed at a series of national spatial development outcomes that will ultimately lead to the ideal national spatial development pattern. National spatial development lever three refers to the establishment of productive rural regions by making use of 'functional rural regions' (refer Section 3.2.1) (Department of Planning, Monitoring and Evaluation, 2019:89). This lever is aimed at achieving national spatial outcome four, which states that productive rural regions must be supported by sustainable resource economies based upon the wise use, management and protection of nationally significant natural resources, among others (Department of Planning, Monitoring and Evaluation, 2019:101).

National spatial development lever five refers to the establishment of a national ecological infrastructure system in order to ensure the sustainable use of natural resources for the just access to such resources for current and future generations by means of their inclusion in all provincial, regional and municipal SDFs (Department of Planning, Monitoring and Evaluation, 2019:98). This lever is aimed at achieving national spatial outcome five, which states that national ecological infrastructure must be protected and well managed in officially protected national and provincial parks and ocean areas (Department of Planning, Monitoring and Evaluation, 2019:101-102).

National spatial development lever six refers to the use of a national transport, communication and energy infrastructure network in order to ensure a sustainable economy, by taking into consideration the high costs associated with the upgrading and maintenance of such networks which necessitates the careful planning of where such infrastructure must be built with specific mention of renewable energy generation, storage and distribution (Department of Planning, Monitoring and Evaluation, 2019:98-99). This lever is aimed at achieving national spatial development outcome three which states that national energy-distribution infrastructure (among others) must be expanded, upgraded and maintained to ensure national energy supply and distribution (Department of Planning, Monitoring and Evaluation, 2019:100-101).

The ideal pattern for national spatial development is detailed out in five 'sub-frames' namely: (1) Inter-Regional Connectivity, (2) The National System of Nodes and Corridors, (3) The National Resource Economy Regions, (4) The National Movement and Connectivity Infrastructure System, and (5) the National Ecological Infrastructure and Natural Resource System. These five sub-frames were developed by taking into consideration the NDP and SPLUMA principles as well as the national spatial development vision and logic by making use of the aforementioned

national spatial development levers in pursuit of the national spatial development outcomes (Department of Planning, Monitoring and Evaluation, 2019:108). The ideal national spatial development vision and sub-frames provide a national spatial schema that directs infrastructure investment and strategic spatial development decisions by government and the private sector to optimise 'place-based' (refer Section 4.5.1) potential (Department of Planning, Monitoring and Evaluation, 2019:108). The sub-frames that are relevant to this study will be discussed briefly in the following section.

Sub-frame one, i.e. Inter-Regional Connectivity, refers to the linkages that relate to energy supply (among others) between regions on a supra-national scale, i.e. between regions in South Africa with regions in the SADC (Department of Planning, Monitoring and Evaluation, 2019:112). These linkages enable South Africa to buy electricity from and sell electricity to neighbouring SADC countries when there is a shortage or excess of supply, respectively, as highlighted in the SADC Energy Sector Plan (Department of Planning, Monitoring and Evaluation, 2019:112). Sub-frame three, i.e. National Resource Economy Regions, refers to the delineation and development of productive, functional rural regions by making sustainable use of the natural resources (among others) they possess (Department of Planning, Monitoring and Evaluation, 2019:123). In terms of the third sub-frame, the NSDF highlights the potential contribution of solar- and wind-energy generation as well as the oceanic regions to contribute towards regional and national economic development (Department of Planning, Monitoring and Evaluation, 2019:124, 128-129). Sub-frame four, i.e. National Movement and Connectivity Infrastructure Systems, refers to the expansion and maintenance of energy transmission networks (among others) and their ability to accommodate new-generation capacity (Department of Planning, Monitoring and Evaluation, 2019:131).

Building on the above-mentioned sub-frames, the NSDF identifies five National Spatial Action Areas (NSAA) (refer Figure 8.9) to serve as a catalyst for achieving the ideal spatial pattern (Department of Planning, Monitoring and Evaluation, 2019:142). NSAA one highlights National Transformation Corridors for which an RSDF is proposed over a five-year horizon aimed at achieving regional development by making use of the marine economy, among others (Department of Planning, Monitoring and Evaluation, 2019:175). NSAA five highlights the Arid Innovation Region for which an RSDF is proposed over a five-year horizon aimed at making full use of this region's potential for renewable energy generation and the marine economy, among others (Department of Planning, Monitoring and Evaluation, 2019:178).

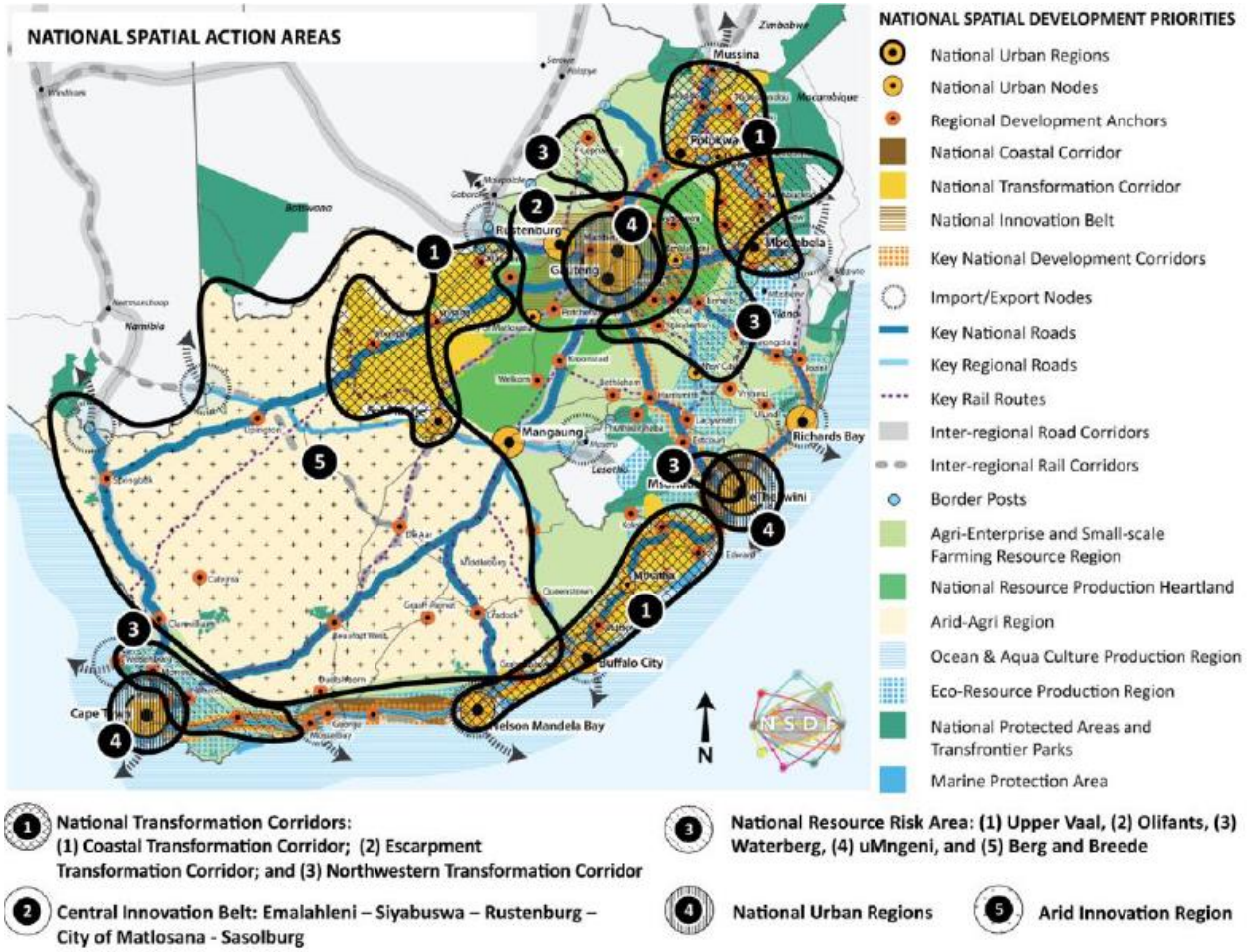

Figure 8.9: National spatial action areas (NSAAs)

Source: Department of Planning, Monitoring and Evaluation (2019:145)

In October 2019, an updated IRP was published by the DMRE wherein the envisaged energy mix to ensure sufficient electricity supply for South Africa was outlined. The IRP (2019) includes several changes from the IRP (2010) such as; requiring an additional 14.4 GW of wind power and 6.0 GW of Solar PV power by 2030, declining renewable energy technology costs as well as extending the study period from 2030 to 2050 (Department of Mineral Resources and Energy, 2019b:8-10). Eskom subsequently published their annual Transmission Development Plan (TDP) (2021-2030) in October 2020 with the intention of mapping out medium- to long-term electricity grid infrastructure planning aimed at accommodating the envisaged additional generation capacity, with specific reference to the IRP (2019) and IPPs (refer Figure 8.10) (Eskom, 2020:36-55).

Even though the IRP indicates how much renewable energy needs to be connected, it does not indicate specific geographic locations as to where the energy will be generated as the location of new REI4P projects are only announced after preferred bidders have been approved, which makes it difficult to formulate plans for grid expansion, especially long transmission lines and new substations which could take up to 10 years from inception to commissioning (Eskom,

2018:113-115). The components of grid infrastructure expansion that lead to this long completion time includes planning, environmental authorisation, land procurement and construction (Eskom, 2018:115). Contrasting to this, is the relatively short time necessary to finalize IPP plant development meaning that grid scenario planning needs to be done to determine locations for grid infrastructure expansion (Eskom, 2018:115).

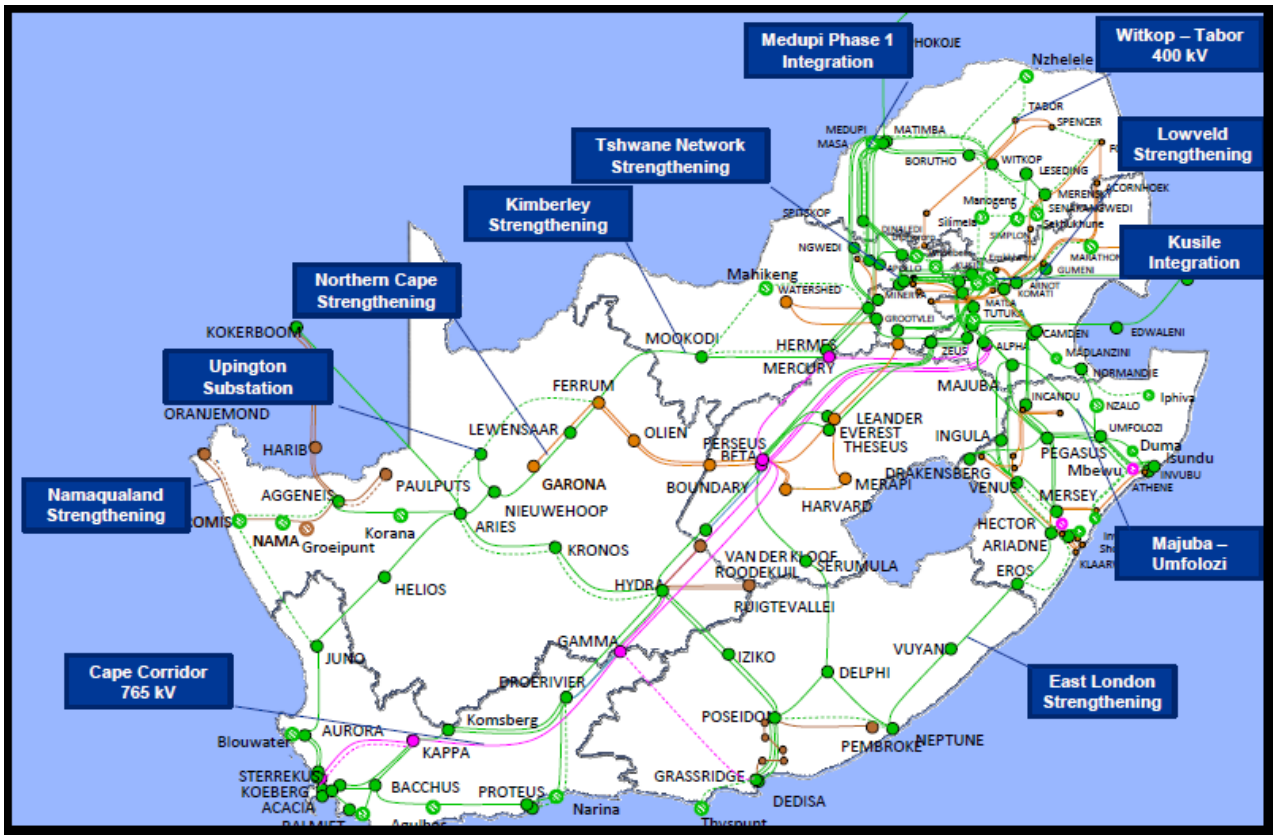

Figure 8.10: Medium- to long-term transmission expansion plans for IPPs

Source: Eskom (2020:10)

The scenario planning process is made even more difficult due to the fact that the initial rounds of the REI4P have consumed the majority of the grid capacity in areas with high renewable energy potential, especially in the Northern Cape, Western Cape, and Eastern Cape Provinces, necessitating substantial grid expansion requirements to further accommodate IPPs in these provinces (Eskom, 2018:113-115). The locations of existing renewable energy generation plants, combined with information from independent studies relating to historical IPP applications, discussions with the DoE and REDZ studies are used in order to estimate locations and grid capacity volumes for the medium to long term, i.e. from 2023 to 2028 (Eskom, 2018:116-118). The scenario planning has revealed that the Northern Cape, Western Cape, and Eastern Cape requires the majority of new grid infrastructure to not only accommodate the envisaged renewable energy generation plants in these provinces, but also to enable them to evacuate additional electrical power generated from renewables due to these provinces' likelihood of becoming net exporters of power (Eskom, 2018:122-123).

In order to advance power trading, the SADC region has steadily progressed in connecting the various generation plans by means of interconnectors and the transmission system which has led to the establishment of the Southern African Power Pool (SAPP) trading platform enabling Member States to buy and sell energy from one another (SADC, 2018:14). The primary policy document in this regard is the SADC Energy Protocol (1996), as well as supporting documents such as the SADC Regional Infrastructure Development Master Plan – Energy Sector (2012) and the SADC Industrialization Strategy and Roadmap (2015) (SADC, 2018:19).

8.4 Conclusion

Studies have shown that South Africa is richly endowed with naturally occurring sources of energy that can be harvested to fuel the country's overall development and in particular, those regions where the energy sources occur while simultaneously reducing the harmful effects of GHG emissions that come with burning fossil fuels for energy generation. South Africa is particularly blessed with solar energy as this source ranks among the highest in the world, especially in the western and central regions of the country. South Africa is also blessed with a considerable amount of wind energy, especially in the coastal provinces of the Western and Eastern Cape. Despite not being fully ready for commercial exploitation at this point in time due to high technology costs, the world's oceans contain a vast amount of energy that can be harvested, and South Africa is blessed with a variety of ocean-based energy sources, particularly ocean-current energy within the Agulhas Current flowing along the east coast, ocean-wave energy concentrated around Cape Point and offshore wind energy in both the Atlantic and Indian Oceans.

The first piece of national legislation in South Africa that dealt exclusively with energy was the 1998 White Paper on Energy which guided all subsequent energy policies. In 2003, the growing need to transition to a low-carbon energy sector saw the publication of the White Paper on Renewable Energy and set a national renewable energy target of 10 000 GWh (or 1 664 MW) to be in place by 2013 and proposed the establishment of a National Energy Regulator (NER) to manage the energy market. To guide spatial planning and energy infrastructure investments that can support localities where growth poles can be established, the National Spatial Development Perspective (NSDP) was formulated in 2003.

In 2005, the National Energy Regulator of South Africa (NERSA) was established and spelled the beginning of private sector involvement in the energy sector by means of clean energy generation. Private energy generators were allowed to sell electricity to the Department of Minerals and Energy (DME) but when this procurement process failed, Eskom was allowed to buy privately generated electricity through its Single Buyers Office (SBO). This procurement

process also failed largely due to Eskom's fear of losing their monopoly and as a result, NERSA introduced Feed-In-Tariffs (FITs) in 2009. The White Paper on Energy was formally enacted in 2008; Chapter 2 of The National Energy Act (34 of 2008) specifies that South Africa must seek to minimize the negative environmental impacts associated with energy carriers and ensure universal access to appropriate forms of energy by taking into account the available resources and the need for new infrastructure among others. Chapter 3 of the Act specifies that the Minister of Minerals and Energy must prepare an Integrated Energy Plan (IEP) with a planning horizon of no less than 20 years considering issues relating to the security of supply, environmental impacts and the optimal use of indigenous energy resources which subsequently led to the promulgation of the Integrated Resource Plan (IRP) in 2010 that set a target of 17 800 MW of renewable energy capacity to be in place by 2030.

The New Growth Path (NGP) was published in 2010 and through its Green Accord aimed to grow the renewable energy industry in South Africa to create sustainable jobs, and the National Development Plan (NDP) published in 2011 increased the 2030 renewable energy target set in the IRP (2010) from 17 800 MW to 20 000 MW, in addition to prescribing that that the constraints on energy generation, and distribution should be removed. The NDP also proposed that Eskom's Single Buyers Office (SBO) be replaced with an Independent System and Market Operator (ISMO) among others. The National Infrastructure Plan (NIP) adopted in 2012 sought through Strategic Integrated Projects (SIPs) 8, 9, and 10 to support investment in green energy generation infrastructure as well as the necessary transmission and distribution infrastructure, respectively. It was also during this time that the FIT programme was replaced with a tender-based system as seen successfully implemented in other countries around the world. The Renewable Energy Independent Power Producer Procurement Programme (REIP4) finally allowed Independent Power Producers (IPPs) to participate in the energy market as this procurement programme was successfully implemented.

Due to important shortcomings of the Development Facilitation Act (DFA)(67 OF 1995), the South African government passed the Spatial Planning and Land Use Management Act (SPLUMA)(16 of 2013) to provide a policy framework for national spatial planning and land use management. The SPLUMA critically makes provision for the Minister of Rural Development and Land Reform to declare any area in the Republic a region for the purpose of establishing a Regional Spatial Development Framework (RSDF) that will guide strategic development-orientated decision making in that area. In accordance with the National Energy Act (34 of 2008) the IEP was promulgated to guide South Africa's future energy landscape using related energy policies and, where necessary, provide a framework wherein such policies can be implemented. According to the IEP, solar and wind technologies should play a significant role in achieving the IRP targets.

In 2016, the Department of Environmental Affairs (DEA) and the Council for Scientific and Industrial Research (CSIR) identified eight Renewable Energy Development Zones (REDZs) wherein renewable energy development (particularly wind and solar) is encouraged through a less stringent application process, which was subsequently increased to eleven REDZs in 2019. The identification process commenced with a positive mapping exercise that included areas with a high renewable energy resources potential combined with close proximity to the national power corridors, which was followed by a negative mapping exercise that excluded areas with sensitive environments.

In line with international trends, the South African government adopted the country's first marine spatial planning legislation in the form of the Marine Spatial Planning Act (MSPA) (16 of 2018) and the Marine Spatial Planning Framework (MSPF). The MSPA provides a framework for marine spatial planning via Marine Spatial Plans (MSPs) as well as the institutional arrangements necessary for their implementation. The aforementioned policies will make it possible to legitimize ocean-based renewable energy developments by means of Marine Area Plans (MAPs) located in South Africa's Exclusive Economic Zone (EEZ). In order to simplify the implementation of marine spatial planning, South Africa's ocean space is divided into smaller geographic areas known as planning areas including the following: (1) Western Marine Planning Area, (2) Southern Marine Planning Area, (3) Eastern Marine Planning Area, and (4) the Prince Edward Islands Marine Planning Area.

For each of the four Marine Planning Areas, a MAP will be developed for which a spatial management system is proposed consisting of (a) general development guidelines, (b) sectoral development guidelines, and (c) a zoning scheme. The general development guidelines will be broad enough to apply to all Marine Planning Areas and should be aligned with terrestrial plans, i.e. SDs and IDPs, for example, whereas sectoral development guidelines will be more specific to each sectoral marine activity with the aim of achieving the sectoral objectives and will apply throughout the specific Marine Planning Area. Each zoning scheme will organize uses in terms of three types of uses, namely (1) primary uses, (2) consent uses, and (3) prohibited uses. Zones are delineated based on the natural conditions for economic opportunities and the distribution of key resources among others. The following zones are applicable to this study namely (1) Mining Zones, and (2) Underwater infrastructure Zone.

The NSDF highlights that long-term spatial and infrastructure planning must consider future renewable energy developments as well as the opportunities presented by the SADC in terms of energy generation and trade. In order to realize the NSDF vision, South Africa's natural resources need to be more effectively protected and managed, there also needs to be a shift towards the use of renewable resources to achieve regional development by making use of

spatial targeting planning policies that are coordinated across the three spheres of government. To achieve sustainable regional development, rural regions need to become more productive by delineating functional regions that operate on the wise use of indigenous resources such as solar, wind and the oceans among others. According to the NSDF, South Africa needs to invest in building, upgrading, and expanding national energy infrastructure to accommodate new generation capacity as well as for intra- and international trade. The NSDF, once adopted, will become South Africa's apex spatial plan, and must therefore inform all subsequent spatial plans both on national and sub-national scales by means of provincial, regional, and municipal SDFs.

In 2019, an updated version of the IRP was published with several noteworthy changes from the IRP (2010); most importantly, the increased volume of renewable energy (particularly from wind and solar) that must be procured. This has necessitated the planning of grid infrastructure expansion, which was subsequently undertaken by Eskom in their Transmission Development Plan (TDP) for 2021–2030. The process involved scenario planning which has revealed that the majority of new grid infrastructure must be located in the Northern Cape, Eastern Cape and Western Cape Provinces, which is planned to not only accommodate new generation capacity in these provinces, but also make it possible to export excess electricity. To export electricity to neighbouring countries, the SADC region has established the Southern African Power Pool (SAPP) as a trading platform.

In the following chapter, a synthesis of the most important findings will be presented to provide a clear picture of the lessons that have been learned during the course of this study. Thereafter, the proposed policy framework that will be able to facilitate renewable energy deployment will be presented.

CHAPTER 9: SYNTHESIS AND PROPOSALS

9.1 Introduction

In the previous chapter, regions within South Africa where renewable energy sources have sufficient potential for exploitation were identified, a policy overview discussing spatial and energy planning policies that can facilitate renewable energy deployment was carried out, in addition to highlighting the energy infrastructure expansion plans aimed to accommodate additional renewable energy capacity. This chapter is aimed towards achieving the overall research aim of this study, i.e. to formulate an integrated policy framework in which regional development can occur through renewable energy deployment. The rest of the chapter is divided into three sections: The first section will provide a synthesis of the study findings that are relevant to achieving the above-mentioned aim; the second section will present contextually appropriate proposals as to how the above-mentioned aim can be achieved; and the third section will conclude the chapter.

9.2 Synthesis

The synthesis will distil the most relevant findings from the various components of this study and combine them into a coherent narrative in a manner that generates new knowledge capable of increasing its applicability. To do this, the theoretical principles on which this study is based will be integrated with the empirical findings.

9.2.1 Regional planning

As this study aims to utilize regional planning as a development instrument, it was necessary to define the discipline both in terms of the regional concept as well as the act of regional [spatial] planning to provide a framework within which the study's aim can be achieved. The regional concept can be defined based on three criteria i.e. scale, function, and class. In terms of scale; the region is generally believed to be on a scale between local and national scale (refer Section 3.2.1) and is significant for spatial planning professionals as it is seen as the most appropriate scale on which to achieve sustainable development due to the 'region' being sufficiently large to incorporate most social, economic and environmental systems (refer Section 4.4.2). This can be seen in testimonies from practitioners who aimed to implement Agenda 21 for the UN on a national scale before realizing that the most effective scale on which to achieve their outcome is on a sub-national or regional level (refer Section 4.4.2). It is for this reason that it is suggested that planning professionals and planning departments focus on implementing renewable energy strategies on a regional scale (refer Section 7.2.8). Policies at this scale should aim to foster

economic growth while taking into consideration the environmental and social impacts as to achieve development via a low-carbon and resource efficient manner (refer Section 5.3).

In terms of function; regions can be viewed as either a naturally occurring manifestation with no particular purpose, or as an abstract instrument that can be used to achieve a predetermined goal where the former refers to the objective view and the latter to the subjective view. Spatial planning professionals naturally view regions from a subjective perspective (refer Sections 3.2.1 & 8.3.3), as it enables such professionals to use the region as a development instrument to affect a desired outcome. It is for this reason that this study focuses on regional planning as a development instrument ultimately to achieve effective renewable energy implementation on a regional scale.

In terms of class; regions can be classified based on either homogeneous characteristics, or based on interlinking heterogeneous elements where the former is referred to as a formal region and the latter as a functional region, both allowing for the formulation of regional development plans through policy instruments known as ‘planning regions’ (refer Section 3.2.1). The homogeneous characteristics of formal regions can refer to physical features such as climate or topography (known as the natural region), or human features such as ethnicity, social or economic markers making formal regions relatively straightforward to delineate creating a clear boundary wherein administrative functions can take place (refer Section 3.2.1). As renewable energy resources are naturally distributed across the surface of the earth (refer Section 7.3.2.1, 7.3.2.2 & 8.2), this study will make use of the ‘natural region’ as part of the implementation proposals. Natural regions that contain exploitable resources can additionally be classified as ‘resource frontier planning regions’. Development policies can be formulated for such planning regions on their own, however, as renewable energy forms part of a larger system within the energy sector, resource frontier planning regions will rather form part of a broader framework. Functional regions, however, are more complex to delineate due to their interlinking characteristics and involve the actual and predictive movement patterns of people and activities (refer Section 3.2.1). Fortunately, South Africa’s apex spatial planning policy document, i.e. the NSDF has incorporated broadly delineated functional regions as part of its spatial proposals (refer Section 8.3.3), one of which (i.e. the arid innovation region) has been delineated adequately to incorporate the majority of renewable energy resource potential in South Africa and will therefore form part of the implementation proposals.

Spatial planning as an activity is generally speaking a future-orientated process aimed at fixing or improving social and/or economic systems and when combined with the regional concept (to form regional planning) can be redefined as a future-orientated process aimed at achieving regional [economic] development (refer Section 3.2.2). Development is a relatively broad

statement as there is no single universally accepted definition for what development means. Several authors and international development organizations have put forth their own definition and when considering the common themes between them, the term can be defined as an increase in economic growth (generally measured in GDP or GNI per capita) combined with an increase in human welfare (generally measured in factors such as education, employment, health and environmental quality) (refer Section 5.1). South Africa is in need for economic development (refer Section 8.3) to increase the quality of life for its citizens, making regional planning an ideal discipline for achieving this outcome.

9.2.2 Endogenous factor development

The United Nations (UN) has urged countries around the world to affect development in a more sustainable manner and subsequently developed seventeen Sustainable Development Goals (SDGs) (refer Section 7.2.3). However, it is not made clear how countries can achieve economic development, due to regional differences in factors of production and comparative advantages. Regional development theories are divided on the source (or origin) of development as Neoclassical theories based on the export base theory (Hoyt, 1939) and the Solow-Swan Model (1956) propose that due to the diminishing returns to scale of endogenous factors, i.e. factors from inside the region such as savings (capital investment) and labour, conditional convergence per capita over time is inevitable, i.e. the margin of growth in that region decreases over time by relying on endogenous factors alone (refer Section 4.2.1). This theoretical paradigm, therefore, asserts that growth must come from exogenous factors, i.e. income generated through exports.

However, since the 1980s, a new theoretical paradigm has taken precedence known as the ‘new growth theory’ which proposes that due to innovations in technology (among others), endogenous factor growth does not diminish and that development is primarily driven by the optimum exploitation of endogenous factors (refer Section 4.2.1). Albrechts (2006) states that as regions differ from one another, strategic spatial planning should seek to exploit whatever resources are available to achieve regional development (refer Section 3.2.2). South Africa has high levels of naturally occurring renewable energy resources in many regions of the country that, based on the above-mentioned prescription, need to be exploited to affect regional development. South Africa is particularly blessed with solar and wind energy resources. Solar energy levels in the western and central regions of the country rank among the highest in the world, and wind energy is considerable in the coastal provinces of the Western and Eastern Cape (refer Section 8.2). South Africa is also blessed with a variety of ocean-based renewable energy sources. Off-shore wind may not be ocean derived, but is considered to be an ocean-based energy source and South Africa has significant potential in this resource all along the entire coast of the country (refer Section 8.2). Ocean-wave energy is increasing in popularity

due to the technologies for this resource becoming more economically viable in addition to the base-load potential for this form of energy, and according to scientific studies, South Africa has sufficient wave-energy potential for exploitation, especially along the coast of the Western Cape (refer Section 8.2). Ocean current energy is still a relatively unexplored energy source. However, technologies for this resource are being developed at an increasing rate and promises to be economically viable in the near future. South Africa is fortunate to be located near a strong and easily accessible ocean current in the form of the Agulhas current flowing along the east coast which also has sufficient potential for exploitation (refer Section 8.2).

9.2.3 Technology-driven development

With the advent of the Modernist movement, theories on regional development have increasingly attributed development to innovations in technology (see role of technology theory Section 4.4.1) in line with the new growth theory. Structuralist theories on development such as the “waves of development theory” put forth by Marshall (1987) describe regions as moving through escalating phases of development over time due to increased innovation over intervals of 50 to 60 years, again highlighting technology’s prominent role in achieving development (refer Section 4.3.3).

This study explored the prospects of using renewable energy technologies as the technological component in achieving development by examining the causal relationships between the two variables (refer Section 5.4). This investigation commenced with examining the relationship between development and energy in general during which three lessons were learned. Firstly, it was learned that casualty tests should not be used in the policy formulation decision-making process due to the variability in their results (refer Section 5.2.1.1); secondly, that energy generally does have a positive impact on development as a factor in economic production and by enabling human welfare outcomes (among others) particularly energy that comes in the form of electrical energy i.e. electricity (refer Section 5.2.2); and thirdly, if energy is generated in environmentally damaging methods it can negate one of the identifiers of development, i.e. environmental quality and health (refer Section 5.3).

Renewable energy technologies, however, have come a long way in terms of sophistication over the past couple of decades, and each has the potential to provide valuable energy at little to no environmental costs (refer Section 6.3). Renewable energy deployment can have a positive impact on regional development by providing the necessary energy needed for economic growth to occur while limiting the negative environmental impacts associated with conventional fossil-fuel-based energy carriers (refer Section 6.2). South Africa’s primary national development policies, including the NGP, NDP, NIP, and the NSDF acknowledge the above-mentioned fact and subsequently prescribe that renewable energy should play an

increasing role in the South African energy landscape to achieve development (refer Section 8.3.2 & 8.3.3).

Renewable energy was initially prioritized in the White Paper on renewable energy (2003) and formally legitimized in Chapter 2 of the National Energy Act (NEA) (34 of 2008), prescribing that South Africa must seek to minimize the negative environmental impacts associated with energy generation and to ensure universal access to appropriate forms of energy by taking into account the available resources (refer Section 8.3.1). This policy lends itself to a 'place-based' or 'spatial targeting' policy approach wherein specific locations are identified, for which development policies can be formulated to achieve development (refer Section 4.5.1.3). The NEA (No 34 of 2008) put into effect objectives concerned with the management of resources and in March 2011, the Integrated Resource Plan (IRP 2010) was promulgated and set a target of 17 800 MW of renewable energy to be in place by 2030, of which 8 400 MW was to come from wind energy, and 9 400 MW from solar energy (refer Section 8.3.1).

Chapter 3 of the NEA (No 34 of 2008) specifies that the Minister of Minerals and Energy must prepare an Integrated Energy Plan (IEP) with a planning horizon of no less than 20 years considering issues relating to the security of supply, environmental impacts and the optimal use of indigenous energy resources (refer Section 8.3.1). Per the aforementioned White Paper, the National Energy Regulator of South Africa (NERSA) was established in 2005 to manage the energy sector and spelt the beginning of private sector involvement in the energy sector through the Renewable Energy Independent Power Producer Procurement Programme (REIP4).

In 2012, the PICC prepared South Africa's NIP which through SIPs 8, 9 and 10 aimed to support investment in green energy generation infrastructure as well as the expansion of relevant transmission and distribution infrastructure, respectively (refer Section 8.3.2). In addition to the SIPs, the NSDF also highlights that long-term spatial and infrastructure planning must consider future renewable energy developments as well as the opportunities presented by the SADC in terms of energy generation and international trade (refer Section 8.3.3). Eskom recently developed a Transmission Development Plan (TDP) for the period 2021–2030 to accommodate new IPPs. The process involved scenario planning which has revealed that the majority of new grid infrastructure must be located in the Northern Cape, Eastern Cape and Western Cape Provinces, which is planned to not only accommodate new generation capacity from IPPs in these provinces but also make it possible to export excess electricity as stipulated in the NSDF. For exporting electricity to neighbouring countries, the SADC region has established the Southern African Power Pool (SAPP) as a trading platform (refer Section 8.3.3).

9.2.4 Energy, infrastructure, and spatial planning considerations

To utilize renewable energy to affect regional development through regional planning, it is necessary to have a clear understanding of the technical aspects related to electrical energy infrastructure in general, as well as to renewable energy technologies. Electricity grids comprise three components, i.e. generation, transmission, and distribution, where the first component refers to the conversion of one form of energy into electrical energy, and the latter two components refer to the delivery of generated electricity to end-users (refer Section 6.2). Electricity grids are physical structures that occupy space along the surface of the earth, thus affecting the use of land and therefore requires careful spatial planning (refer Section 3.2.2). According to a professional spatial planning statutory council, professional spatial planners must be profoundly involved in developing renewable energy strategies, as this profession has the greatest ability to coordinate the complex process of energy infrastructure and spatial planning at national, regional and local scales (refer Section 7.2.8).

Onshore wind-farms and solar PV-farms require large tracts of land for commercial-scale operation (refer Section 6.4.). Commercial-scale off-shore wind-farms also require large areas, albeit within the ocean. Ocean current turbines do not require much space and are generally placed below the surface of the ocean, whereas ocean wave energy converters generally float along the surface of the ocean (refer Section 6.3). The location of industry theory developed by Weber (1909) is based on the premise that industries will determine their location based on where operational costs will be lowest by taking into consideration the location of raw materials, labour and transportation costs (refer Section 3.4.3). The theory was expanded upon by Lösch (1954) by taking into consideration demand and distribution costs, resulting in the demarcation of the market area. However, as with theories in general, real-world circumstances dictate that industries cannot merely be established in locations based on theoretical considerations. Due to the relative falling prices of transportation cost and innovations in communication technology (among others), social and environmental factors as well as the existence of established infrastructure and markets have been playing an increasing role in the locations of industries (refer Section 3.4.3).

In determining where renewable energy generation sites must be located, it was found that there are generally four main considerations (refer Section 6.4). The first consideration refers to the availability of the particular energy source and is the most obvious locational consideration, as renewable energy generation must take place in the location it naturally occurs (refer Section 6.4.2). Each source has its own specific requirements in terms of minimum energy thresholds which must be adhered to. For wind energy sites, a minimum average wind speed of 6 metres per second is required; for solar PV sites, a minimum annual solar radiation of 2 000 kWh/m² is

required; for wave energy sites, an output of 30 kW/m is required; and for ocean current sites, a minimum flow velocity of 1 m/s is required (refer Section 6.4.2).

The second consideration refers to sites being suitable for constructing the specific infrastructure and can refer to easily accessible sites, favourable topography and geology, sufficient space, non-conflict with existing commercial and/or industrial activities, and areas where the environment is not sensitive to damage (refer Section 6.4.3). The third consideration refers to the proximity to existing electricity grid infrastructure which must be as close as possible. In addition to grid proximity, the electricity grid must also be able to accept newly generated electricity, which is referred to as grid availability, and the grid also needs to be able to accommodate the volume and loading ratio of newly generated electricity, also referred to as grid capacity (refer Section 6.4.4). This was also highlighted in the NSDF wherein it is expressed that solar and wind generation sites must be located in close proximity to the national grid (refer Section 8.3.3). The fourth consideration refers to statutory planning requirements such as zoning and land-use management. Energy generation sites generally need to be constructed on land that is zoned for industrial purposes and in some cases, a buffer zone between the generation site and neighbouring uses will need to be in place to minimise any potential negative impacts (refer Section 6.4.5).

Ocean-based renewable energy generation sites in Scotland are planned for in Sectoral Marine Plans (SMP) by the relevant national government sector department using a similar process to determine locations. Renewable energy generation sites are prioritized in SMPs as Plan Options, which represent areas wherein specific renewable energy uses are permitted (refer Section 7.3.1). Plan Option sites are identified via a multi-stage process that commences with a Regional Locational Guidance that highlights areas where sufficient renewable energy resource potential exists, combined with close proximity to existing electrical grids (refer Section 7.3.1). Once such areas have been identified, they are labelled as Draft Plan Options before being subjected to public participation and consultation. After the consultation phase, a Sustainability Appraisal consisting of a Strategic Environmental Assessment (SEA), a Habitat Regulation Appraisal (HRA), and a Socio-economic Impact Assessment (SEIA) is carried out, whereafter such sites are labelled as Adopted Plan Options (refer Section 7.3.1). South Africa also followed a similar process when in 2016, the Department of Environmental Affairs (DEA) and the Council for Scientific and Industrial Research (CSIR) identified eight Renewable Energy Development Zones (REDZs) (refer Figure 8.6) wherein renewable energy developments are encouraged. The REDZs were identified through a positive mapping exercise which included areas with sufficient renewable energy resource potential combined with close proximity to the national electricity grid, which was followed by a negative mapping exercise that excluded areas with sensitive environments.

9.2.5 Policy frameworks

Modernist theories of development have also highlighted the concept and importance of sustainable development (see sustainability theory Section 4.4.2), which refers to an increase in economic, social, and environmental conditions in harmony with one another. It has become critical during the past two decades to maintain the natural qualities of ecological systems with social and economic development and even though there is no agreement on the exact balance between the three variables, it is commonly accepted that a holistic approach is needed wherein natural resources are used efficiently and responsibly by using regional planning instruments such as development policies and plans (refer Section 4.4.2). One of the inherent outcomes of the new growth theory is that policy measures can be used to support the sustainable exploitation of endogenous resources through technology to achieve development, which is extremely appealing for regional planning professionals, since this will act as the instrument to achieve their targets (refer Section 4.2.1).

Such policy measures normally include spatially orientated policies that influence the future distribution of economic activities in space. Spatial policy can be divided into two main categories; the first place neutral and the second place based, where the former proposes that development initiatives focus equally across space, allowing natural market forces to determine which areas develop and which areas do not, and the latter proposes that development initiatives focus on specific locations seeking to exploit particular local assets (refer Section 4.5.1). The NSDF subscribes to the latter approach in prescribing that South Africa's natural resources need to be more effectively protected and managed to achieve regional development by making use of spatial targeting (i.e. place based) planning policies that are coordinated across the three spheres of government (refer Section 8.3.3).

Spatial planners need to possess the correct set of skills to meet the challenges of climate change as they have an important role to play in developing energy strategies (refer Section 7.2.8). Spatial planning is the profession with the greatest ability to coordinate the variety of interchangeable linkages that make up energy planning in such a way that mitigates the adverse effects of climate change (refer Section 7.2.8). It must be noted, however, that spatial planning policy and regulatory systems differ substantially across the globe and each unique set of policies must be utilized effectively to ensure effective energy planning (refer Section 7.2.8). In August of 2013, the South African government enacted the Spatial Planning and Land Use Management Act (SPLUMA)(16 of 2013) to provide a legislative framework for spatial planning and land use management across the three spheres and critically makes provision for the Minister of Rural Development and Land Reform (RDLR) to declare any area in the Republic a region to guide strategic development-orientated decision making in that area through an RSDF

(refer Section 8.3.2). The SPLUMA, therefore, will play a central role in potentially achieving regional development.

Ocean energy can increasingly be harvested as the technologies become more economically viable, which necessitates a relatively new regulatory policy framework that includes what is commonly known as Marine Spatial Planning (MSP) (refer Section 7.2.8). Scotland is one of only a few countries in the world that currently make use of MSP. It has in place a National Marine Plan (NMP) that provides a framework for strategic and statutory planning in Scottish ocean waters (refer Section 7.3.1). For marine spatial planning on a smaller scale, the NMP is divided into smaller plans known as Regional Marine Plans (RMPs) to achieve development in such regions and is aligned with terrestrial planning policy such as Local Development Plans (LDPs) (refer Section 7.3.1). Ocean-based and terrestrial spatial developments in Scotland are reviewed and approved by separate government departments as they are guided by separate legislation, i.e. the Marine Act, the Marine and Coastal Access Act (combined known as the Marine Acts), and the Scottish Planning Bill respectively. However, as mentioned above, to achieve coherence these plans are linked to one another through what is known as a 'planning circular' system (refer Section 7.3.1).

In accordance with international trends, the South African government adopted the country's first marine spatial planning legislation in the form of the Marine Spatial Planning Act (MSPA) (16 of 2018), along with the Marine Spatial Planning Framework (MSPF) to provide a framework for ocean-based spatial developments through Marine Area Plans (MAPs) in addition to the necessary institutional arrangements for their implementation (refer Section 8.3.3). The DEA heads Marine Spatial Planning in South Africa. However, MAPs are to be developed and overseen by the National Working Group on Marine Spatial Planning (NWGMSP) consisting of officials from all relevant national state departments (including energy) and are reviewed and approved in terms of Section 14 of the MSPA by the Directors General Committee on Marine Spatial Planning (DGCMSP) and the Ministerial Committee on Marine Spatial Planning (MCMSP) (refer Section 8.3.3). To assist the NWGMSP with the preparation of MAPs, a dedicated team known as the Marine Area Planning Group (MAPG) will be established (refer Section 8.3.3). MAPs are integrated sustainable development plans and are distinct from sectoral development plans meaning that sector plans can traverse MAP and coastal boundaries.

Renewable energy development in South Africa's Exclusive Economic Zone (EEZ) will be legitimized through the MAPs (refer Section 8.3.3). The South African EEZ will be divided into four planning areas, including (1) the Western Marine Planning Area, (2) the Southern Marine Planning Area, (3) the Eastern Marine Planning Area, and (4) the Prince Edward Island Marine

Planning Area (refer Figure 8.7). Each of the Planning Areas will be assigned a MAP which provides a regulatory framework consisting of (a) general development guidelines, (b) sectoral development guidelines, and (c) a zoning scheme (refer Section 8.3.3). The general development guidelines are sufficiently broad to apply to all MAPs, whereas sectoral development guidelines are specific to each sectoral marine activity to achieve the sectoral objectives and apply throughout the specific MAP and should be aligned with terrestrial plans (refer Section 8.3.3). Each zoning scheme will organize space in terms of three types of uses, namely: (1) primary uses, (2) consent uses, and (3) prohibited uses. Zones are delineated based on the natural conditions for economic opportunities and the distribution of key resources among others (refer Section 8.3.3).

The following section will make use of existing and proposed energy, infrastructure and spatial planning policy mechanisms to illustrate how renewable energy developments can be facilitated in South Africa.

9.3 Proposals

9.3.1 Preamble

The proposals presented in the following section represent new contributions to the science, policy and implementation of regional planning in general as well as in South Africa. The proposals will be divided into five segments. The first segment will present a generic policy framework (refer Section 9.3.2) demonstrating how renewable energy sector planning (which includes strategic, infrastructure, and spatial planning) can be integrated with regional spatial planning by highlighting the theoretical foundation on which the proposed framework is based, before moving on to the planning phase, and lastly the implementation phase (refer Figure 9.1). The second segment will adapt the generic policy framework to be applicable to the current South African policy context (refer Section 9.3.3), demonstrating how renewable energy sector planning can be integrated with terrestrial and marine spatial planning systems on a regional planning level. The third segment will narrow down the focus towards the identification of specific geographic location where renewable energy can be exploited, also known as Adopted Plan Options (APOs), as part of energy sector spatial planning (refer Section 9.3.4). The fourth segment will include APOs into a terrestrial spatial planning policy (i.e. RSDF) for implementation, and the fifth segment will include APOs into marine spatial planning policy (i.e. MAPs) for implementation (refer Sections 9.3.5 & 9.3.6).

9.3.2 Renewable energy planning framework

The research synthesis has revealed that endogenous factors of production can be used in collaboration with technology to achieve regional development as per the new growth theory. In the case of this study, the endogenous factors to be used refer to renewable energy resources and the technology to be used refers to the various renewable energy technologies capable of converting the naturally occurring energy sources into electrical energy (refer Section 6.3). This theoretical foundation provides the basis for the renewable energy sector and marks the starting point for the planning phase in this generic policy framework (refer Figure 9.1). This study contributes this currently absent policy framework, which will additionally be used as the basis for renewable energy planning and implementation in South Africa (refer Section 9.3.3).

The research synthesis has additionally revealed that spatial planning professionals must form an integral part of the electricity planning and implementation process (refer Section 9.2), thus the reason for integrating energy, infrastructure, and spatial planning. The renewable energy-sector planning phase includes three elements: (1) energy strategic planning, (2) energy infrastructure planning, and (3) energy spatial planning (refer Section 8.3). The first element refers to the establishment of energy demand and supply within any given country or region, the second element refers to the identification of electrical grid infrastructure needs to deliver generated electricity to end uses building on the established supply and demand, and the third element refers to the identification of specific geographic location where renewable energy can be harvested (APOs). Once APOs have been identified, it is proposed that they be incorporated into regional spatial planning policy frameworks for implementation. The implementation of APOs on land can be done by using terrestrial planning policy, whereas the implementation of APOs in the ocean can be done by using marine planning policy.

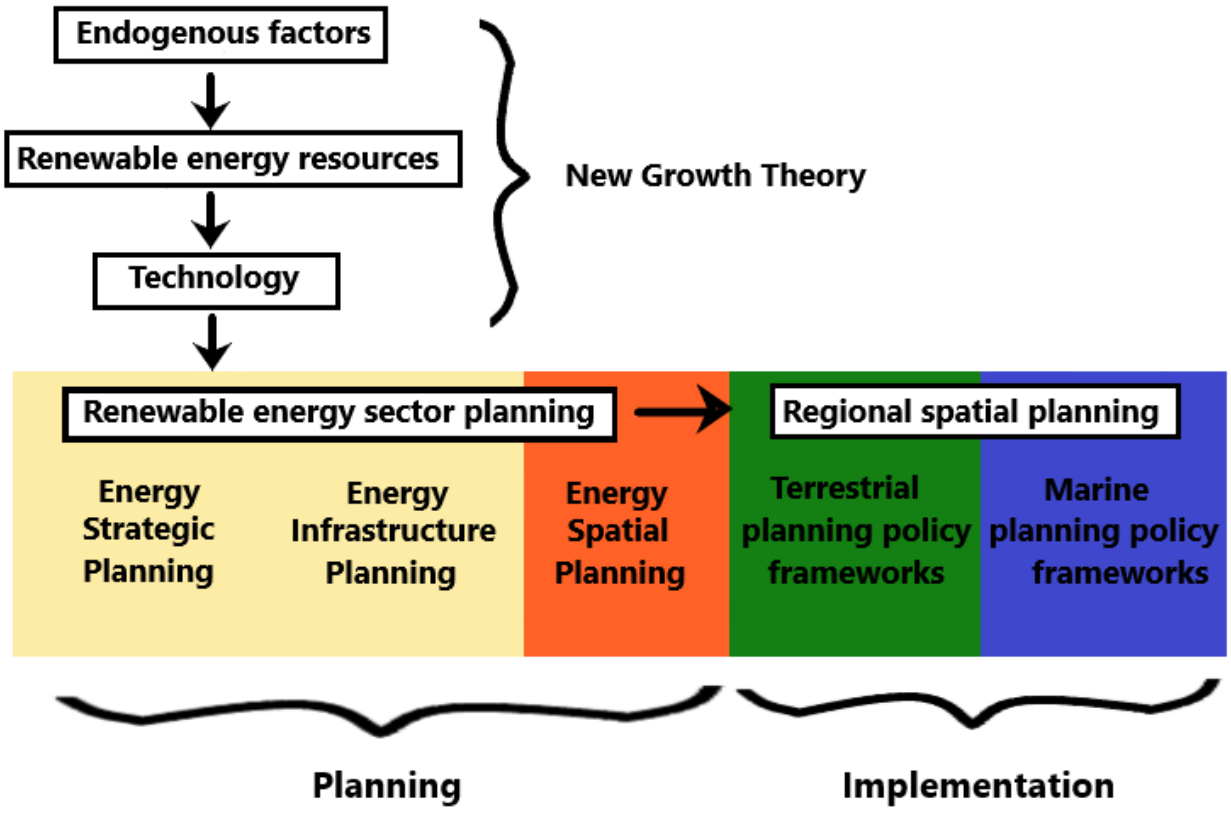

Figure 9.1: Generic policy framework

Source: Own Compilation (2020)

9.3.3 Renewable energy planning framework (South Africa)

The renewable energy planning framework represents a framework that will allow for the planning and implementation of renewable energy via the South African spatial planning system by integrating [renewable energy] sector and regional spatial planning (refer Figure 9.2). It is proposed that the process begins with an instruction from South Africa's primary development policy i.e. the National Development Plan (NDP), as well as South Africa's primary energy legislation i.e. the National Energy Act (NEA) (34 of 2008). In terms of the NDP and Chapter 2 of the NEA, renewable energy must form part of South Africa's energy mix, which subsequently resulted in the formulation of the Integrated Resource Plan (IRP). The NDP, NEA and IRP together should provide the mandate for:

1. Energy strategic planning, which may be done by the Department of Mineral Resources and Energy (DMRE) through the Integrated Energy Plan (IEP). The IEP provides strategic direction for South Africa's energy landscape by making projections relating to energy supply and demand while guiding the selection and investment strategies for specific technologies up to 2050 (refer Section 8.3.2).

2. Energy infrastructure planning, which may be carried out by the Presidential Infrastructure Coordinating Committee (PICC) through Strategic Integrated Projects (SIP's) 8, 9 and 10, and Eskom (refer Section 8.3.2 & 8.3.3). SIP 8 sets out support for green energy infrastructure investment, SIP 9 sets out support for the increase in electrical generation capacity, and SIP 10 sets out support for the expansion of distribution and transmission infrastructure. Eskom may also assist in energy infrastructure planning through its annual Transmission and Development Plan (TDP) by using scenario planning to determine where future energy infrastructure can be located to support Independent Power Producers (IPPs). The latter has revealed that the Northern, Eastern, and Western Cape Provinces should receive the bulk of new infrastructure.
3. Energy spatial planning, which may be carried out by the Department of Environmental Affairs (DEA), the Department of Mineral Resources and Energy (DMRE) and the Department of Performance Monitoring and Evaluation (DPME). The specific geographic locations for renewable energy exploitation can be identified during this stage. Both ocean-based and terrestrial-based locations should then be labelled as Adopted Plan Options (APOs) for the purpose of this framework (refer Section 9.3.4).

The APOs identified through the energy sector spatial planning process can then be included into the terrestrial and marine spatial planning systems governed by the SPLUMA (16 of 2013) and the MSPA (16 of 2018), respectively where they can be facilitated and implemented though Regional Spatial Development Frameworks (RSDF) and Marine Area Plans (MAP), respectively (refer Sections 9.4 & 9.5). The APOs can then be included into relevant strategic spatial planning policies on local, provincial, and national spheres to ensure a coherent approach.

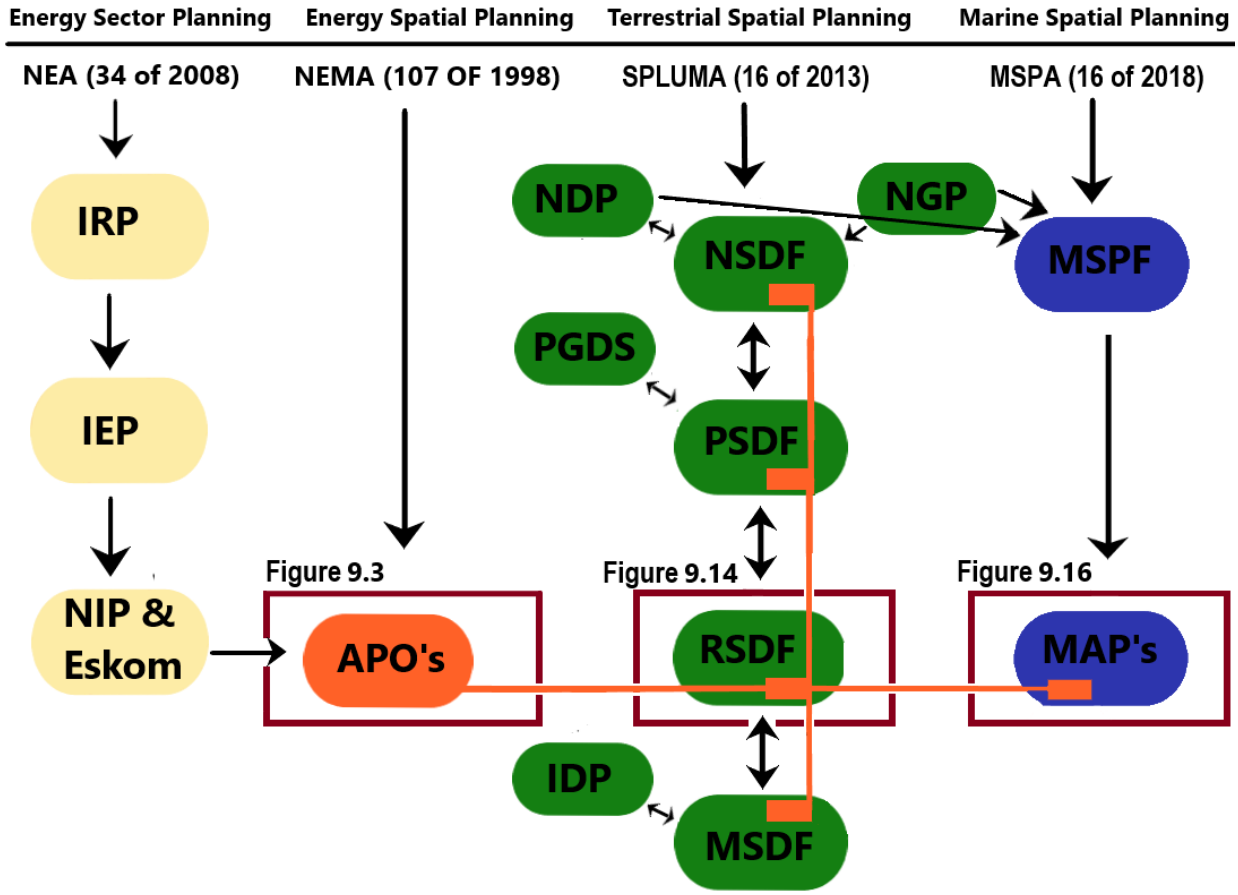

Figure 9.2: Renewable energy planning framework (South Africa)

Source: Own Compilation (2020)

9.3.4 Adopted plan options (APO)

The spatial planning purpose of the sector planning process is to identify renewable energy, APOs, i.e. specific geographic locations where renewable energy can and/or should be harvested. The institutional arrangements and regulatory policies for such developments are not dealt with during this stage, but rather as part of the terrestrial and marine planning processes, respectively (refer Sections 9.4 & 9.5). The sector spatial planning process can be divided into three main phases (refer Figure 9.3); the first phase (referred to as Locational Guidance) consists of two parts and leads to the identification of Draft Plan Options; the second phase consists of one part and is an intermediary phase during which public and private stakeholders are allowed to voice their opinions regarding the identified Draft Plan Options; and the third phase (referred to as the Sustainability Appraisal) consists of three parts that build upon the first two phases and lead to the identification of Adopted Plan Option. The following section will provide an overview of how the sector spatial planning process can be applied in the South African context for both terrestrial and marine-based renewable energy.

Figure 9.3: Adopted plan options (APOs)

Source: Own Compilation (2020)

1. It is proposed that the Locational Guidance commences with a study wherein specific renewable energy resource potential is mapped (refer Figures 9.4, 9.5, 9.6 & 9.7). The resource potential information can be obtained from various sources, including independent studies, global surveys, and forums, among others. Once the necessary information relating to the relevant resource potential has been gathered, it is proposed that the Locational Guidance then narrow down the areas of search by only considering areas that are in close proximity to existing (or planned) electricity grid infrastructure and power corridors as the generated electricity will need to be fed into the national grid for transmission and distribution to end-users (refer Figures 9.8 & 9.9). The above-mentioned steps result in the identification of Draft Plan Options (refer Figures 9.10 & 9.11).

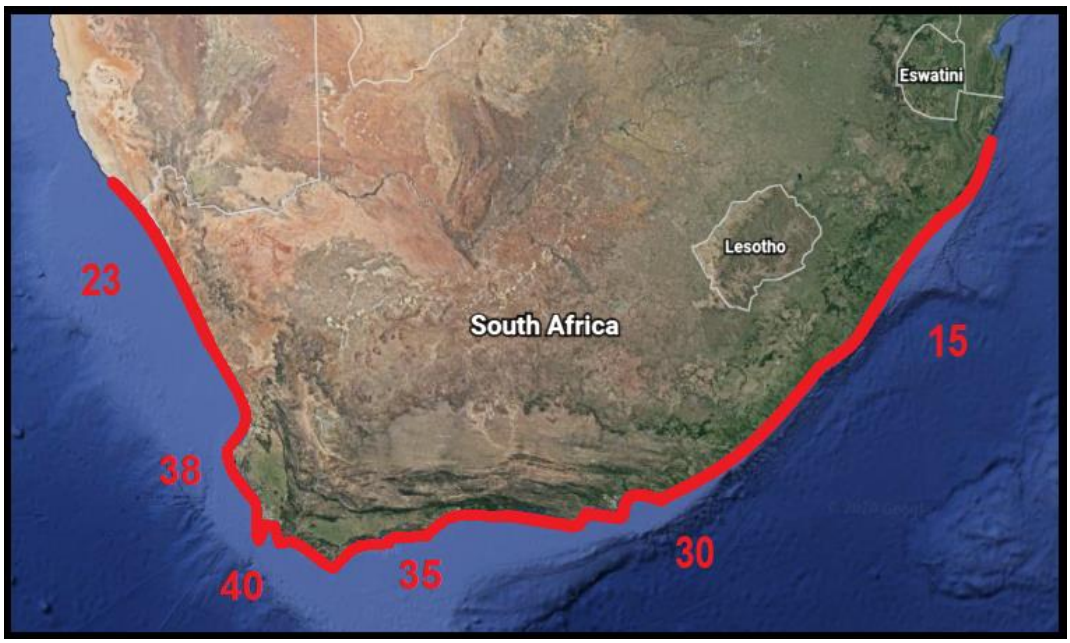

Figure 9.4: Ocean wave energy potential

Source: Van Niekerk (2013:1)

Figure 9.4 (above) illustrates the wave energy potential along the coast of South Africa as determined during an independent study undertaken by Van Niekerk (2013). The study found that sufficient potential exists along the coast of the Western Cape Province. Figure 9.5 (below) illustrates the off-shore wind energy potential along the coast of South Africa as prepared by the Global Wind Atlas (GWA) illustrating that there is sufficient potential all along the entire coast.

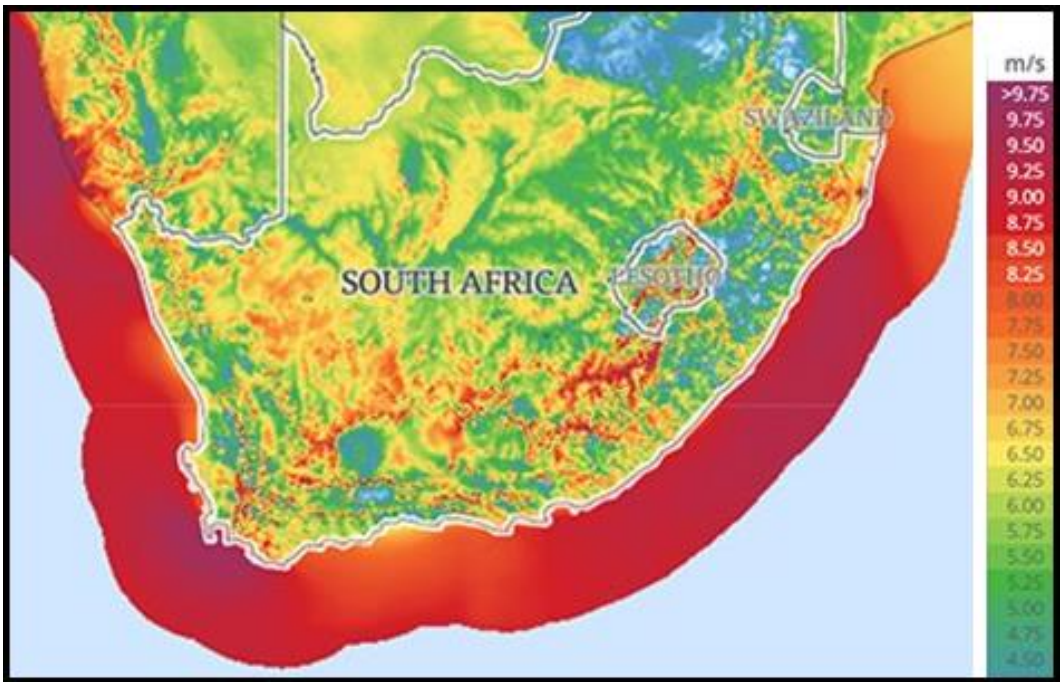

Figure 9.5: Off-shore wind energy potential

Source: GWA (2019)

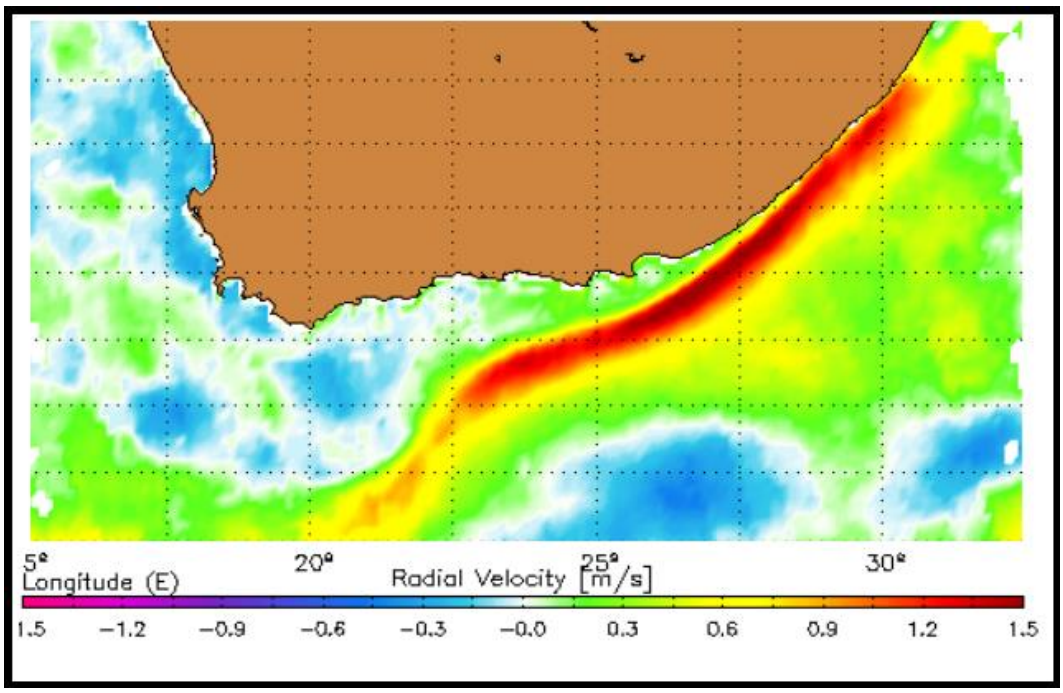

Figure 9.6: Ocean-current energy potential

Source: Van Niekerk (2013:2)

Figure 9.6 (above) clearly illustrates the presence of a high-velocity ocean current flowing along the South African East Coast and critically meets the 1 m/s minimum threshold required for current turbines. Figure 9.7 (below) illustrates both wind and solar energy potential indicating that the Free State, Northern, Eastern, and Western Cape Provinces have sufficient potential.

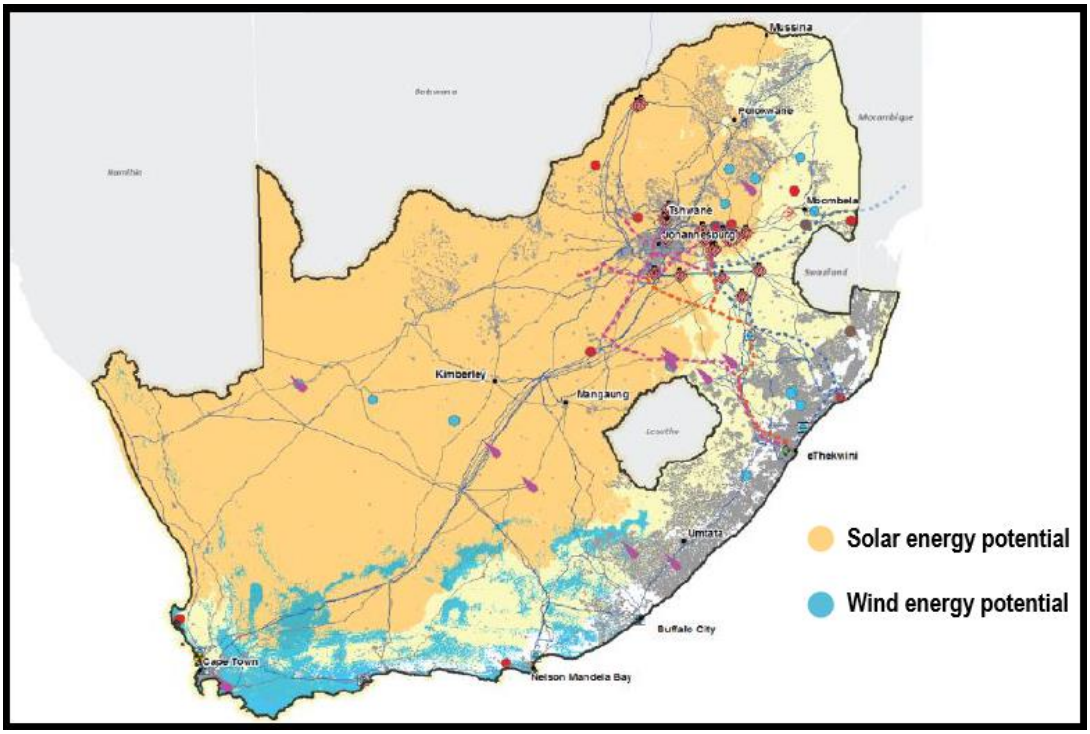

Figure 9.7: Solar and onshore wind energy potential

Source: Adapted from Department of Planning, Monitoring and Evaluation (2019:70)

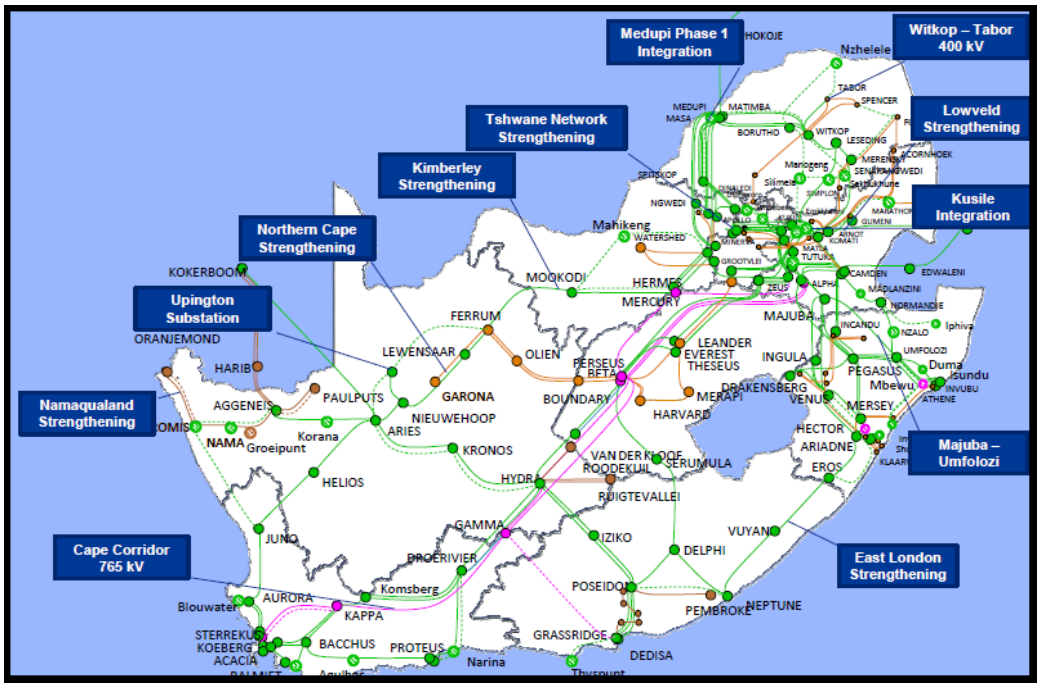

Figure 9.8: Existing and planned substations and transmission lines

Source: Eskom (2020:10)

Figure 9.8 (above) makes it possible to identify substations where renewable energy from APOs can be connected to the transmission grid, whereas Figure 9.9 (below) illustrates the power corridors in which it will be most practical to locate APOs.

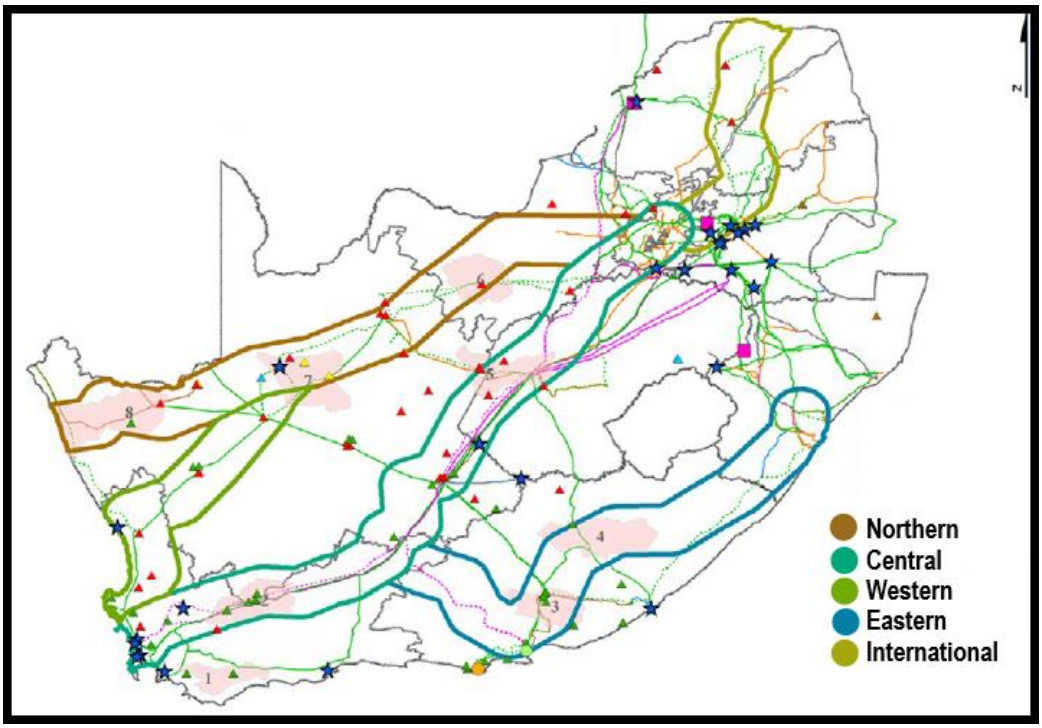

Figure 9.9: Transmission corridors

Source: Adapted from Eskom (2016:16)

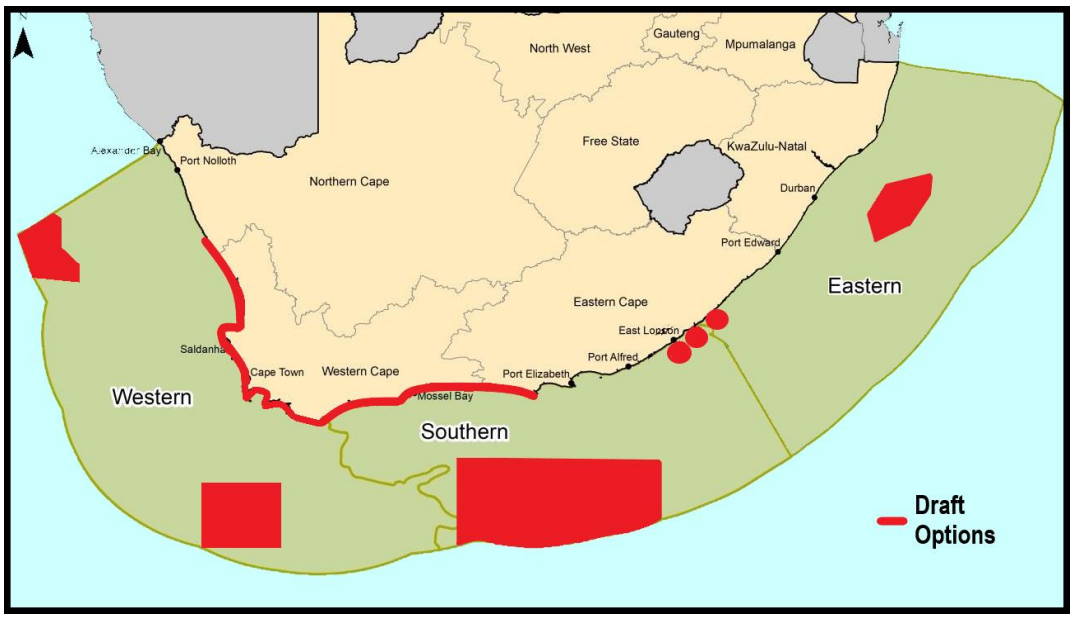

Figure 9.10: Ocean-based renewable energy draft options

Source: Own compilation from Section 8.2.3 & 8.3.3

Figure 9.10 (above) illustrates the potential location for the various ocean-based renewable energy sites within South Africa's EEZ as determined by independent studies and international surveys. Figure 9.11 (below) used the resource potential maps for wind and solar energy and eliminated the locations outside existing power corridors culminating in Draft Plan Options.

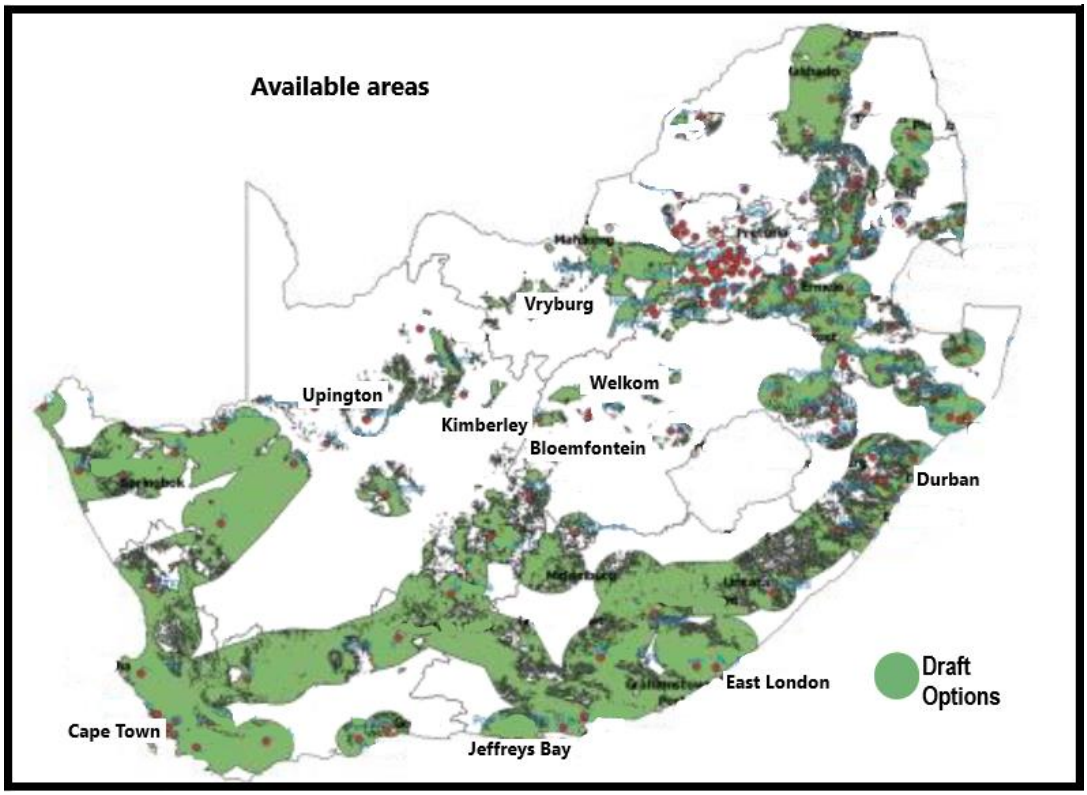

Figure 9.11: Terrestrial-based renewable-energy draft options

Source: Adapted from Eskom (2020:44)

2. The identified Draft Plan Options are further narrowed down during the scoping and consultation process. It is proposed that identified Draft Plan Options be made publicly available with sufficient time set aside for public participation. Representatives from Government Departments (including the DMRE, the DEA), State-Owned Enterprises (SOEs) (including Eskom), private consultants as well as the general public should be given the opportunity to comment and provide their inputs as to enhance the effectiveness of the process and to eliminate potential future hardship.

3. After the aforementioned contributions have been considered, it is proposed that the Sustainability Appraisal phase commence. This phase can include a Habitat Regulation Appraisal during which the impacts of the Draft Plan Options are considered in relation to native fauna and flora, a Socio-economic Impact Assessment during which the Draft Plan Options is considered in terms of their impact on existing industrial and commercial activities as well as their potential economic and social consequences, and finally a Strategic Environmental Assessment during which the Draft Plan Options are considered in a strategic manner including their environmental impacts and subsequent mitigation measures. Once the above-mentioned steps have been completed, it is proposed that the identified locations be labelled as Adopted Plan Options (refer Figures 9.12 & 9.13), which can then be included into terrestrial and/or marine strategic plans for implementation (refer Figure 9.2).

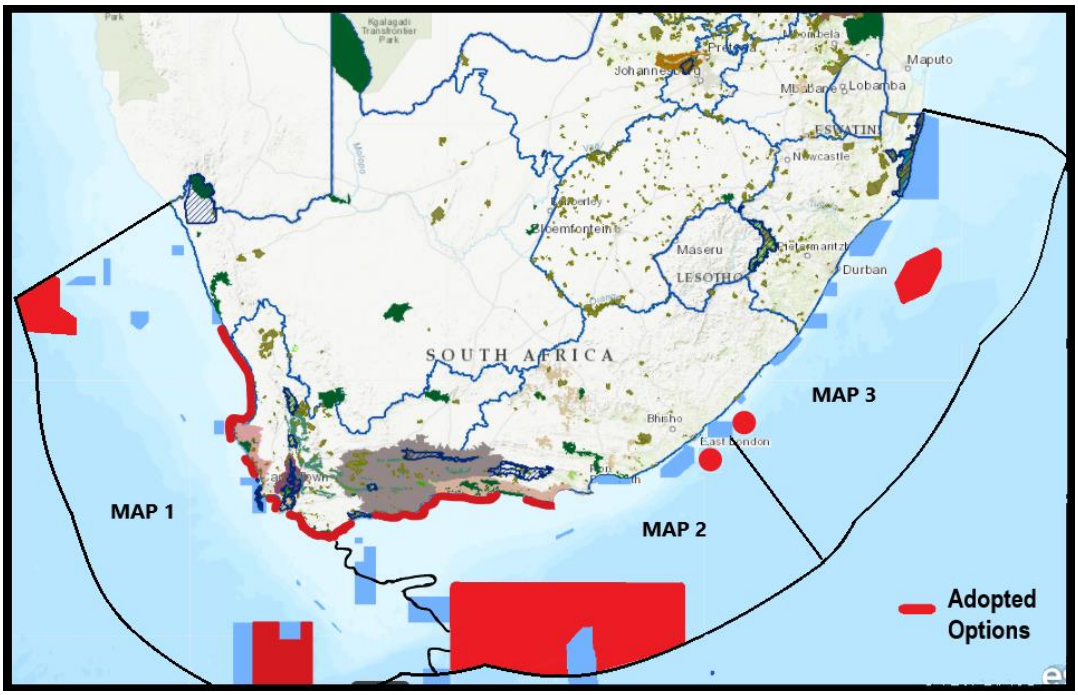

Figure 9.12: Ocean-based renewable energy adopted options

Source: Own compilation from Sections 8.2.3 & 8.3.3

Figure 9.12 (above) illustrates the locations of APOs within South Africa's EEZ that resulted by using the Draft Plan Options as a base and narrowing down the locations by taking into consideration the public participation phase as well as the Sustainability Appraisal. Figure 9.13 (below) illustrates the locations of APOs on land that resulted using the same process as was the case with the ocean-based APOs.

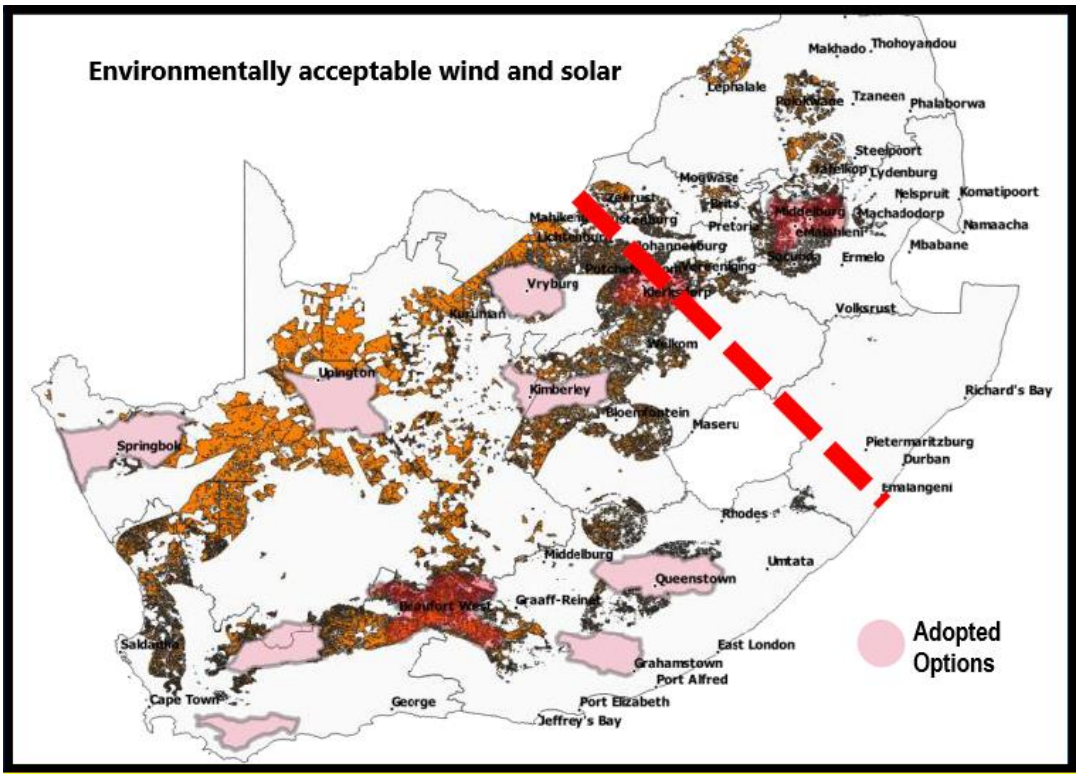

Figure 9.13: Terrestrial-based renewable-energy adopted options

Source: Adapted from Eskom (2020:48)

The following section will provide an explanation as to how terrestrial-based renewable energy within APOs can be implemented by using a Regional Spatial Development Framework (RSDF).

9.3.5 Regional spatial development framework (RSDF)

The NSDF highlights five National Spatial Action Areas (NSAAs) (refer Figure 8.9) that must be utilized to contribute towards achieving the desired national spatial development pattern for South Africa (refer Section 8.3.3). One of the NSAAs is the Arid Innovation Region (refer Figure 9.15) in which the NSDF aims to exploit renewable energy to achieve regional development by utilizing a Regional Spatial Development Framework (RSDF) as the facilitation instrument. However, before the proposed RSDF can be formulated, it is proposed that the Minister of Rural Development and Land Reform (RDLR) first consult with the North West, Free State, Northern Cape, Western Cape and Eastern Cape Provincial Premiers, as well as the relevant Municipal

Councils to declare the geographic area a region for the purpose of guiding strategic spatial and land-use planning. The process for preparing the proposed RSDF consists of six stages (refer Figure 9.14). The following section will provide a demonstration of how the above-mentioned NSDF outcome can be achieved by describing the proposed RSDF preparation stages and, where appropriate, make provision for the inclusion of renewable energy development strategies within APOs as part of the RSDF content.

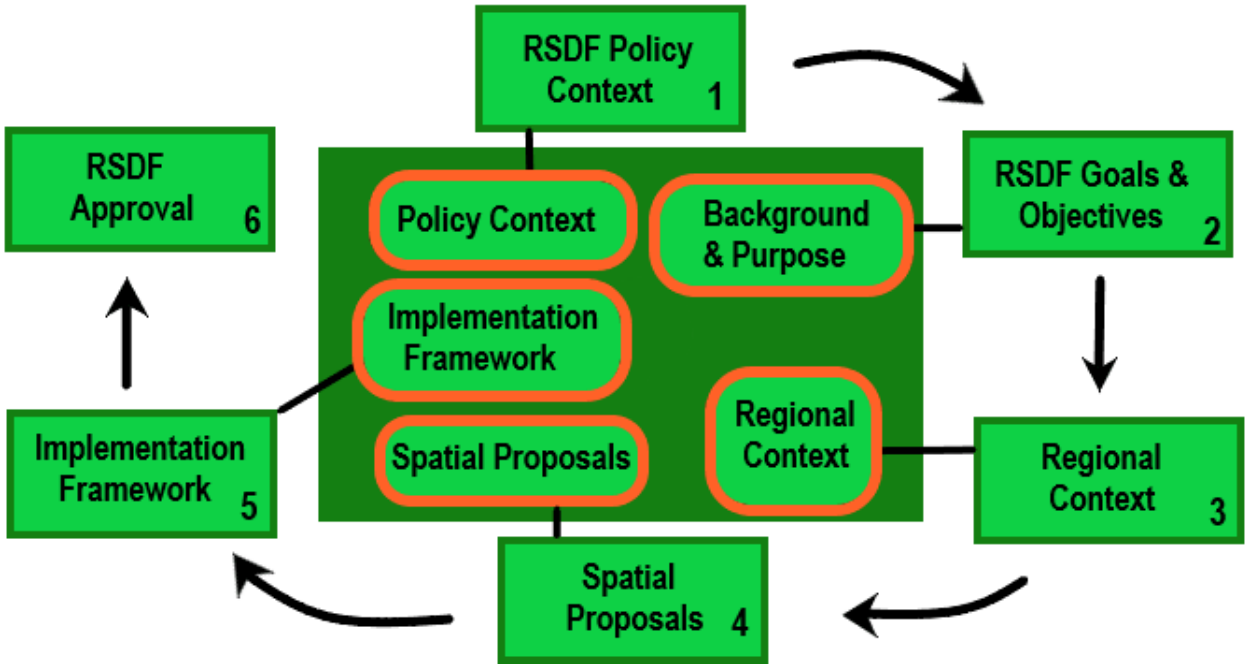

Figure 9.14: Regional spatial development framework (RSDF)

Source: Own Compilation (2020)

1. The policy context section should provide the justification and strategic direction for the RSDF being developed. To do this, relevant legislation, spatial and infrastructure development policies and institutional structures and arrangements are analysed on national, provincial, and local scales. The proposed Arid Innovation RSDF should receive its mandate from Chapter 4 (Part D) of the SPLUMA (16 of 2013). On a national scale, the proposed RSDF should adhere to the five SPLUMA principles, i.e. spatial justice, spatial sustainability, efficiency, spatial resilience and good administration, as set out in Chapter 2 of the Act and indicate how these principles will be applied. The proposed RSDF should then consider and give effect to the National Development Plan (NDP) principles relating to the economy, employment, infrastructure, environmental sustainability, and rural and human settlement transformation, among others. The content of the proposed RSDF should also comply with environmental legislation

including the National Environmental Management Act (NEMA) (107 of 1998) principles relating to environmental sustainability.

As the proposed Arid Innovation RSDF will include APOs for execution, the RSDF must consider and give effect to Chapter 2 of the National Energy Act (NEA) (34 of 2008) and the Integrated Resource Plan (IRP), which provides the mandate for renewable energy planning and implementation. The proposed RSDF should adhere to the guidelines of the Integrated Energy Plan (IEP), which relates to strategic energy planning. The proposed RSDF should and reconcile Strategic Integrated Projects (SIPs) 8, 9 and 10 of the National Infrastructure Plan (NIP) and Eskom's Transmission Development Plans (TDP), which relates to green energy generation, transmission, and distribution infrastructure planning. The proposed RSDF should also make provision for the Southern African Power Pool (SAPP) as a trading platform, and the National Energy Regulator of South Africa (NERSA) as the energy regulator.

On a provincial scale, the proposed RSDF should consider and give effect to relevant Provincial Growth and Development Strategies (PGDSs) relating to geographic focus areas, as well as socio-economic and built environment strategies. The proposed RSDF should also align with relevant Provincial Spatial Development Frameworks (PSDFs) in terms of established spatial development strategies and land-use directives. Where an RSDF goes beyond the boundaries of more than one province, the spatial policies in each need to be referenced and reconciled. On a local scale, the proposed RSDF should clarify and reconcile with agendas as articulated in relevant Municipal Spatial Development Frameworks (MSDFs) and Integrated Development Plans (IDPs).

2. The proposed RSDF goals and objectives should build on the vision statement of the NSDF and applicable PSDFs and MSDFs and, where necessary, redefine them to suit the region. Goals are abstract targets that the proposed RSDF is aimed to achieve, whereas the objectives are stepping stones towards achieving the goals and are formulated in accordance with the SMART rule, meaning that they should be specific, measurable, achievable, relevant and time bound. The NSDF has prioritized renewable energy development in the Arid Innovation Region as a medium-term (Five-year horizon) priority (refer Section 8.3.3).

3. The regional context section of the proposed RSDF should be a point of departure to provide the reference frame for identifying key spatial challenges such as potentially conflicting spatial targeting policies, and identify investment opportunities in emerging sectors (including renewable energy) on a regional scale by reflecting the current state of affairs in the region in terms of its biophysical, socio-economic and built environment characteristics. It is proposed that the biophysical status quo analysis consider the state

of the region's natural environment and climate conditions by examining existing Strategic Environmental Assessments (SEAs), Environmental Management Frameworks (EMFs) as well as South African National Biodiversity Institute (SANBI) research studies. At this stage, the proposed Arid Innovation Region's high solar radiation levels and wind speeds can be highlighted as these natural features form an integral part of the regional context. It is proposed that the socio-economic status quo analysis consider the current socio-economic attributes of the region by examining relevant PSDFs, MSDFs, sector plans and strategies (including renewable energy) as well as census data. It is proposed that the built environment status quo analysis consider the region's current built environment by examining relevant PSDFs, MSDFs and sector plans (including renewable energy). Such information can then be used to create a scaled diagrammatic map of the region on which to identify and illustrate particular challenges that the proposed RSDF aims to address, specifically referring to their spatial implications.

4. The spatial proposals are considered to be the most critical component of the proposed RSDF and can include the spatial vision and development concepts, the spatial strategies, and the composite RSDF proposals, all of which can be presented on the proposed RSDF map, supplemented by sub-regional maps, where necessary. The spatial vision and development concept can set out proposals for spatial transformation by indicating the desired patterns of land use in the region. It is at this stage of the proposed RSDF preparation stage that the previously identified APOs for wind and solar energy can be included and indicated on the RSDF map (refer Figure 9.15). The spatial strategies can present a conceptual [policy] framework indicating how the spatial vision is to be achieved. As the APOs were established during the sector spatial planning process, it is proposed that their inclusion does not warrant a spatial strategy; however, their impact on proposed spatial strategies within the RSDF must be considered and reconciled.

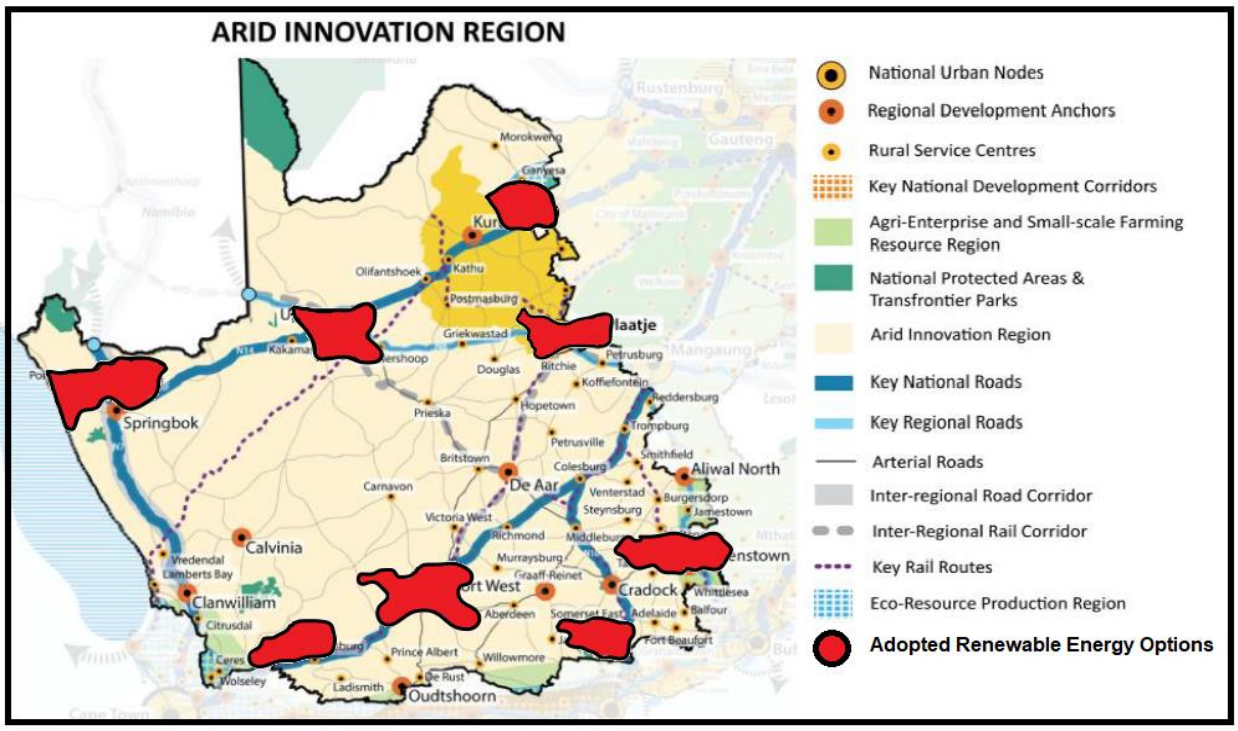

Figure 9.15: Renewable energy APOs in the arid innovation region

Source: Adapted from Department of Planning, Monitoring and Evaluation (2019:173)

5. It is proposed that the implementation framework provide basic guidelines for spatial planning, land development and land use management in the region and indicate how the strategies contained within the proposed RSDF be implemented and funded. It is proposed that the implementation framework tied to the spatial proposals (as discussed in stage 4) focus on spatial policies and guidelines, a spatial framework for capital investments, and a spatial governance framework.

   In terms of APOs; the spatial policies and guidelines can accommodate the Renewable Energy Independent Power Producer Procurement Programme (REI4P) as the regulatory framework for renewable energy procurement, the capital investment framework can give effect to SIPs 8, 9 and 10 as well as highlighting the necessary funding arrangements, and the spatial governance framework can designate the Department of Mineral Resources and Energy (DMRE) as the lead authority for renewable energy procurement, Eskom as the purchaser of renewable energy (among others) and grid licence authority, NERSA as the market regulator, and the SAPP as an international trading platform.

6. Once the proposed RSDF is finalized, it may be presented to the Ministerial Committee for approval where after the RSDF is published in the relevant Gazette as well as the relevant Department's website.

The following section will provide a similar explanation as to how ocean-based renewable energy Adopted Options can be implemented by making use of Marine Area Plans (MAPs).

9.3.6 Marine area plan (MAP)

Utilizing Marine Spatial Planning (MSP) to facilitate the renewable energy is explicitly called for in South Africa's Marine Spatial Planning Framework (2017) and provided for in South Africa's newly adopted Marine Spatial Planning Act (MSPA) (16 of 2018) by using Marine Area Plans (MAPs) as the implementation mechanism under the leadership of the DEA (refer Section 8.3.3). The process for developing the proposed MAP is a continuous cycle consisting of eight stages (refer Figure 9.16). The following section will provide a demonstration of how previously identified APOs can be facilitated by describing the proposed MAP preparation stages and where appropriate, make provision for the inclusion of renewable energy strategies within APOs as part of the MAP content.

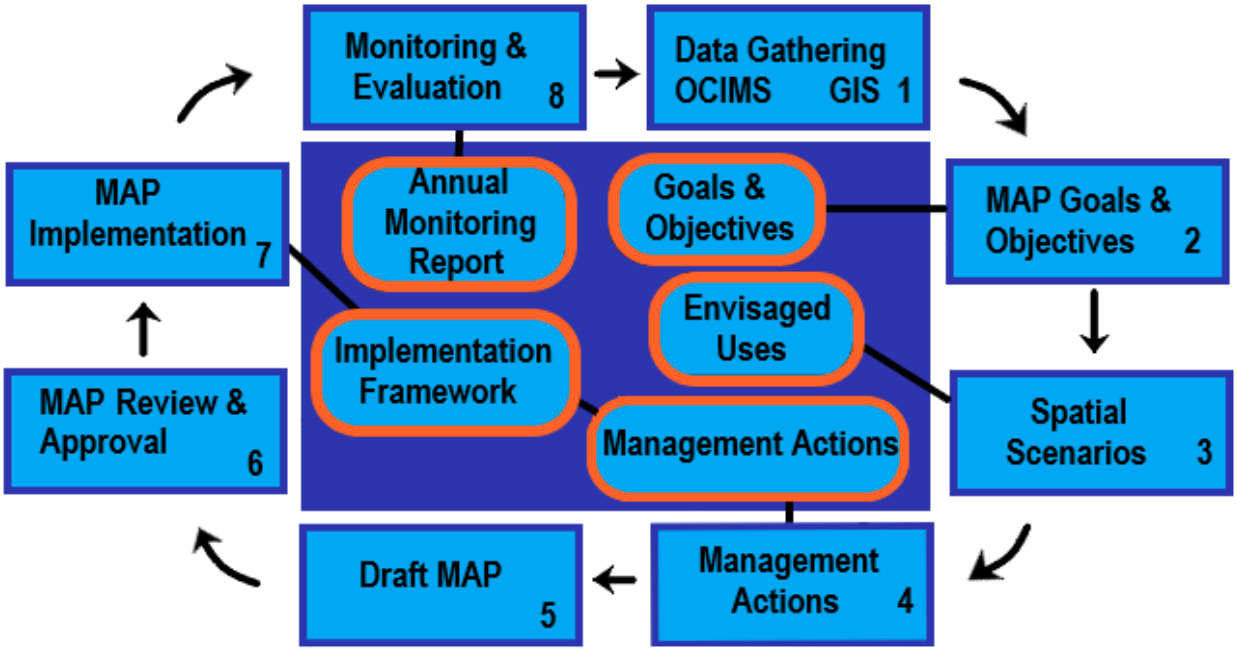

Figure 9.16: Marine Area Plan (MAP)

Source: Own Compilation (2020)

1. The starting point for developing the proposed MAP is to gather all the relevant data for each sectoral activity (including renewable energy) contained within South Africa's Exclusive Economic Zone (EEZ), which should then be placed into a central repository from which information can be drawn when needed for each plan (refer Section 8.3.3). Emphasis will be placed on gathering high-quality spatial data (such as the location and dimensions of APOs), which can then be integrated into a geodatabase building upon the Ocean and Coast Information Management System (OCIMS) currently being developed by the DEA to inform a Geographic Information System (GIS), which should

allow for the production of maps indicating information such as the presence of natural resources and areas with potential economic opportunity among others (refer Section 8.3.3).

2. Once all the relevant data have been gathered, the specific objectives that each of the proposed MAPs are intended to achieve can be drawn up by the Marine Area Planning Group (MAPG) in collaboration with the relevant stakeholders (refer Section 8.3.3). The objectives must also follow the SMART rule (as in the case of an RSDF), meaning that they must be specific, measurable, achievable, relevant, and time bound. It is proposed that, at this stage of the process, the Minister of Mineral Resources and Energy (among others) may include objectives relating to renewable energy developments.

3. It is proposed that the next step in the process involve the illustration of the various spatial outcomes that will result from implementing the proposed MAP while considering external factors such as economic development and climate change (among others) which will allow the National Working Group (NWGMSP) and the Marine Area Planning Group (MAPG) to select a desired spatial scenario (refer Section 8.3.3). At this stage of the process, the specific locations for APOs may be included as part of a variety of spatial scenarios, however, as this stage is merely for illustration purposes it is proposed that the relevant policy mechanisms and institutional arrangements for APOs is not included.

4. Contextually appropriate management actions may then be developed for each of the above-mentioned spatial scenarios. Management actions include three main instruments; namely (1) general development guidelines, (2) sectoral development guidelines, and (3) a zoning scheme (refer Section 8.3.3).

   The general development guidelines should be sufficiently broad to apply to all MAPs and include (among others) alignment between marine- and terrestrial planning policies (refer Section 8.3.3). For this study, it is recommended that this alignment be limited to sectoral activities in order to avoid unnecessary or unwanted sharing of information. For example, energy sector policies and plans within marine areas only

   Sectoral development guidelines should be specific to each sectoral activity and apply throughout the applicable MAP (refer Section 8.3.3). It is at this stage of the MAP preparation process that more specific rules applicable to APOs can be drawn up. In terms of renewable energy, the (REI4P) should be accommodated as the regulatory framework for renewable energy procurement; the Department of Mineral Resources and Energy (DMRE) should be identified as the lead authority for procuring renewable energy, Eskom should be listed as the purchaser of renewable energy (among others)

and grid licence authority, NERSA should be accommodated as the market regulator, and the SAPP should be included as an international trading platform.

The proposed MAP zoning scheme (as with conventional zoning schemes) assigns a specific zone to a specific geographic area, which either permits or prohibits specific uses in that area (refer Section 8.3.3). In certain instances, zones may permit varying uses to coexist in the same area, known as consent uses. The zones can then be indicated on the proposed zoning MAP map(s) (refer Figures 9.17, 9.18 & 9.19) for ease of reference. For the purpose of this study, two zones were assigned to specific locations in three proposed MAPs to enable renewable energy strategies to be implemented. The first is Mining Zones, which can allow uses such as renewable energy generation plants (among others), and the second is Underwater Infrastructure Zones which can allow electric cables (among others) to carry the generated electricity to the nearest substation on land. The proposed Mining Zones are based on identified locations done in existing studies (refer Section 8.2) and the proposed Underwater Infrastructure Zones are based on Eskom's TDP (2021-2030) for substation locations.

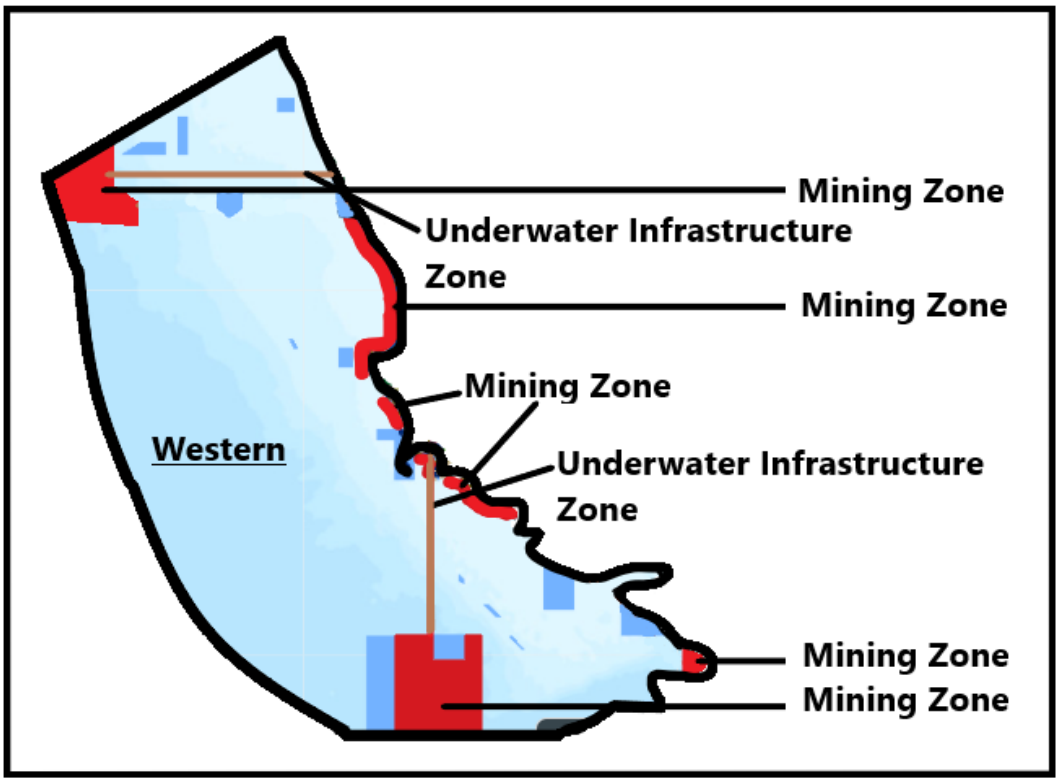

Figure 9.17: Western marine area plan

Source: Own compilation from Sections 8.2.3 & 8.3.3

Figure 9.17 (above) illustrates proposed Mining Zones and proposed Underwater Infrastructure Zones within South Africa's Western Marine Planning Area whereas Figure 9.18 (below) illustrates such zones within South Africa's Southern Marine Planning Area. The specific

locations for the Mining Zones were determined during the energy sector spatial planning phase that resulted in the identification of APOs, and the specific locations for Underwater Infrastructure Zones were determined using the latest substation infrastructure maps.

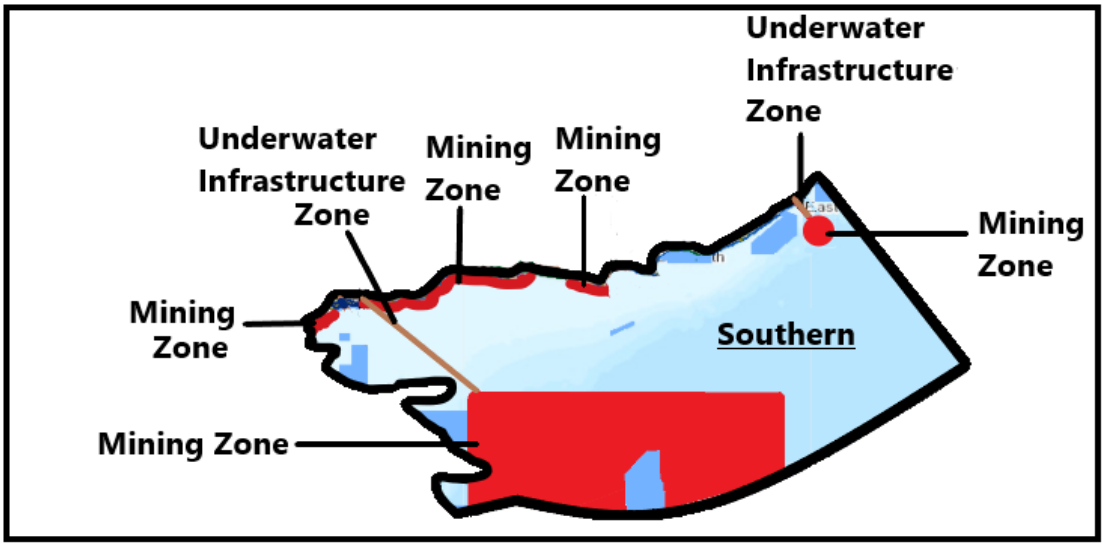

Figure 9.18: Southern marine area plan

Source: Own compilation from Sections 8.2.3 & 8.3.3

Figure 9.19 (below) illustrates the aforementioned zones within South Africa's Eastern Marine Planning Area. The specific location of the proposed zones were determined during the same process as was the case with the Western and Southern Marine Planning Areas.

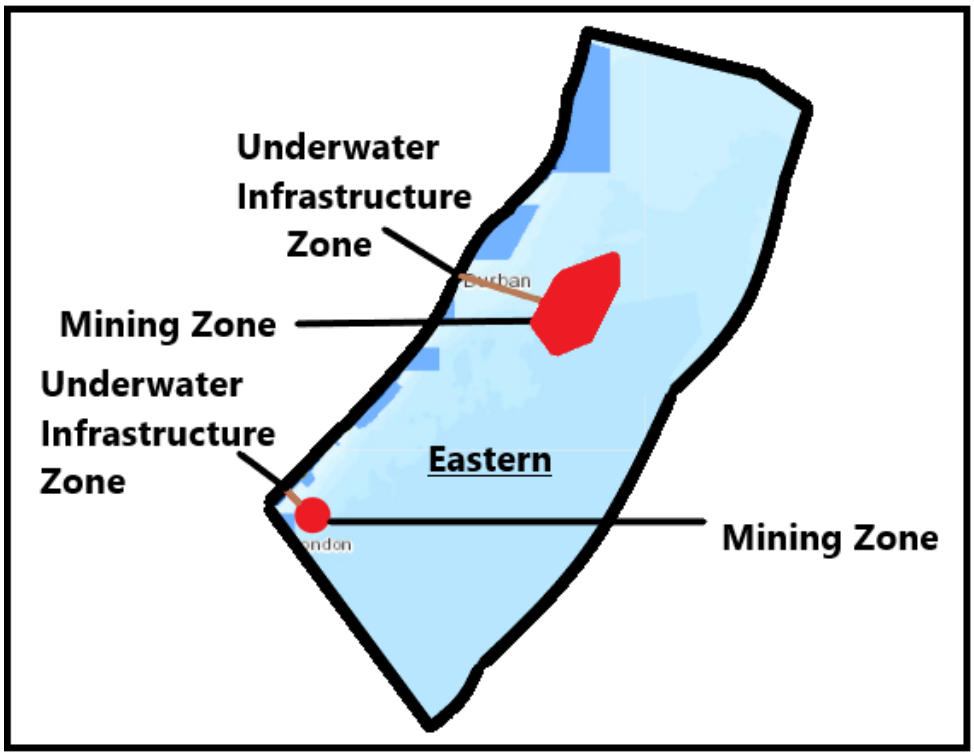

Figure 9.19: Eastern marine area plan

Source: Own compilation from Sections 8.2.3 & 8.3.3

5. Once the management actions have been finalized, it is proposed that the National Working Group oversee the preparation of a draft proposed MAP allowing for inter-departmental and international consultation (refer Section 8.3.3). Key elements within the draft proposed MAP should include a land-use plan indicating the current and envisaged marine activities (including renewable energy uses) along with the management actions for each which should include(among others) a statement regarding the authorities responsible for the implementation of each marine activity (Department of Environmental Affairs, 2017:51).
6. Once the above-mentioned consultation process has been completed it is proposed that the relevant discussions be collated into a report which should assist the National Working Group in making the necessary revisions in collaboration with outside parties (Department of Environmental Affairs, 2017:51). Once all parties concerned are satisfied with the draft, it is proposed that the final MAP be prepared by the National Working Group and approved in terms of Section 14 of the MSPA by the Directors General Committee on Marine Spatial Planning (DGCMSP) and the Ministerial Committee on Marine Spatial Planning (MCMSP) (refer Section 8.3.3).
7. The final proposed MAP should include all the elements of the draft MAP in addition to an implementation plan prescribing how the agreed-upon management actions (as described in stage 4) should be implemented. The prepared MAP will be expressed in the form of a map accompanied by a written document.
8. The National Working Group should monitor the extent to which the proposed management actions have been implemented according to three categories: (1) those that have been successfully implemented; (2) those that have been partially implemented; and (3) those that have made little to no progress (Department of Environmental Affairs, 2017:52). The results, along with recommendations, should then be published in an annual monitoring report that may be made publicly available. MAPs should be revised regularly to allow for new knowledge to be applied, thus making the MAP preparation process a cyclical one.

9.4 Conclusion

This chapter commenced with a synthesis of this study's most relevant findings which was proceeded by the formulation of contextually appropriate proposals. The synthesis combined the various elements of the study creating a textual unit from which meaningful insight was gathered. The potential of regional planning as a development instrument was revealed and meant that the study's main aim of providing a framework in which regional development can be

affected could be achieved. The importance of exploiting endogenous factors of production combined with technology through policy measures to achieve regional development as proposed by the new-growth theory provided the basis for this study as well as the ultimate proposals. The proposals consisted of five parts:

The first part proposed a generic framework based on the new growth theory directed towards the use of renewable energy resources as the endogenous factor and renewable energy technologies as the technological component. Building on this theoretical foundation was the generic planning and subsequent implementation policy framework. As it has been suggested that spatial planning professionals should form an integral part of the energy planning process on a regional scale, it was proposed that renewable energy sector planning (which consists of strategic, infrastructure, and spatial planning) be integrated with regional spatial planning allowing for both planning and implementation of renewable energy strategies.

The second part was based on the generic policy framework (as proposed in the first part), which was adapted to make provision for South African energy sector and regional spatial planning systems and frameworks. The energy sector strategic planning process was proposed to be carried out in accordance with the National Energy Act (NEA) through the Integrated Resource Plan (IRP) and the Integrated Energy Plan (IEP). The energy sector infrastructure planning process was proposed to be carried out by the Presidential Infrastructure Coordinating Committee (PICC) through the National Infrastructure Plan (NIP) Strategic Integrated Projects (SIPs) 8, 9 and 10 as well as by Eskom through their annual Transmission Development Plan (TDP). The energy sector spatial planning process was proposed to be carried out in accordance with the National Environmental Management Act (NEMA) with the aim of identifying specific geographic locations wherein renewable energy can be exploited referred to as Adopted Plan Options (APOs). It was further proposed that identified APOs be included into spatial planning policy frameworks both for terrestrial and marine implementation in accordance with the Spatial Planning and Land Use Management Act (SPLUMA) and the Marine Spatial Planning Act (MSPA) respectively.

The third part focused on the proposed energy sector spatial planning process during which APOs can be identified. The identification process consists of three phases: The first phase identifies areas where sufficient renewable energy resource potential exists, followed up by excluding areas that do not fall within previously identified power corridors (i.e. close proximity to existing or proposed electricity grid infrastructure) resulting in the identification of Draft Plan Options (DPOs). The second phase allows for public participation and consultation to narrow down the DPOs, if necessary, in addition to prevent any future grievances. The third phase narrows down the location of identified DPOs even further and includes a Habitat Regulation

Appraisal, a Socio-economic Impact Assessment, and a Strategic Environmental Assessment resulting in the identification of Adopted Plan Options (APOs).

The fourth part focused on the terrestrial implementation section of the proposed generic policy framework. During this phase, identified APOs are proposed to be included into the Arid Innovation Regional Spatial Development Framework (RSDF). The proposed RSDF should act as the implementation instrument for renewable energy strategies by firstly including identified APOs as part of the spatial proposals on the RSDF map, and secondly by providing the necessary regulatory and institutional arrangements that will allow for renewable energy strategies to be executed in line with the current South African renewable energy procurement process as part of the proposed RSDF implementation framework.

The fifth part focused on the marine implementation section of the proposed generic policy framework. During this phase, identified APOs are proposed to be include into South Africa's Eastern, Southern, and Western Marine Area Plans (MAPs). Renewable energy strategies can be implemented through the proposed MAPs Management Actions containing general development guidelines, sectoral development guidelines and a zoning scheme. Within the sectoral development guidelines, the necessary regulatory and institutional arrangements in line with South Africa's current renewable energy procurement process can be made and the zoning map will act as a land-use management system indicating zones wherein marine activities are permitted or prohibited. The proposed MAPs zones for this study include Mining Zones and Underwater Infrastructure Zones allowing for renewable energy technologies and electrical cables, respectively.

9.5 Future research

This study explored the use of both RSDFs and MAPs to facilitate the implementation of renewable energy in South Africa. Both of these instruments are relatively new, thus limiting this research's ability to be practically applicable. It is proposed that further research be done on how these instruments can be used for renewable energy implementation after the first RSDF and MAPs have officially been developed.

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