A strategic management framework for the commercialisation of multi-technology renewable energy systems: The case of concentrating solar power technologies in South Africa

by

Gregory Stuart Kennedy Prentice

Thesis presented in partial fulfilment of the requirements for the degree of Master of Engineering Management in the Faculty of Engineering at Stellenbosch University

Supervisor: Prof A.C. Brent

Co-supervisor: I.H. de Kock

March 2018

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Signature: …………………………………….

Date: ……………………………………………

Abstract

A strategic management framework for the commercialisation of multi-technology renewable energy systems: The case of concentrating solar power technologies in South Africa

G.S.K Prentice
Department of Industrial Engineering
University of Stellenbosch

Thesis: MEng (Engineering Management)
March 2018

In today's globalised world, mankind faces an increasing number of economic, social, and environmental problems. The complexity and integrated nature of these challenges has led to recognition of the need for sustainable development. One of the underlying elements of sustainable development is the need for clean sources of energy, such as that produced from renewable energy technologies (RETs). In order to increase the rate of adoption of RETs into the global energy supply, there is a need to increase the rate of commercialisation of these types of technologies. It is likely that as the time taken for RETs to reach the market is reduced, a faster rate of adoption will be realised, thus contributing towards the transition to a sustainable energy supply, and sustainable development efforts.

In response to this need, a strategic management framework was developed as a tool to support the development of strategies, aimed at increasing the rate of commercialisation of RETs. Given that many subcomponents of RETs may already be considered commercialised, the conceptual term *multi-technology renewable energy system* (MTRESs) was introduced as an umbrella term for such systems, highlighting the need to focus on those components within the system hierarchy that lie in a pre-commercialised state. As a case study for the framework, concentrating solar power (CSP) technologies in South Africa were selected based on the unique value proposition of CSP, able to operate as a dispatchable, mid-merit, or baseload energy source, the relatively immature state of CSP technologies, and South Africa's immense solar resources.

Following completion of the research study, it is clear that there is no single or universal approach to commercialisation. Comprehensive tools such as the framework developed, which supports strategy development via multiple avenues, are able to provide commercialisation practitioners with a range of options for their toolkit. However, presently there are significant barriers to the use of such tools.

In a demonstration of the current political ecology of South Africa's energy sector, the national government appears not to favour the incorporation of CSP technologies into the country's energy mix on a large scale. This hinders the potential effectiveness of any strategy developed through use of the framework, given the weak market prospects for CSP technologies in South Africa, and possible loss of technology champions likely to use such a tool, especially within the country's solar thermal energy associations. While alternative commercialisation prospects may exist in the global production network of CSP technologies, it is difficult to commercialise a technology for a foreign market.

As such, the framework presents a proof-of-concept approach of how the rate of commercialisation may (theoretically) be increased, should industry conditions permit. Moreover, it encourages dialogue on the subject, while highlighting the need to investigate how buy-in can be secured from different stakeholders in South Africa's energy sector, given the country's complex socio-political dynamics. Lastly, the study contributes towards a recent trend in literature, which aims to move the debate from the analysis of energy transitions towards practical measures aimed at increasing the speed at which such transitions occur, thus accelerating progress towards a sustainable future.

Keywords: Technology commercialisation, concentrating solar power, strategic management framework

Uittreksel

‘n Strategiese bestuursraamwerk vir die kommersialisering van hernubare energiestelsels met verskeie tegnologieë: Die konsentrasie van sonkragtechnologieë in Suid-Afrika

(“A strategic management framework for the commercialisation of multi-technology renewable energy systems: The case of concentrating solar power technologies in South Africa”)

G.S.K. Prentice
Departement Bedryfsingenieurswese
Universiteit van Stellenbosch

Tesis: MIng (Ingenieursbestuur)
Maart 2018

In vandag se geglobaliseerde wêreld, staar die mensdom 'n toenemende aantal ekonomiese, sosiale en omgewingsprobleme in die gesig. Die kompleksiteit en geïntegreerde aard van hierdie uitdagings het gelei tot erkenning van die behoefte aan volhoubare ontwikkeling, en dat hierdie soort probleme nie in isolasie oorweeg of opgelos kan word nie. Een van die onderliggende elemente van volhoubare ontwikkeling, is die behoefte aan skoon bronne van energie, soos dié wat deur hernubare energie tegnologieë (RET) opgewek word. Ten einde die aanwendings koers van sulke tegnologieë as deel van die globale energie-voorsienings industrie te verhoog, is dit nodig om die huidige kommersialisasiekoers te bespoedig. Dit is waarskynlik dat soos die tyd wat dit vir RET's neem om die mark te bereik, verminder word, sal 'n hoër tempo van aanwending gerealiseer word, wat daardeur vêrder bydra tot die oorgang na meer volhoubare energie voorsiening, en ontwikkeling.

In antwoord op hierdie behoefte is 'n strategiese bestuursraamwerk ontwikkel as 'n instrument om die ontwikkeling van strategieë te ondersteun, wat daarop gemik is om die kommersialiseringskoers van RETs te verhoog. Aangesien baie subkomponente van RETs egter reeds as gekommersialiseer gesien kan word, is die konseptuele term multi-tegnologie hernubare energie sisteme (MTRESs) as 'n sambreelterm vir sulke stelsels bekendgestel, wat die klem vestig op die komponente binne die stelselhiërargie wat lê in 'n pre-

gekommersialiseerde fase. As 'n gevallestudie vir die raamwerk, is gekonsentreerde sonkrag-tegnologieë (CSP) in Suid-Afrika gekies, gebaseer op die land se geweldige sonkrag hulpbronne, en die unieke waarde-toevoeging van CSP, wat as 'n versendbare, middel-aanvraag of basislas-energie bron kan funksioneer, en in lig van die feit dat CSP-tegnologië tans nog relatief onvolwasse in Suid Afrika is.

Na afloop van die navorsing studie is dit duidelik dat daar geen enkele, of universele, benadering tot gekommersialisering is nie. Dus, is omvattende gereedskap, soos hierdie raamwerk, wat strategie ontwikkeling via verskeie kanale ondersteun, beter geskik om kommersialisasiepraktisyns met 'n verskeidenheid aanpasbare opsies te voorsien. Daar is egter tans steeds opmerklike struikelblokke in die gebruik van sulke raamwerke.

As ‘n demonstrasie van die huidige politiese ekologie van Suid Afrika se energie sektor, blyk dit dat die regering afgunstig is teenoor die grootskaalse inkorporering van CSP tegnologië in die land se energie voorsienings netwerk in. Hierdie afgunstigheid verhinder die potentisiële effektiwiteit van enige strategie wat ontwikkel is in hierdie raamwerk, gegewe die swak mark vooruitsigte van CSP in Suid Afrika, en moontlike verlies aan tegnologie kampioene wie ideale verbruikers van so raamwerk so wees, veral binne die land se termiese sonkrag verenigings. Terwyl alternatiewe kommersialisasie geleenthede dalk kan bestaan in die globale netwerk van CSP, is dit moeilik om ‘n tegnologie vir ‘n buitelandse mark te komersialiseer.

As sodanig, bied hierdie raamwerk ‘n bewyse-van-konsep benadering van hoe die kommersialiseringskoers verhoog kan word, indien industriële toestande dit toelaat. Verder, moedig hierdie studie diskoers aan op die onderwerp, en in parallel lig dit die nood uit om verdere ondersoek te doen oor hoe aanvaarding verseker kan word by die verskillende belanghebbendes in die Suid Afrikaanse energie sektor, gegewe die land se komplekse sosio-politiese dinamiek. Laastens, dra die studie ook by tot 'n onlangse tendens in die literatuut wat daarop gemik is om die debat te beweeg van die analise van energie-oorgange na praktiese maatreëls. Hierdie maatreëls is daarop gemik om die tempo waarteen sulke oorgange voorkom, te verhoog en sodoende die vordering na 'n meer volhoubare toekoms te versnel.

Sleutelwoorde: Tegnologie kommersialisering, konsentreer sonkrag, strategiese bestuursraamwerk

Acknowledgements

The author would like to acknowledge and thank the following for their contribution to the research study:

- Prof Alan C Brent and Mrs Imke H de Kock for the invaluable supervision given during the entirety of this research study
- The National Research Foundation, for the financial assistance provided during this research study
- Mr Dries Frank Duvenhage and Ms Alita Wilkens for their assistance in editing and translation
- My family, for their continuous support and encouragement during the course of this research study
- All the participants who participated in the validation process, and the valuable feedback they gave

Dedications

The thesis is dedicated to my immediate family, Caryn, Penny, and Graham Prentice, for their unwavering support and faith in me, and to Mr Peter Pare, may you always rest in peace.

Contents

List of Figures

List of Tables

List of acronyms and abbreviations

ANT	-	Actor Network Theory
CRSES	-	Centre for Renewable and Sustainable Energy Studies
CSIR	-	Council for Scientific and Industrial Research
CSP	-	Concentrating Solar Power
CTA	-	Constructive Technology Assessment
CVM	-	Contingent Valuation Method
DBSA	-	Development Bank of Southern Africa
DNI	-	Direct Normal Irradiation
DoE	-	Department of Energy
EIA	-	Environmental Impact Assessment
EPC	-	Engineering, Procurement & Construction
EST	-	Energy Storage Technology
EVA	-	Economic Value Added
FET	-	Further Education and Training
FIT	-	Feed-In Tariff
GDP	-	Gross Domestic Product
GHG	-	Greenhouse gas
GPN	-	Global Production Network
IDC	-	Industrial Development Corporation
ILC	-	Industry Life Cycle
IP	-	Intellectual Property
IPP	-	Independent Power Producer
IRP	-	Integrated Resource Plan
IRR	-	Internal Rate of Return
JiBAR	-	Johannesburg Interbank Average Rate
LCA	-	Life Cycle Analysis
LCOE	-	Levelised Cost of Electricity
LFC	-	Linear Fresnel Collector
LPOE	-	Levelised Profit of Electricity
MAPPS	-	Market Adoption, Promotion and Penetration Strategy
MTRES	-	Multi-Technology Renewable Energy System
MVA	-	Market Value Added
NERSA	-	National Energy Regulator of South Africa
NGO	-	Non-Government Organisation

NIMBY	-	Not-in-My-Back-Yard
NPV	-	Net Present Value
OA	-	Organisational Analysis
OCGT	-	Open Cycle Gas Turbine
O&M	-	Operation and Maintenance
PD	-	Parabolic Dish
PIMBY	-	Please in My Back Yard
PLC	-	Product Life Cycle
PPA	-	Power Purchase Agreement
PTC	-	Parabolic Trough Collector
PV	-	Photovoltaic
R&D	-	Research and Development
RDI	-	Research, Development and Innovation
RE	-	Renewable Energy
REI4P	-	Renewable Energy Independent Power Procurement Programme
RET	-	Renewable Energy Technology
ROA	-	Return on Assets
ROE	-	Return on Equity
ROI	-	Return on Investment
ROS	-	Return on Sales
SASTELA	-	Southern Africa Solar Thermal and Electricity Association
SCOT	-	Social Construction of Technology
SDG	-	Sustainable Development Goal
SOE	-	State Owned Enterprise
STASA	-	Solar Thermal Association of Southern Africa
STERG	-	Solar Thermal Energy Research Group
TA	-	Technology Assessment
TCO	-	Technology Commercialisation Officer
TCB	-	Technology Commercialisation Board
TCT	-	Technology Cycle Time
TDP	-	Transmission Development Plan
TES	-	Thermal Energy Storage
TGC	-	Tradeable Green Certificate
TLC	-	Technology Life Cycle
TM	-	Transition Management
TPB	-	Theory of Planned Behaviour
TRM	-	Technology Roadmap

UOID	-	User-Orientated Instructional Development (model)
USA	-	United States of America
VR	-	Virtual Reality
WCED	-	World Commission on Environment and Development
WTP	-	Willingness-to-pay
ZAR	-	South African rands

Chapter 1

Introduction

Chapter 1 presents an introduction to the research study. The reader is provided with a background to the study, detailing the review of the subject area from which the research problem was defined, as well as placing the study into context. The rationale for the study is explained, followed by an outline of the research problem, and subsequent identification of the study's aim and objectives. The scope of the study is established, together with a discussion of the research design and methodology followed. Lastly, an outline of the thesis and its chapters is provided. Figure 1.1[1] illustrates an overview of the thesis. The figure is presented at the beginning of each chapter, serving to guide the reader through the document, with the current chapter highlighted in black.

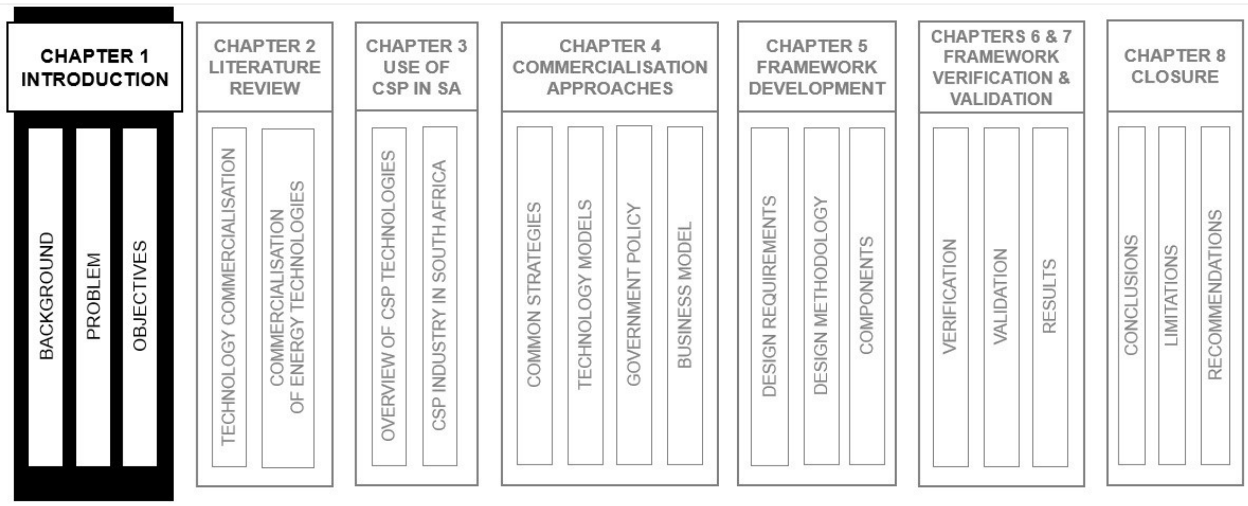


Figure 1.1: Thesis overview

[1] This figure is an adaption of that used by Swart (2015).

1.1 Background

In today's globalised world, mankind faces an increasing number of social, environmental and economic problems (Hopwood, 2005). These challenges are not independent of one another, as there is a growing recognition of the complex relationships which exist between them (Hopwood, 2005). Awareness of the need for multi-faceted and integrated solutions, given that each problem cannot be considered, nor solved, in isolation, has led to the rise in prominence of the concept of sustainable development (see Figure 1.2) (Giddings, Hopwood & O'Brien, 2002). This concept is defined in the now well-known *Our Common Future* report[2] as: "*meeting the needs of the present without compromising the ability of future generations to meet their needs*" (Hopwood, 2005). Through sustainable development[3], interlinked social, environmental, and economic challenges can be addressed, while securing a healthy future for future generations (UNEP, 2015).

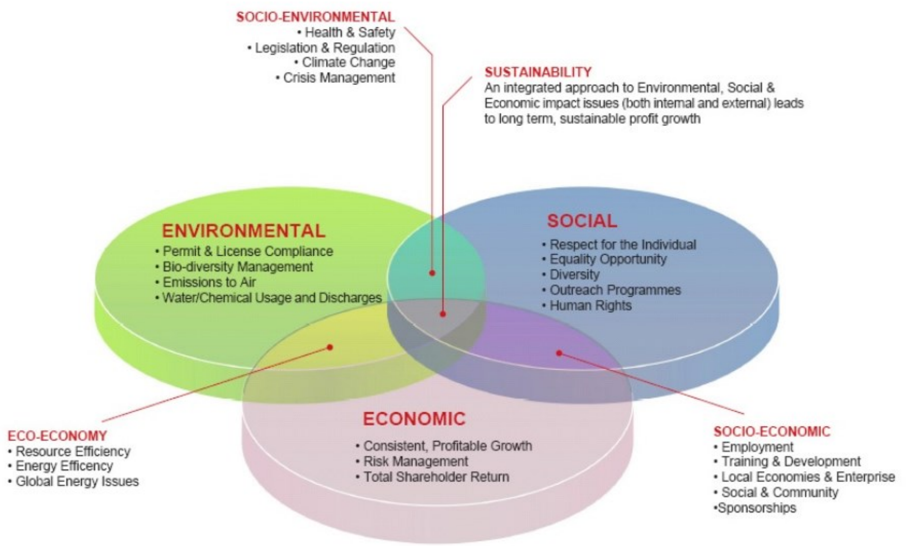


Figure 1.2: Sustainable development

(Source: Samuel, 2009)

One of the key contributors towards sustainable development is energy (Meadowcroft, 2009). Many people lack access to energy globally, especially in developing countries (IEA, 2017), while population growth, and an ever-increasing use of technology in our daily lives, have helped fuel the growing energy demand (Dincer, 2000). In addition, current sources of energy,

---

[2] Also known as the Brundtland Report, published by the World Commission on Environment and Development (WCED) in 1987 (Hopwood, 2005).

[3] Currently, there is considerable debate and ambiguity about the meaning and implications of the term *sustainable development* (Hopwood, 2005). While a full discussion of the term lies outside the scope of this research study, in the context of this study it is understood to refer to the combination, and integration, of elements which collectively are able to address various environmental, social, and economic challenges.

which are dominated by fossil-fuels, have been linked to environmentally-harmful phenomena, such as global warming, air pollution and acid precipitation (Akella, Saini & Sharma, 2009). Hence, in order to meet the goals[4] associated with sustainable development, there is a need to ensure the effective and efficient use, and supply, of sustainable energy resources. Sustainable energy resources are described as being easily and sustainably available at an acceptable cost, and which can be used for all required activities without resulting in detrimental social or environmental impacts in the long-term (World Nuclear Association, 2013).

The need for sustainable energy resources has focused attention on clean energy technologies[5]. These technologies are able to support sustainable development, by addressing the identified energy-related issues through their lower environmental impact, and their potential for enhanced socio-economic development (World Nuclear Association, 2013). There are many different types of clean energy technologies in use today, such as nuclear technologies, (natural) gas technologies, and renewable energy technologies (RETs)[6] (Dincer, 2000).

However, it is arguably RETs that offer the optimal solution towards a sustainable future. Both nuclear and gas technologies rely on finite, albeit substantial, resources (Soon Heng, 2017). There are also environmental considerations. Nuclear waste is radioactive, incurring additional end-of-life costs to dispose of safely (World Nuclear Association, 2017). Gas technologies, given their methane-orientated nature, have the potential to be even more detrimental to the environment than coal and oil. Should leaks exist in these gas systems, they will allow methane to escape into the atmosphere (Bittman, 2013). In comparison, RETs are blessed with a near infinite supply of resources, such as the sun and wind, both of which are considered environmentally friendly (RESET, 2015).

The argument for RETs as the primary sustainable energy technology also needs to be considered from an economic and social perspective, in line with the nature of sustainable development. The renewable energy (RE) industry has experienced tremendous growth over

[4] While each country may have its own set of sustainable development goals, the most well-known goals are the seventeen Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development, which were adopted by global leaders at a UN summit in 2015. These seventeen goals and 169 targets build on the Millennium Development Goals (MDGs) towards addressing the three fundamental elements of sustainable development: economic growth, social inclusion, and environmental protection. (United Nations, 2017)

[5] Defined as energy technologies which emit significantly lower levels of greenhouse gases (GHGs), such as CO_2, into the earth's atmosphere than traditional fossil fuel technologies such as coal and oil.

[6] Defined as any technology which derives its energy from a renewable source, such as the sun, wind, hydro, biofuel, and so forth.

the past decade through billions of dollars of global investment (see Figure 1.3). Such investment comes at a time when commodities, such as oil and coal, continue to enjoy low prices, thereby demonstrating continued commitment by investors to the RE industry (MacDonald, 2016). In addition, many RETs have reached cost parity with established energy technologies, and are even cheaper in some cases (REN21, 2017a). Such economic growth is likely to continue as many nations seek to incorporate a greater share of RETs into their energy mixes (Ferroukhi, Lopez-Peña, Kieffer, Nagpal, Hawila, *et al.*, 2016).

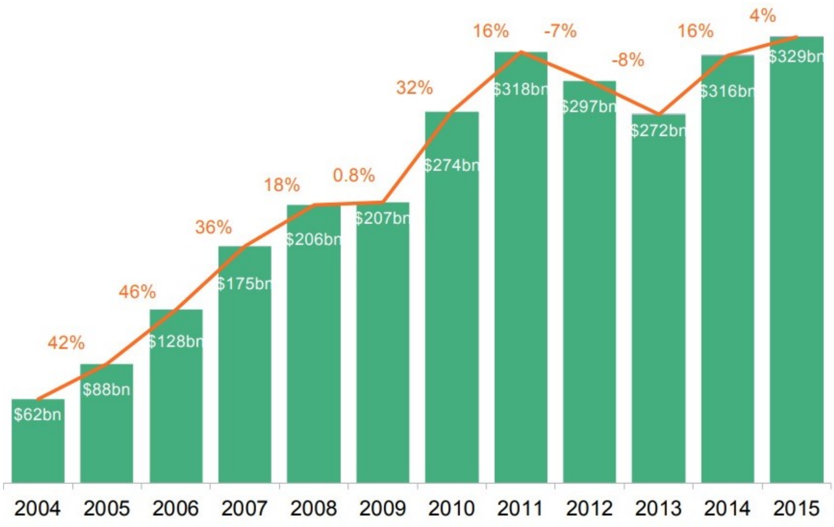


Figure 1.3: Global RE investment 2004 - 2015

(Source: MacDonald, 2016)

From a social perspective, one of the main advantages of RETs is their application as a decentralised source of energy (Blenkinsopp, Coles & Kirwan, 2013). This allows the technology to be used as a cost-effective means of providing energy access to the world's population, especially in rural areas where there is a lack of grid infrastructure (Balachandra, Kristle Nathan & Reddy, 2010). This flexibility can also be of benefit to national grids, where RETs are able to be added in incremental amounts to meet small increases in demand, in comparison to large-scale coal and nuclear power plants (Yelland, 2017). Therefore, while it is acknowledged that the energy mix of the future will likely contain other (clean) energy technologies, this research study will focus on the use of RETs as a means of ensuring a sustainable supply of energy[7] for the future.

[7] While this research study focuses on the use of clean energy technologies, in particular RETs, to develop a sustainable energy supply for the future, it is acknowledged that other elements such as energy savings with respect to energy demand, and efficiency improvements in energy generation, are equally important (Lund, 2007). However, they lie outside the scope of this study.

1.1.1 The commercialisation of renewable energy technologies

Recent evidence has made it clear that a transition to a more sustainable energy sector, containing a greater share of RETs, is currently taking place (Meadowcroft, 2009). However, the global energy supply is still dominated by fossil-fuel technologies (International Energy Agency, 2016). In fact, the actual percentage contribution of RETs to the global energy supply has changed little over the past four decades (see Figure 1.4), with the primary shift being that of oil to coal, nuclear, and natural gas. The RE industry (hydro, biofuels and waste, and others), on the other hand, has grown by only 1.3%. This lack of substantial change can be understood further with reference to Figure 1.5, comparing the levels of growth in the global energy supply of different energy technologies over the same time period.

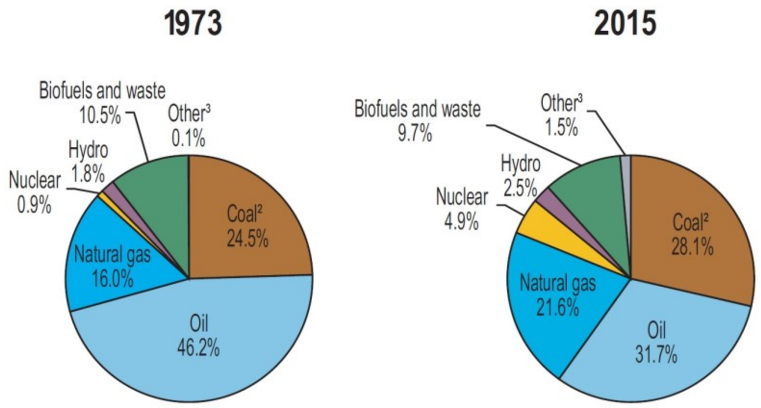


Figure 1.4: Composition of global energy supply - 1973 vs 2015[8](Source: International Energy Agency, 2017)

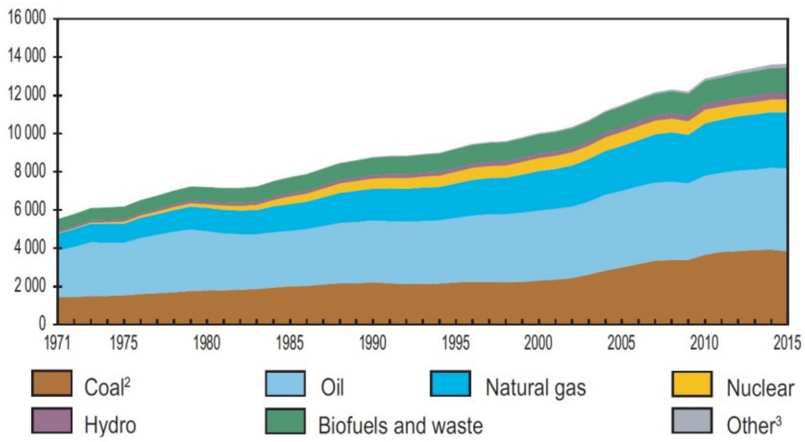


Figure 1.5: Growth in global energy supply 1971 - 2015 by fuel (million tonnes oil equivalent)

(Source: International Energy Agency, 2017)

[8] Other includes energy sources such as geothermal, solar, wind, heat, and so forth (International Energy Agency, 2016). The same description applies to Figure 1.5..

The lack of significant change in the energy sector up to this point is perhaps to be expected, given that despite efforts to *“speed up the development, diffusion and implementation of RETs, experience in different countries show that this is a very slow and tedious process”* (Negro, Alkemade & Hekkert, 2012). If one considers past transitions that have taken place within the global energy sector[9], it is often a decades-long process owing to the complexities of the technological system in place, which comprises multiple integrated technologies, infrastructure, and institutions (Grubler, Wilson & Nemet, 2016).

Yet, there is cause for optimism. There have been instances of rapid energy transitions in the past, although these rates of transition are subject to how they are defined, the circumstances in which they took place, and the set of assumptions used in the analysis of the respective transition (Sovacool, 2016). Kern & Rogge (2016) highlight how the transition to a sustainable energy supply may differ from previous large-scale energy transitions in a number of ways. Past energy transitions have often not been managed purposefully, which is in contrast to the modern era, where there is widespread engagement between many stakeholders who are actively pursuing such a transition. Furthermore, there is international consensus for a more sustainable energy supply, demonstrating that the necessary political will exists in favour of RETs, and other clean energy technologies. Lastly, the use of global innovation dynamics can also be harnessed to increase the rate at which the sustainable energy transition is able to take place. (Kern & Rogge, 2016)

However, Grubler *et al.* (2016) sound a cautionary note, stating that:

> “*there is a risk of failing to communicate that faster transitions, while possible in theory, require a deep understanding of the determinants of the rates of change of complex social, economic, and technological systems that need to be translated into carefully designed policies, incentives, and communication strategies in order to achieve accelerated transition*.”

Nonetheless, based on the evidence presented, it is possible that a transition to a sustainable energy sector may not take as long as previous transitions. While acknowledging that there are practical limits concerning (the speed of) such transitions (Grubler *et al.*, 2016), in order to realise the target of a sustainable energy supply as soon as possible, there is a need to increase the rate at which RETs are adopted into the global energy mix. Yet this is no simple task, given that “*despite many efforts of governments, multilateral institutions, NGO’s, and even a number of companies and investors, there has been no sustained take-off”*

---

[9] Defined as: “*a change in the state of an energy system as opposed to a change in an individual energy technology or fuel source*” (Grubler *et al.*, 2016).

(Balachandra *et al.*, 2010). The task is complicated further in the face of the numerous systematic barriers currently limiting the development and diffusion of RETs (Negro *et al.*, 2012).

One of the primary arguments used against the adoption of RETs is that they have not reached the same level of maturity as other more established energy technologies (EPRI, 2015), with their intermittent nature and high cost often cited as motivating factors behind any decision not to adopt them (Pyke, 2017). However, these arguments are fast losing credibility, due to the ability of energy storage technologies (ESTs) (Yekini Suberu, Wazir Mustafa & Bashir, 2014) and hybrid RE systems (Mohammed, Mustafa & Bashir, 2014) to mitigate the intermittency issue. Moreover, many RETs have experienced significant cost reductions, some of which have become cost-competitive with established energy technologies (REN21, 2017b). However, despite this progress, it is clear that based on the present technology life cycle (TLC) stage of different RETs (see Figure 1.6), many of them still require a considerable degree of effort to reach full maturity.

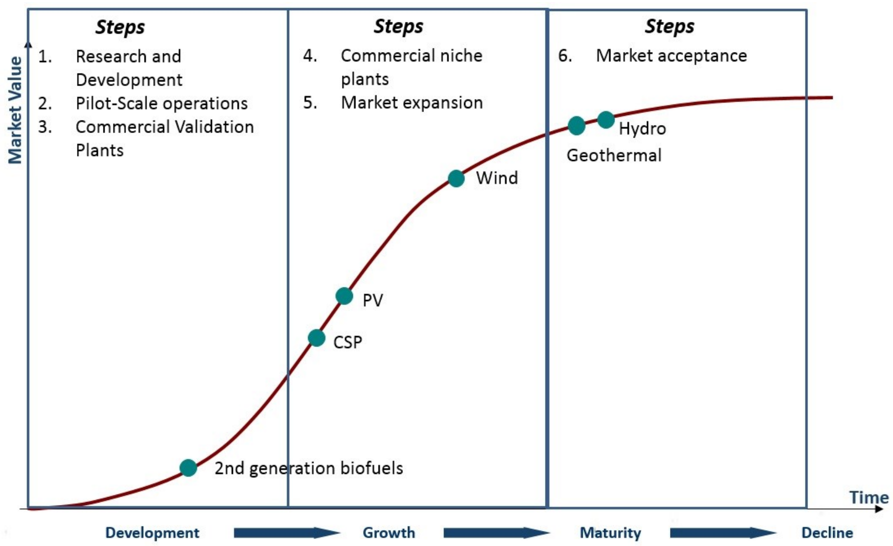


Figure 1.6: Global technology life cycle positions of various RETs

(Source: Grobbelaar, 2016)

In order to increase the rate at which RETs are adopted into the global energy mix, there is a need to increase the rate of commercialisation[10] of such technologies. By increasing the rate of commercialisation, namely: the speed at which RETs are able to reach the market, it is

[10] While technology adoption and commercialisation share a relationship, technology adoption is positioned as the wider process in which commercialisation plays a role. This is valid if we consider that technology diffusion, of which technology commercialisation is an internal process, maps the change in the rate of adoption over time (see Chapter 2, Figure 2.1). Furthermore, the greatest level of adoption typically occurs only after a technology has reached commercial status (Balachandra *et al.*, 2010).

likely that the time taken for RETs to reach maturity will be reduced. Thus, they are more likely to present a feasible option regarding the choice of which energy technology to use. Once RETs are able to compete on a level basis with other energy technologies, it is likely that the environmental benefits they offer will cement their status as a preferred energy technology. This will enable greater progress to be made towards a global sustainable energy supply[11], and contribute towards sustainable development.

It is acknowledged that increasing the rate of commercialisation of RETs to reach maturity is not the only factor responsible for increasing the rate of adoption of RETs in the global energy supply, and achieving a sustainable energy transition, given that energy transitions are "*irreducible to a single cause, factor, or blueprint*" (Sovacool, 2016). Many factors exist (He, 2014), one of which is a heavy reliance on political commitment at all levels of decision-making (Kern & Rogge, 2016). Hence, while the author does not presume to attach a specific level of importance to commercialisation over other factors, this research study limits its scope to the field of technology commercialisation.

1.2 Rationale for the research study

Achieving an increased rate of commercialisation will have a number of benefits. As previously mentioned, the increased rate will improve the rate of adoption of RETs into the global energy mix, thereby nurturing progress towards a global sustainable energy supply, and contributing toward sustainable development efforts. In addition, it is likely that achieving such a goal will have a number of other benefits.

Established carbon-based energy sources, such as coal and oil, are faced with a number of restrictions which have been receiving greater prominence of late, such as a finite source of supply, price fluctuations, and increasing costs (Aslani & Mohaghar, 2013). Given the considerable financial capital invested in the RE industry recently (Masini & Menichetti, 2013), organisations are finding the margin for error quickly diminishing as the industry becomes more competitive (Hartmann & Huhn, 2009). The ability to deliver RE at low prices offers firms a source of competitive advantage, and greater market share, in the energy industry (World Economic Forum, 2016).

As more RETs reach a commercialised state, the RE industry is likely to experience rising levels of growth, with new products and technologies able to establish themselves in the

---

[11] The attainment of a global sustainable energy supply is to be measured through the composition of the global energy supply, being a more accurate depiction of the actual change achieved than, for instance, the annual level of new financial investment (Grubler *et al.*, 2016).

market faster, and with improved resilience to (detrimental) market forces (World Economic Forum, 2016). An increase in the survival rate of RETs will likely have a domino effect, spurring development across multiple industries in the form of (supportive) financial operations, associated (energy) services, manufacturing activities, and employment opportunities (Hartmann & Huhn, 2009). The cumulative effect of such development will lead to greater economic growth worldwide (Balachandra et al., 2010). This will prove particularly advantageous for developing countries such as South Africa, which frequently prioritise socio-economic development over other goals, to alleviate poverty levels, and reduce inequality (Nahman, Wise & Lange, 2009).

Socio-economic growth may prove particularly relevant for rural communities, which often lack access to basic services such as energy due to their location, away from national grids and urban centres (Stapleton, 2009). This lack of access to energy inhibits poverty reduction, identified as one of the key elements of the SDGs (United Nations, 2017). As a viable solution, RETs have been recognised as a cost-effective means for overcoming this barrier, assisting socio-economic development in the process (Akella *et al.*, 2009).

Security of energy supply is another challenge faced in the modern era (Aslani, Naaranoja & Wong, 2013). The need for a secure energy supply, due to factors such as rising fuel prices and the finite supply of fossil-fuel sources, has prompted many governments to take steps to diversify their energy mix, often through the inclusion of RE sources (Rao & Kishore, 2010). This problem, which is likely to grow with a predicted increase in global energy demand (Dincer, 2011), is more prevalent in developing countries that encounter persistent grid instability, and a lack of financial resources to fund grid extensions to the entire population (Thiam, 2011).

The environmental impact also acts as an important driver towards increasing the rate of commercialisation of RETs (Blazejczak, Braun, Edler & Schill, 2014). Traditional sources of energy have a detrimental effect on human society and the natural environment, through phenomenon such as global warming, acid rain, and air pollution (Akella *et al.*, 2009). Global warming, in particular, has received greater attention from world leaders in recent years, recognising the need to secure a universal climate deal that ensures lasting agreements to cut GHG emissions, and limits the influence of global warming on the environment (Harvey, 2015).

The negative impact of global warming is arguably best characterised by the rise in global temperatures. This impact is widely associated with being responsible for extreme weather conditions of increasing frequency and magnitude, such as the rise in sea levels, droughts, floods, and heatwaves (Harvey, 2015). These adverse weather effects place the most vulnerable groups of human society at risk, such as low-income groups, the elderly, and indigenous populations (United States Enviromental Protection Agency, 2017), as well as inhabitants in many low-lying areas, such as the Solomon Islands in the Pacific Ocean(Reuters, 2016). The use of low-carbon technologies, such as RETs, is thus vital to efforts aimed at safeguarding the environment (Negro *et al.*, 2012).

Finally, completion of this research study will aid the development of the knowledge base regarding mechanisms used to increase the rate of commercialisation of RETs. Moreover, the research will highlight potential avenues for further research in the field towards the broader aim of increasing the rate of adoption of RETs in the global energy supply, thereby achieving a sustainable energy supply, and contributing towards sustainable development. In addition, Suzuki (2013) emphasises how the expansion of this knowledge base may prove especially important in strengthening the existing institutional support offered to RETs, through greater information availability, as well as increased local capacity for managing such technologies.

1.3 Multi-technology renewable energy systems

It is important to recognise that of the numerous technologies which comprise RE systems (Lund, 2009), many may already be considered mature, with no need for individual commercialisation, such as turbines, pumps, and compressors. To address this fact, the term *multi-technology renewable energy system (MTRESs)* is introduced. ‘Multi-technology’ acknowledges the hierarchy of such systems and the differences in the state of commercial maturity, while ‘renewable energy system’ is used as an umbrella term to describe the integrated collective of technologies used to harness power from RE sources. Thus, while the term MTRES is essentially conceptual in nature, it holds value in drawing attention to the need to distinguish commercialisation efforts between those technologies of RE systems that are already commercialised, and those technologies that lie in a pre-commercialised state. As such, it will be used from here onwards in the study in place of RETs.

One of the prominent challenges encountered with RE is the variable nature of supply (Gauché, Rudman, Mabaso, Landman, von Backström, *et al.*, 2017). Energy can only be harnessed under certain conditions; for example, when the sun is shining, or the wind is blowing (Gauché *et al.*, 2017). This has led to a strong focus on the use of ESTs, which are able to store energy, and thus extend the hours of electricity generation (REN21, 2016). A popular EST is that of thermal energy storage (TES), which stores energy in the form of heat (Romero & González-Aguilar, 2014). One MTRES that is particularly suitable for integration with TES technology is concentrating solar power (CSP) (Baharoon, Rahman, Omar & Fadhl, 2015).

CSP technologies[12] present a viable means of storing and providing energy when needed, overcoming one of the chief barriers to the widespread use of MTRESs (Grobbelaar, Gauche & Brent, 2014). Furthermore, CSP technologies have the potential for system hybridisation, as well as being a scalable technology that can operate in off-grid situations (Grobbelaar *et al.*, 2014). Lastly, if one considers Figure 1.6, it is clear that extensive progress still needs to be made with respect to CSP before it reaches a state of maturity, and is able to contribute significantly to the transition towards a sustainable energy supply. As such, CSP presents an interesting case study for exploring the rate of commercialisation of MTRESs may be increased.

Figure 1.7 presents a direct normal irradiation (DNI) map of the world's solar irradiation resources. As shown, Southern Africa has some of the best solar resources, together with Australia and the western coasts of North and South America. However, despite the abundance in solar resources, the CSP industry in South Africa, known as the regional powerhouse of Southern Africa, remains largely underdeveloped (Grobbelaar *et al.*, 2014). In South Africa, only a small number of CSP projects have been commissioned under the country's Renewable Energy Independent Power Procurement Programme (REI4P) (Gauché *et al.*, 2017). Hence, this study will focus on the case of CSP technologies in South Africa.

[12] CSP technologies represent a class of (solar) energy generation technologies which convert sunlight into thermal heat for the purposes of generating thermal energy and/or electricity, with several different variations in design type. They are differentiated from other solar thermal energy technologies through their focus on higher levels of solar radiation flux densities, which allow for higher temperatures and system efficiencies, thus improving the feasibility of electricity production. (Gauché *et al.*, 2017)

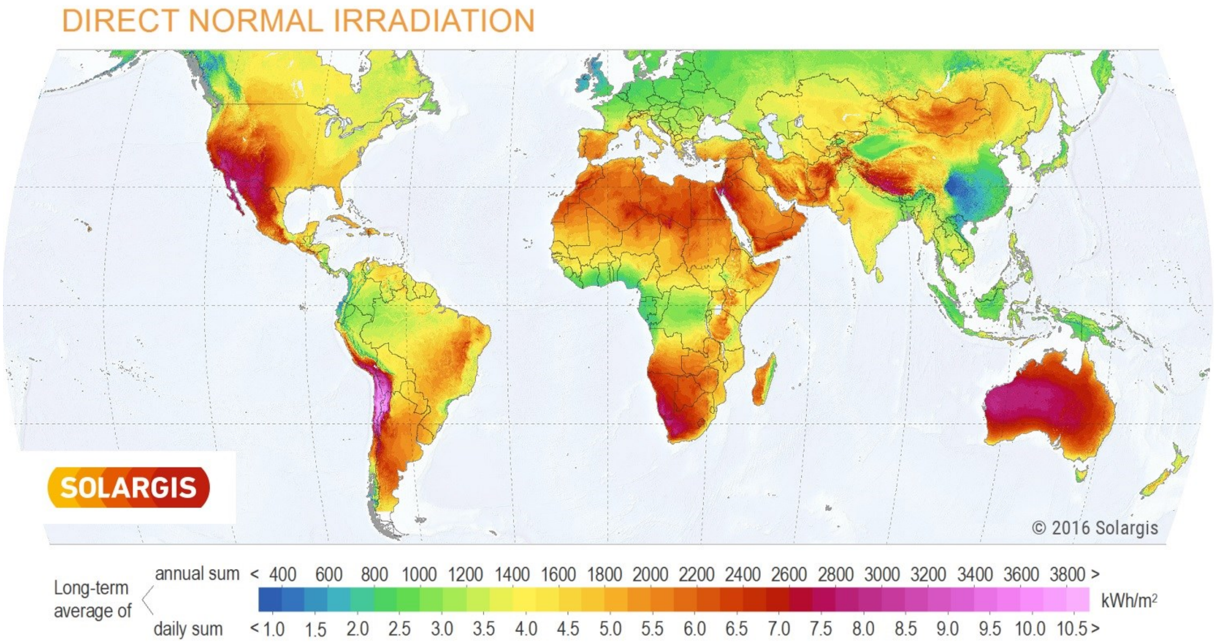


Figure 1.7: Global DNI map

(Source: Solargis, 2016)

1.4 Research problem

The problem statement for this research study is as follows: to assist and improve progress towards a global sustainable energy supply, there is a need to increase the rate of adoption of MTRESs within the global energy mix. This increased rate can be assisted by increasing the rate of commercialisation of MTRESs, such as CSP technologies in South Africa. The following research questions are raised:

- What are some of the key factors currently limiting the rate of commercialisation of MTRESs, specifically CSP technologies in South Africa?
- What are some of the existing approaches presently used towards the commercialisation of MTRESs, and how may they be applied to CSP technologies in South Africa?
- Which approach, tools and/or methods should be used, or developed, to increase the rate of commercialisation of CSP technologies in South Africa?
- How does the chosen approach, tools and/or methods support efforts to increase the rate of commercialisation of CSP technologies in South Africa?

By addressing these research questions, it is intended that the rate of commercialisation of CSP technologies in South Africa will be increased. Despite the localised focus, the research study may hold lessons for other MTRESs, thereby potentially resulting in a greater adoption of MTRESs into the global energy mix. Ultimately, this may lead to a more sustainable global energy supply, as well as contributing towards sustainable development.

1.5 Research aim & objectives

1.5.1 Aim

The aim of this research study is to develop an approach to increase the rate of commercialisation of CSP technologies in South Africa.

1.5.2 Objectives

The primary objective is the development of an approach to increase the rate of commercialisation of CSP technologies in South Africa. The secondary objectives are as follows:

i. Identify existing barriers currently limiting the commercialisation of MTRESs, specifically CSP technologies in South Africa.
ii. Evaluate past and existing efforts for the commercialisation of MTRESs, and their applicability to CSP technologies in South Africa.
iii. Document the process followed to develop an approach for increasing the rate of commercialisation of CSP technologies in South Africa.
iv. Verify that the approach developed addresses all the existing barriers to commercialising MTRESs identified, specifically those relating to CSP technologies in South Africa.
v. Validate the approach developed by engaging with experts in the field.
vi. Refine the approach developed based on feedback received from experts.

1.6 Research scope

The scope of the research study needs to be established to ensure that the focus remains on the study's objectives. This involves a discussion of both internal and external aspects to the research study, as well as factors responsible for the delineation of the study. In the past, the commercialisation of technologies within the energy sector has been dominated by government-related efforts (Balachandra *et al.*, 2010). However, the ineffectiveness and persistent uncertainty of such efforts relating to MTRESs in the modern era suggests that other factors should also play a role in attempts to commercialise MTRESs. Moreover, these additional factors need to be considered in the development of any commercialisation approach. As such, the research study was intentionally given a wide scope, as represented by the broad nature of the primary objective.

While the subject of technology commercialisation is covered in Chapter 2, it is necessary to state what is understood by the term 'technology'. While an extensive review of the etymology of the term is considered outside the scope of the study, Pieterse (2005) identifies several descriptions from literature, which are adopted here. According to Khalil (2000), technology is understood to be "*all the knowledge, products, processes, tools methods, and systems employed in the creation of goods or in the provision of services"*, while also referring to Pieterse's (2005) definition of "*the integration of people, knowledge, tools, and systems with the objective to improve people's lives*", and Van Wyk's (1988) description of the "*created capability manifesting in artefacts with the purpose of which is to augment human skill*."

As previously mentioned, CSP technologies represent a class of solar thermal energy generation technologies that convert sunlight into thermal heat to produce thermal energy and/or electricity (Gauché *et al.*, 2017). However, it is a complicated technology due to its many internal components, along with different design types, uses, and operating environments, for the purposes of generating thermal energy and/or electricity (Gauché *et al.*, 2017). As a result, this research study concerns itself with a macro-level view, covering the entire class of the technology. A 'CSP commercialisation universe', illustrated in Figure 1.8, describes the boundary points set for the study in terms of the commercialisation process (horizontal axis), the class of CSP technology (vertical axis), and the South African context. TES is also included in the classification as a CSP technology, given the role it plays in CSP's potential to operate as a dispatchable technology, as well as the associated production processes.

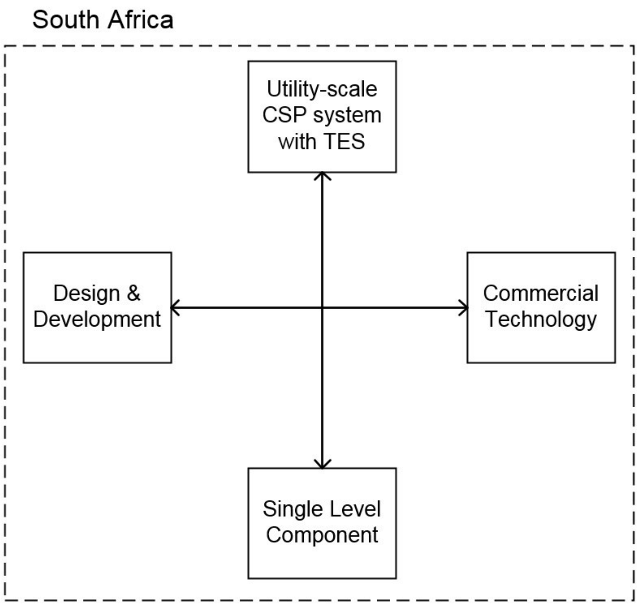


Figure 1.8: CSP commercialisation universe

Another point to mention is the scope selected for the literature review (Chapters 2 and 3). Technology commercialisation is a complex and multi-faceted process (Thosago, 2011). As a result, the 5W1H model was chosen to address the more important questions in order to present the reader with a solid understanding of the field, with the answers guiding the direction of the research study. However, it remains possible that other aspects, of equal importance relating to the commercialisation process, may exist, and were not covered in the review. These aspects could have influenced the approach developed to increase the rate of commercialisation of CSP technologies in South Africa.

The evaluation of existing strategies, approaches and techniques for the commercialisation of MTRESs saw a number of different methods assessed to identify their strengths and weaknesses. This list comprises the strategies the researcher encountered most often in a study of the relevant literature. However, it is acknowledged that a more thorough literature review may have given greater importance to those approaches not mentioned, or revealed other legitimate approaches not identified. This in turn would have affected the scope established for the development of the commercialisation approach of this research study, which is based primarily on the strengths and weaknesses of the different approaches evaluated.

1.7 Research strategy

1.7.1 Research approach

A research approach is defined by Bryman, Bell, Hirschsohn, Dos Santos, Du Toit, *et al*. (2011:30) as: "*a general orientation to the conduct of business research"*, acting as a broad guide to a specific research question, and the underlying subject material. There are two principal approaches utilised in research studies: quantitative research, and qualitative research. Quantitative research is a deductive approach based on (scientific) studies, typically involving gathering and analysing large quantities of (numerical) data to test theories and hypotheses (Bryman *et al.*, 2011:30). Moreover, it involves analysing the relationships between associated variables (Creswell, 2009:4). Qualitative research, on the other hand, is an induction-based approach that focuses on the diction, graphics, and actions ascribed to social or human issues (Creswell, 2009:4; Bryman *et al.*, 2011:30), and/or subsequent formation of (social) theories (Bryman *et al.*, 2011:30).

Although quantitative and qualitative approaches are used to categorise the majority of research studies, the lines between the two approaches are often blurred. This results in many studies that fall into both groups. These studies are termed 'mixed methods research', which combines elements of both approaches into a single approach. Mixed methods research is favoured for its ability to harness the strengths of both research approaches, while mitigating some of the existing weaknesses to a certain degree. (Bryman *et al.*, 2011:56)

There are several factors which influence the choice of research approach, including the nature of the research, and associated research questions, which exert a strong influence over which approach may be more appropriate for a given study. One needs to consider the issues faced by the different approaches pertaining to reliability and validity, as well as which measurements and indicators to use (Bryman *et al.*, 2011:33). In addition, there are concerns specific to each research approach. Quantitative studies are confronted by issues regarding measurement, causality, generalisation, and replication (Bryman *et al.*, 2011:49). In contrast, qualitative studies face questions of trustworthiness, genuineness, transparency, subjectivity, and relevance (Bryman *et al.*, 2011:43). Mixed methods research also encounters constraints, such as those relating to its practical implementation due to available resources (Bryman *et al.*, 2011:66).

Although this research study is predominantly qualitative in nature, the inclusion of a few quantitative aspects classifies the research approach used, as mixed methods research. First, a deductive approach (quantitative) was followed through the development and verification of a conceptual model (qualitative) from the literature in response to the research problem. Second, an inductive approach (qualitative) was deployed, validating the model through engagement with experts (quantitative), and using the feedback received to refine the model (qualitative), and increase the existing base of knowledge (qualitative).

The risk exists with any research topic that the question in mind, or approach proposed, may already have been the subject of numerous studies. The vast multitude of publications makes it difficult for prospective researchers to be sure that any study is not merely a duplication of someone else's work. Consequently, large databases exist, providing a means of investigating whether a research problem has already been sufficiently addressed.

The following databases were used to examine past studies conducted in the field for potential duplication, as well as search for articles relevant to the research study: the online library at Stellenbosch University, SunScholar[13], Google Scholar, Nexus[14], NiPAD[15], and the Web of Science. While several studies have covered the subject of the commercialisation of MTRESs,

[13] A digital archive for research conducted at Stellenbosch University.

[14] A South African database covering both degree and non-degree research in the fields of social sciences and humanities (Mouton, 2001:31).

[15] A database covering research conducted in Africa.

it was found that there was an absence of an approach regarding the specific case of CSP technologies in South Africa, and one which sought to address (in sufficient detail) the practical side of the commercialisation process, instead of merely analysing the process and associated activities.

A final comment on the subject of research approaches draws on the work of Creswell (2009:5), where an approach is defined as: "*the intersection of philosophy, research design, and research methods*". This intersection is illustrated in the framework of Figure 1.9.

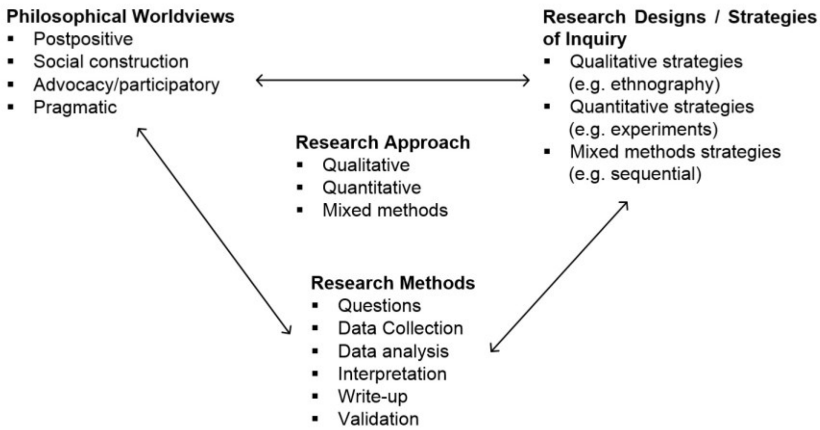


Figure 1.9: Framework for research approach

(Source: adapted from Creswell, 2009)

1.7.2 Philosophical worldviews

There are four dominant philosophical worldviews which influence a researcher's choice of research approach: postpositive, social construction, advocacy/participatory, and pragmatic (Creswell, 2009:5). These worldviews are summarised in Table 1.1. This research study is predominantly aligned with the pragmatic view, in line with the mixed-methods research approach selected.

Table 1.1: Philosophical worldviews

Post positivism	Constructivism
• Determination	• Understanding
• Reductionism	• Multiple participant meanings
• Empirical observation and measurement	• Social and historical construction
• Theory verification	• Theory generation
Advocacy/Participatory	**Pragmatism**
• Political	• Consequences of actions
• Empowerment issue-orientated	• Problem-centred

• Collaborative	• Pluralistic
• Change-orientated	• Real-world practice orientated

(Source: Creswell, 2009:6)

1.7.3 Research design

A research design[16] is defined by Bryman *et al.* (2011:100) as: *"a framework for the collection and analysis of data"*, guiding the choice, and application, of the research method(s)[17] used, and ensuing data analysis. The selection of a research design, similar to that of a research approach, depends on the nature of the research being conducted, the research question(s) to be answered, and the personal preference of the researcher, together with the emphasis placed on different aspects of the research process (Bryman *et al.*, 2011:100).

Bryman *et al.* (2011:100) present five research designs used in research studies: (1) experimental, (2) cross-sectional (social surveys), (3) longitudinal (ethnographic studies), (4) case study, and (5) comparative design. A similar classification is proposed by Creswell (2009:12) in Table 1.2. Each design has its own set of strengths and weaknesses that need to be evaluated in the context of the research's objectives, thereby assessing the suitability of the different design types for the respective study (Bryman *et al.*, 2011:100).

Table 1.2: Research designs

Quantitative	Qualitative	Mixed Methods
• Experimental designs • Non-experimental designs, such as surveys	• Narrative research • Phenomenology • Ethnographies • Grounded theory studies • Case study	• Sequential • Concurrent • Transformative

(Source: Creswell, 2015:12)

The approach developed to increase the rate of commercialisation of MTRESs in this research study was designed based on the design methodology outlined in Chapter 5, and did not make use of any of these design types. The validation process, on the other hand, made use of primary data gathered through a comparative[18] research design, as well as a grounded theory design. Experts in the field were used as data sources, comprising an individual level of

[16] Also known as a strategy of inquiry (Creswell, 2015:5).

[17] A research method is a procedure for gathering data, and is often associated with certain types of research designs. Research methods include: observations, interviews, and questionnaires. (Bryman *et al.*, 2011:100)

[18] A comparative research design uses similar methods, or contrasting sets of circumstances, to identify relevant similarities or differences (Bryman *et al.*, 2011:114).

analysis where the data collected was compared against each other. This comparison was used to assess the validity of the commercialisation approach developed towards addressing the study's objectives.

1.7.4 Ethical issues

Ethical issues often arise during research studies that contain human engagement. Awareness of such problems allows for action to be taken to address them in an appropriate manner. Bryman *et al.* (2011:120) highlight that ethical concerns frequently emerge as a result of (1) the potential for harm to participants, (2) an absence of informed consent, (3) a violation of privacy, and (4) deception of participants. These concerns are elaborated on as follows:

1. Harm to participants. While the research study does not present the potential for any physical harm to participants, it is acknowledged that association with the study may be perceived as causing harm in a non-physical sense, such as emotional stress, or reduced employment opportunities. To mitigate such circumstances, participants' identities were kept confidential at all times.
2. Absence of informed consent. A lack of informed agreement regarding participation in the research study, manifested through participants' ignorance or misunderstanding of the study's objectives, and associated implications and considerations, may have fostered distrust in the research process. To prevent such a situation, efforts were made to ensure clear and concise communication with participants, reducing the potential for any confusion regarding the study's objectives.
3. Violation of privacy. It was possible that during the research study sensitive information relating to the participants may have been disclosed. This concern is made more complicated given the political nature of the energy sector (Hall, Lacey, Carr-Cornish & Dowd, 2015). As such, the decision was made to ensure that all reasonable efforts be taken to keep the private details of participants confidential throughout the study.
4. Deception of participants. To limit the potential for deception during the research study, the researcher clearly and openly conveyed all relevant information to the parties involved, such as that relating to the data collected during the study, fostering transparency and trust in the research process.

1.8 Thesis outline

This section outlines the structure of the thesis, as displayed in the figure at the beginning of each chapter (see Figure 1.1). The chapters address the primary and secondary objectives of the research study in a sequential manner, with a logical flow of ideas and concepts guiding the discussion of the research study.

Chapter 1: Introduction

Chapter 1 provides an introduction to the research study. It discusses the background from which the research problem was identified, the rationale behind the study, as well as the MTRES chosen as a case study: CSP technologies in South Africa. The aim of the study is defined, together with the primary and secondary objectives, the research scope, and the design and methodology employed. Lastly, an outline of the entire thesis report is presented.

Chapter 2: Technology Commercialisation

Chapter 2 presents the first part of the literature review conducted. A systematic analysis[19] was chosen for a review of the relevant theory related to the research study, exploring the process of technology commercialisation through the use of the 5W1H model, namely: what, why, when, who, where and how. These questions were then applied to the commercialisation of energy technologies, with a focus on MTRESs.

Chapter 3: The use of CSP in South Africa

Chapter 3 continues the literature review with an examination of the use of CSP in South Africa. This includes an overview of CSP technologies, the progress made by CSP technologies under the REI4P, the supply and value chains of the technology, supply- and demand-side management, and prospects for the future development of the industry in South Africa.

Chapter 4: Strategies, Approaches, and Techniques for the Commercialisation of MTRESs

Chapter 4 concludes the literature review conducted. Building on the foundation established in Chapter 2, an evaluation was conducted of different strategies, approaches, and techniques for the commercialisation of MTRESs. The full evaluation is provided in Appendix A, with Chapter 3 merely providing a summary. The evaluation was conducted to analyse existing efforts for commercialising MTRESs, and their applicability to the case of CSP technologies in South Africa.

Chapter 5: Development of the Strategic Management Framework

Chapter 5 documents the process used to develop the strategic management framework. The framework was designed based on the strengths and weaknesses of the commercialisation

---

[19] A systematic literature analysis is an evidence-based comprehensive analysis of the relevant material relating to a specific research question or subject, with the aim of aiding management practitioners and decision-makers (Bryman *et al.*, 2011:94). It is worth noting that there are six common types of literature review: systematic analysis, narrative analysis, conceptual analysis, traditional analysis, critical analysis, and state of the art analysis (Petticrew & Roberts, 2006:38).

strategies evaluated in Chapter 4. Chapter 5 covers the design of all internal components, while providing justification of all the decisions made. Consideration was also given to the implementation of the framework, and the interfaces which exist between the various components.

Chapter 6: Verification of the Strategic Management Framework

Chapter 6 discusses the verification of the strategic management framework. This was done by matching the framework and its components to the design requirements, accompanied by a discussion of how the framework could potentially meet these requirements in practice.

Chapter 7: Validation of the Strategic Management Framework

Chapter 7 describes the validation process followed through use of a hybrid-Delphi technique. The results of the process are analysed, with mention made with regards to any changes applied to the framework to better address the research's objectives.

Chapter 8: Closure

Chapter 8 closes the research study by discussing the conclusions drawn, together with the contribution to theory of the study, the limitations encountered, and recommendations for future research.

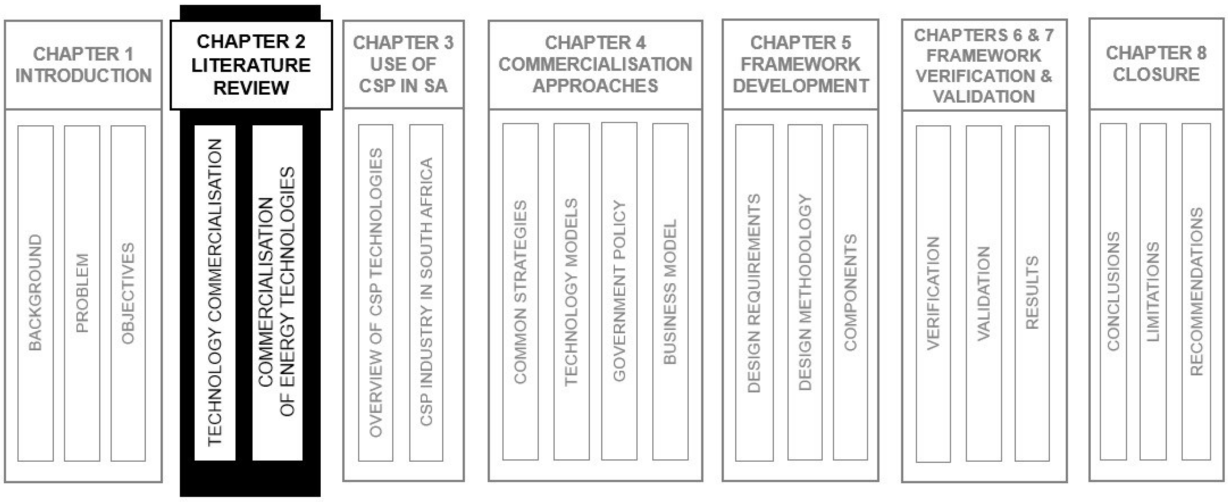
1.9 Summary: Introduction

Chapter 1 provided an introduction to the research study for the benefit of the reader. It discussed the background from which the research problem was identified, namely: a need to increase the rate of commercialisation of MTRESs as part of broader efforts to increase the rate of adoption of MTRESs into the global energy supply, thereby supporting the development of a sustainable energy supply, and contributing towards sustainable development. The rationale behind the research study was discussed, as well as the technology chosen as a case study: CSP technologies in South Africa. The aim of the study was defined, together with the primary and secondary objectives, as well as the factors which contributed to the scope set for the research study, along with the design and methodology selected. Lastly, an outline of the entire thesis report was presented. The following chapter, Chapter 2, presents a review of the literature conducted as part of the research study.

Chapter 2

Literature Review

Chapter 2 presents the first part of the literature review conducted as part of this research study. The subject of technology commercialisation is explored, followed by an investigation of its connotations with respect to energy technologies, with a focus on MTRESs. From the outset, it was anticipated that the greater percentage of literature may pertain to RETs, rather than MTRESs. Instead of discarding these studies, they were included based on their relevant applicability to the literature analysis, and overall research study.



2.1 Technology commercialisation

The field of technology commercialisation is receiving greater attention, specifically from firms eager to preserve and improve their source(s) of competitive advantage amidst an increasingly competitive business environment (Li, 2015). In addition, it is also receiving attention in the policy domain and social science fields, given the close interaction of technology with consumer habits and lifestyles, business models, and socio-political structures (Markard, Raven & Truffer, 2012). However, it remains a complex subject, possessing different meanings and connotations to different individuals (Brzustowski, 2008). In order to assist our exploration of technology commercialisation, the 5W1H[20] model serves as a useful starting point to obtain a clear understanding of the process's fundamentals.

2.1.1 What is technology commercialisation?

The first question to be addressed is what is technology commercialisation? Technology commercialisation is defined by Scott (2012) as: the "*process of introducing a new product or system into the market using new or improved techniques or tools"*. Balachandra *et al.* (2010) provide a more market-focused definition of technology commercialisation: *"the creation of self-sustaining markets that thrive - without any kind of favour - in a level playing field with other competing technologies".* However, they agree that the process involves "*moving a technology from laboratory to market acceptance and use, thus taking it to mainstream economic activity"*. Through commercialisation, a technology is able to compete with other established technologies, satisfying expectations relating to its performance and reliability, while being available at a cost that the consumer is willing to pay (Balachandra *et al.*, 2010). Lastly, it is important to recognise that the net objective of the commercialisation process is to generate revenue (The Department of Trade and Industry of South Africa, 2016).

The definition of technology commercialisation may be strengthened by considering what it is not: technology diffusion. While the two terms are interconnected, and share many elements, key differences do exist (Balachandra *et al.*, 2010). Aslani (2015) describes the diffusion process as being one of innovation, incorporating activities such as invention and commercialisation. This view is supported by Balachandra *et al.* (2010), who define technology diffusion as: "*an innovation-based discipline",* while arguing that by understanding the theory behind the diffusion process, it is possible to achieve a *"systematic and prescriptive model of commercialisation"*. These perspectives position technology diffusion as the broader process, one which encompasses technology commercialisation, and other processes and activities,

---

[20] The 5W1H approach consists of six key questions to be asked when investigating a new subject. In no set order of importance, these questions are: What, Why, Where, Who, When, and How?

while recognising that the process of commercialisation may be better understood through knowledge of technology diffusion[21].

The differences between the two processes may be better understood with reference to the s-curve of technology diffusion (see Figure 2.1), which is a graphical representation of a TLC. The s-curve is based on the cumulative density function[22], where a technology experiences a low rate of growth, followed by a quick rise towards an inflection point, after which the rate of adoption and performance slows as the technology reaches maturity (Battisti, 2008). While the entire curve is representative of the diffusion process, from the initial concept of a technology to its maturity, commercialisation is typically concerned with the progress of a technology from a demonstration or early-growth stage towards market acceptance (Balachandra *et al.*, 2010). In order for a technology to progress up the s-curve, there is a need for it to experience widespread use in the respective target market, resulting in improved technological performance and cumulative adoption (see Figure 2.1). Hence, commercialisation forms a sub-process of technology diffusion.

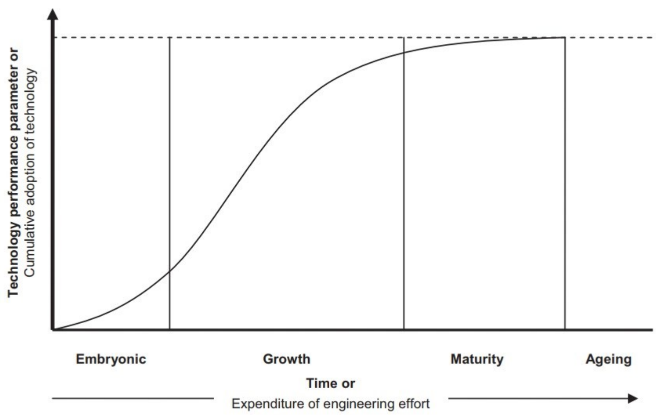


Figure 2.1: S-curve of technology diffusion

(Source: Taylor & Taylor, 2012)

2.1.2 When does technology commercialisation take place?

The s-curve of Figure 2.1 does not provide a great deal of information about each life cycle phase of the TLC, and the delineation of the commercialisation process. However, it does allow for technology commercialisation to be placed into context with respect to the diffusion process. Delving deeper into the field, Figure 2.2 illustrates the commercialisation process as a set of activities, which aid the development of an idea or concept into a commercial technology, product, or service. Although the activities are presented in a linear sequence, it

[21] A detailed exploration of technology diffusion lies outside the scope of this research study. However, readers are welcome, and encouraged, to research the subject further if interested.
[22] Also known as the Ogive or growth curve (Battisti, 2008).

is important to realise that in practice these activities tend to overlap each other, and may run parallel for a period of time (Balachandra *et al.*, 2010).

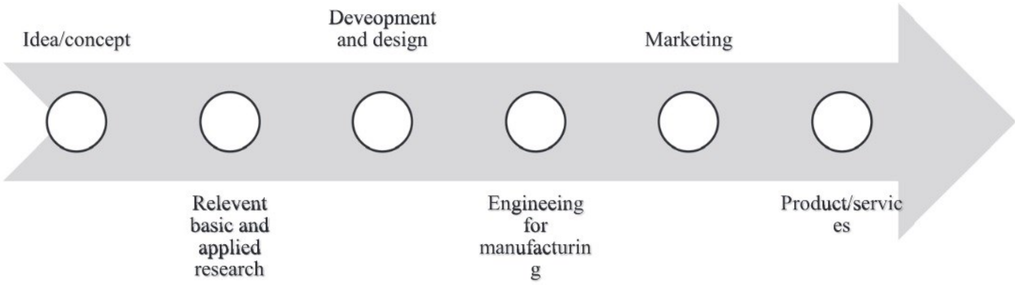


Figure 2.2: Commercialisation process

(Source: Aslani, 2015)

Lund (2009) presents a slightly different set of activities (as seen in Figure 2.3) comprising the commercialisation process, compared to that of Aslani (2015) (in Figure 2.2). While both sets of activities appear valid, this begins to raise the question about the boundaries of technology commercialisation, namely: when does the process begin, and when does it end? Balachandra *et al.* (2010) assess technology commercialisation, and describe the later stages of the innovation chain (see Figure 2.4) as forming the commercialisation process, despite the chain's close resemblance to the process displayed in Figure 2.2.

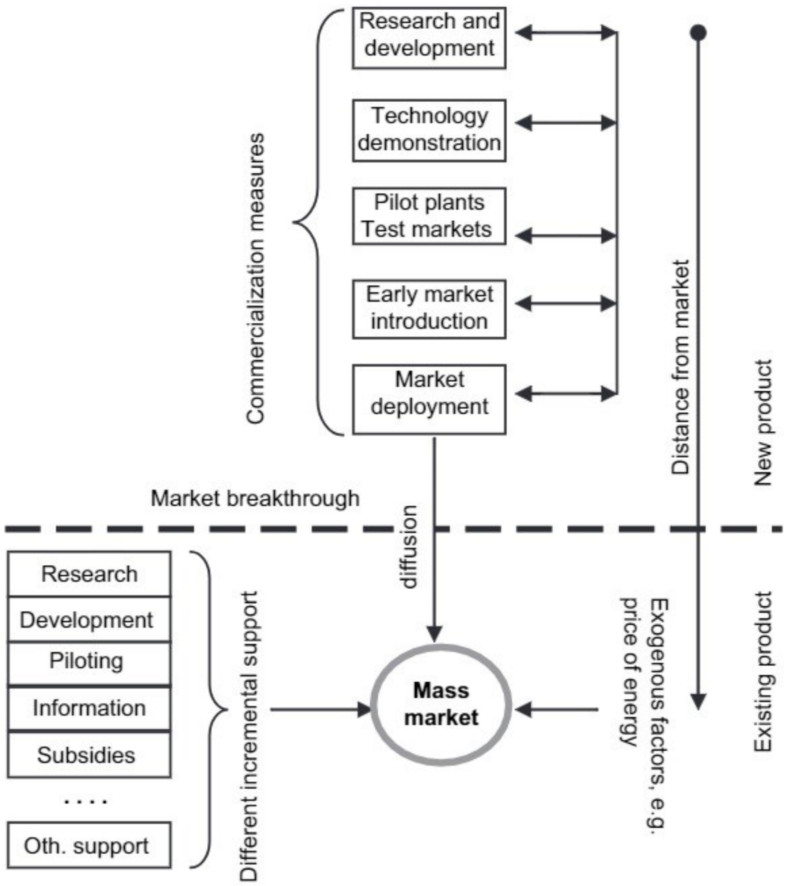


Figure 2.3: Commercialisation process (of energy technologies)

(Source: Lund, 2009)

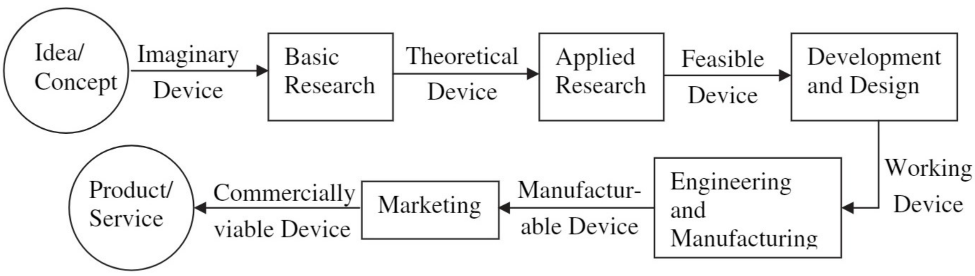


Figure 2.4: Innovation chain

(Source: Balachandra *et al.*, 2010)

These differing definitions suggest that a degree of subjectivity exists in the delineation of the commercialisation process. However, for the purpose of this research study, the process of technology commercialisation will be defined as beginning post the development and design step, with a technology already in existence and having been demonstrated, and ending once a technology achieves commercial use.

The delineation of the commercialisation process raises the question: How to measure the current state of a technology, and track progress achieved in the commercialisation process? Monitoring the progress achieved can prove beneficial in answering many of the questions of the 5W1H model concerning the subject of technology commercialisation. Furthermore, measuring the progress achieved allows for analysis of the relative success of any commercialisation approach (Hyv, 2007), in comparison with the performance and life cycle positions of other technologies (Taylor & Taylor, 2012). Finally, the respective progress will assist in making the choice of which activities to conduct for maximum technological improvement in the face of persistent uncertainty (Troldborg, Heslop & Hough, 2014).

The link between measurement and technological progress is acknowledged by Oxman (1992), as cited in Guan & Chen (2010), who claim that "*measurement is the first step that leads to control and eventually to improvement. If you cannot measure something, you cannot understand it. If you cannot understand it, you cannot control it. And if you cannot control it, you cannot improve it*". However, it is important to recognise that each technology is unique, requiring a different set of metrics for measuring a technology's progress through the commercialisation process, together with the growth of associated industries (Hyv, 2007). Figure 2.5 presents an overview of some of the more common metrics used to measure technological capability and performance.

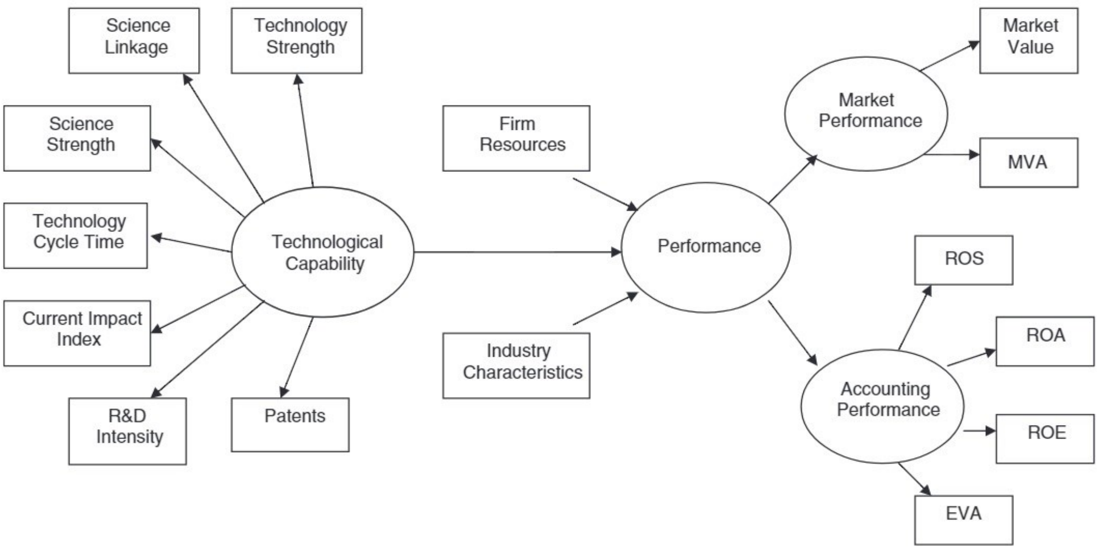


Figure 2.5: Technology capability and performance metrics

(Source: Coombs & Bierly III, 2006)

2.1.3 How does technology commercialisation occur?

The question concerning how technology commercialisation occurs is of great interest to this research study, which seeks a practical approach towards increasing the rate of technology commercialisation. It can be answered in a number of different ways. While this question has already been addressed to a certain extent by the activities contained within Figures 2.2 - 2.4, the discussion presented here examines the question in greater detail. However, due to the complexity of technology commercialisation as explained by Balachandra *et al.* (2010), it is not presumed to be a definitive answer.

Cetindamar, Phaal & Probert (2010:58) describe three methods by which technology commercialisation typically takes place: (1) in-house development, where a technology is developed internally within an organisation, (2) joint commercialisation, where organisations form strategic alliance(s) to commercialise a technology collaboratively, and (3) selling technology, which may take place at any point during the commercialisation process, and includes the transfer of any ideas, initial designs, patents and licenses. The choice of which path to follow depends on the organisation, along with factors such as their core competencies, the desired strategy, direction of the market, and geographical location. (Cetindamar *et al.*, 2010:58)

The Department of Trade and Industry of South Africa (2016) take a similar view to Cetindamar *et al.* (2010:58) on how commercialisation may be achieved in practice. Two options are highlighted, representing two different paths to commercialisation (see Figure 2.6): (1) establishing a start-up company or utilising an existing firm's expertise, or (2) licensing or assigning the IP rights of a technology to another organisation. Each path consists of a number of activities, some of which may be omitted and others repeated in order for a technology to reach commercial maturity, depending on the type of technology and associated circumstances (The Department of Trade and Industry of South Africa, 2016).

Earle & Earle (2001) present an organisational-focused view of the commercialisation process, highlighting the marketing, production, financing, and operational plans needed to successfully commercialise a technology. This perspective is linked to the commercialisation activities of Figures 2.2 - 2.4, providing greater detail on how each plan may be implemented per the respective activity, as well as the degree of information required, and factors to be considered (Earle & Earle, 2001).

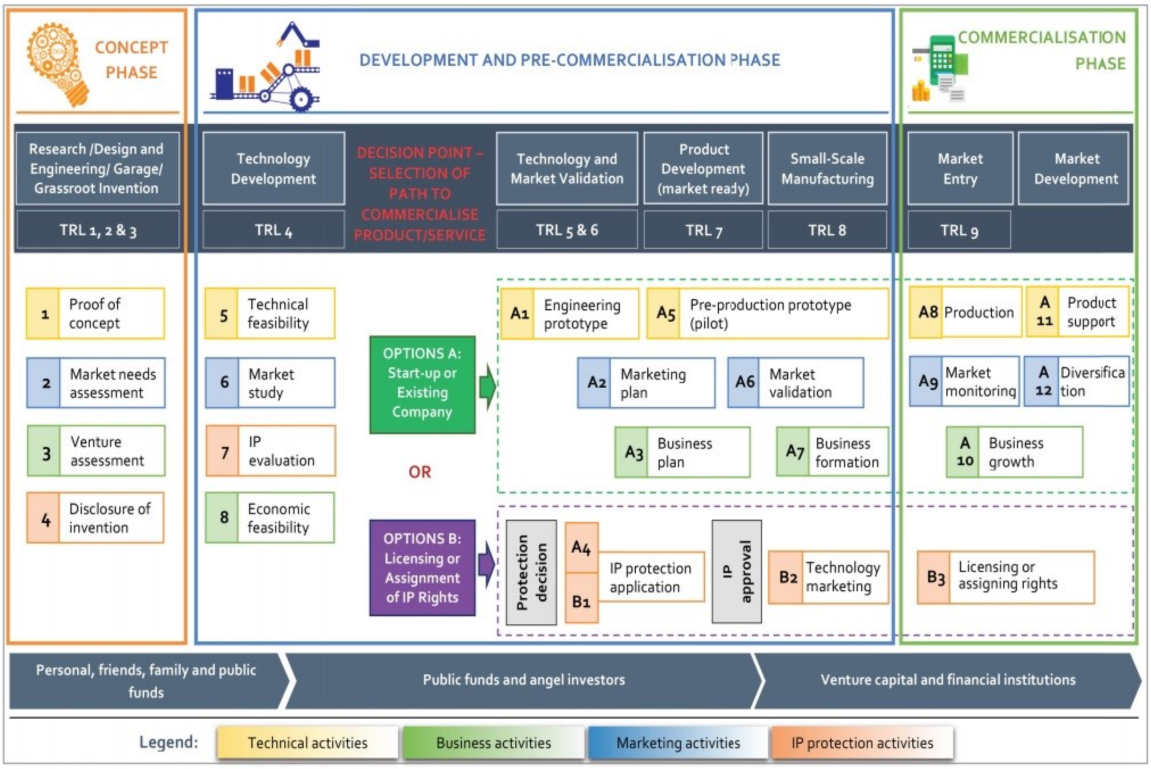


Figure 2.6: The paths to commercialisation

(Source: The Department of Trade and Industry of South Africa, 2016)

One of the key activities within the commercialisation process is that of technological improvement, ensuring that a technology is able to deliver on the performance characteristics desired by the respective target market (Schilling & Esmundo, 2009). Such improvement is typically achieved through R&D measures, thereby overcoming barriers such as cost and reliability with the aid of government policy and stakeholders' efforts (Painuly, 2001), as well as time and money (Schilling & Esmundo, 2009).

Another aspect which contributes significantly to technological improvement is knowledge spillover. Knowledge spillover describes the case whereby technological knowledge that originates in one industry is used in another, fuelling overall technological progress (Organisation for Economic Co-operation and Development, 1998). A leading cause of the spillover effect is that of patent citation, with patents serving as a "*proxy for technology or knowledge itself*" (Lee, Kim & Cho, 2010). Thus, patents have an important role to play in the commercialisation process, given their close association with technological improvement. In addition, patents form an important mechanism[23] that is used by firms to protect their intellectual property (IP)[24].

Knowledge spillover is also important for creating the conditions necessary for a 'dominant' design to emerge (Srinivasan, Lilien & Rangaswamy, 2006). A dominant design is defined by Cetindamar *et al.* (2010:152) as: *"a key technological design that is a de facto standard in its marketplace"*. Although the design may not necessarily have the best technical capabilities (Srinivasan *et al.*, 2006), it will possess attributes considered desirable by the market (Schilling & Esmundo, 2009). Through these attributes, a dominant design comes to enjoy a greater share of the market than competing technological or product designs (Srinivasan *et al.*, 2006), until such a time when a technological discontinuity[25] occurs (Murmann & Frenken, 2006)

An alternative view on dominant designs is presented by Murmann & Frenken (2006). They conceptualise such designs as: "*complex artifacts that evolve in the form of a nested hierarchy of technology cycles"*. This perspective acknowledges the multi-technology hierarchical nature possessed by many technological systems, consisting of a number of levels of subsystems or internal components, all of which have a unique life cycle (Taylor & Taylor, 2012). These life cycles are intertwined, and interact simultaneously, to varying degrees, thereby fuelling progress towards market dominance (Murmann & Frenken, 2006). In addition, the concept of a 'nested hierarchy' highlights the need to utilise different levels of system analysis in order to fully understand the emergence of a dominant design, which may occur on multiple levels within a single system (Murmann & Frenken, 2006).

Although not every technology or product yields a dominant design (Srinivasan *et al.*, 2006), it is nonetheless worthwhile to investigate the reasons behind the potential emergence of such a design. By understanding the underlying factors and circumstances that give rise to technological dominance, it is possible to focus, and improve, efforts to increase the rate of commercialisation for the technology at hand at the expense of other competing designs. Table 2.1 presents some of the causes behind technological dominance in a given market, categorised according to whether the cause is firm- or environment-orientated.

---

[23] Other mechanisms include copyright, trademark, domain name, and industrial design right (Cetindamar *et al.*, 2010:127).

[24] Defined as: "*an umbrella term for various legal entitlements that attach to certain names, written and recorded media, and inventions"*. IP are (intangible) assets from which firms are able to draw revenue and safeguard sources of competitive advantage, provided that the country in which the firm operates possesses sufficient enforcement mechanisms on a legal basis. (Cetindamar *et al.*, 2010:126)

[25] Defined as a technological breakthrough that disrupts the existing status quo of a respective technology, with the potential to either improve or reduce the strength and market share of firms in a given industry (Ehrnberg, 1995; Tushman & Anderson, 1986).

Table 2.1: Causes of technological dominance

Cause	Description	Cause category
Technological superiority	Designs may achieve dominant status due to their clear technological superiority over other designs and models.	Firm
Technological compromise	Many designs represent a compromise on one, or several, functional attributes. The design that offers the best technological compromise in the eyes of the consumer is likely to emerge as the dominant design. This has the effect of forcing competing designs to copy the dominant design in order to stay relevant in the market.	Firm
Radicalness	The greater the perceived radicalness of a new technology is by stakeholders, the less likely the technology will achieve technological dominance, while also taking a longer period of time to reach any state of dominance.	Firm
R&D intensity	Technologies supported by a high degree of R&D intensity[26] are more likely to become a dominant design.	Firm
Complementary assets & credibility	Technological dominance may be achieved due to a design's complementary assets and credibility, such as supportive manufacturing operations, relationships with suppliers, and social perception.	Firm
Economies of scale & standardised products	The dominant design is one that, through 'first mover' status, gains an early lead in the market on competing designs, and subsequently is able to achieve low(est) cost through economies of scale and standardisation.	Firm
Size of firm's existing customer base	The size of a firm's existing customer base affects the willingness of (new) customers to adopt new technologies, as well as ensuring the existence of market potential for the technology.	Firm
Network effects/ externalities and switching costs	The prospect of a design becoming dominant is dependent on network effects, where an increase in the number of consumers of a network increases the demand (function) for a technology, as well as improving the value offered to all other consumers within the network. Switching costs[27] also influence the willingness and ability of consumers to choose between different technologies.	Environmental

[26] "*The depth and breadth of knowledge required to design and commercialize a product*" (Srinivasan *et al.*, 2006).
[27] The cost of switching from one network to another (Suarez, 2004).

Cause	Description	Cause category
Strategic manoeuvring	Through the use of alliances, collaborations, pricing, marketing, time of market entry, and licensing policy, a firm is able to gain an initial leading market share for a respective technology, which often leads to market dominance.	Firm
Sociological, political, institutional, and organisational dynamics	Many designs are complex in nature with significant growth costs, limiting their potential to reach dominance status based only on market competition. Sociological, political, institutional, and organisational dynamics can all exert influence in the battle for technological dominance.	Environmental
Technological industry	The existing structure and dynamics of a technological industry or sector, such as the number of agents and preference for cooperation versus competition, can have a significant impact on the ability of different technologies to reach market dominance.	Environmental

(Sources: Suarez, 2004; Murmann & Frenken, 2006; Srinivasan *et al.*, 2006)

Suarez (2004) presents a timeline (see Figure 2.7) by which the process of technological dominance may be understood, holding value for management practitioners with respect to strategies for the commercialisation process. Phase I describes the application of R&D to develop a new technology for the market, with a focus on securing strong human capital, and realising rapid technological innovation. Phase II examines the technical feasibility of a new technology, and typically includes the emergence of a first working prototype. Phase III sees the introduction of the first commercial model to the market, together with initiatives aimed at expanding the demand for the respective technology. This involves the development of complementary assets, such as manufacturing and public acceptance, to support the technical performance of the respective technology. (Suarez, 2004)

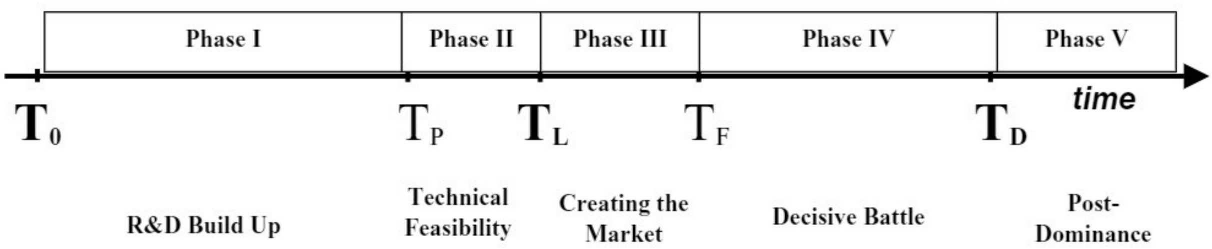


Figure 2.7: Technological dominance process

(Source: Suarez, 2004)

The decisive battle of Phase IV takes place between different technological designs or model variations within the early market. Typically, an obvious leader will emerge, one with extensive assets and credibility. However, achieving success in the dominance battle is subject to a technology's consumer base and market share, rate of market expansion, and ability of the competition to replicate the design's attractive features. Finally, in Phase V, a certain technology achieves technological dominance over the other designs, and is recognised as a standard model for the respective industry for the foreseeable future. (Suarez, 2004)

Given the importance played by the consumer, or entity, who is to purchase and adopt a given technology, it is worthwhile examining the literature concerning the adoption of technology by different individuals. The literature will provide an understanding of their needs, attitudes, and behaviour, which lead to a market need or want (Scott, 2012). This is relevant in light of the need to expand the existing consumer base, creating sustainable demand[28] to ensure continued commercialisation of a technology in the future.

Balachandra *et al.* (2010) classify adopters into five broad categories based on their time of adoption of a (new) technology (see Figure 2.8), providing insight into the willingness of different individuals and organisations to accept a new technology. Quantification of the relative percentage of these different adopter groups is provided in Figure 2.9, with innovators, early adopters, and the early majority constituting 50% of the total participants.

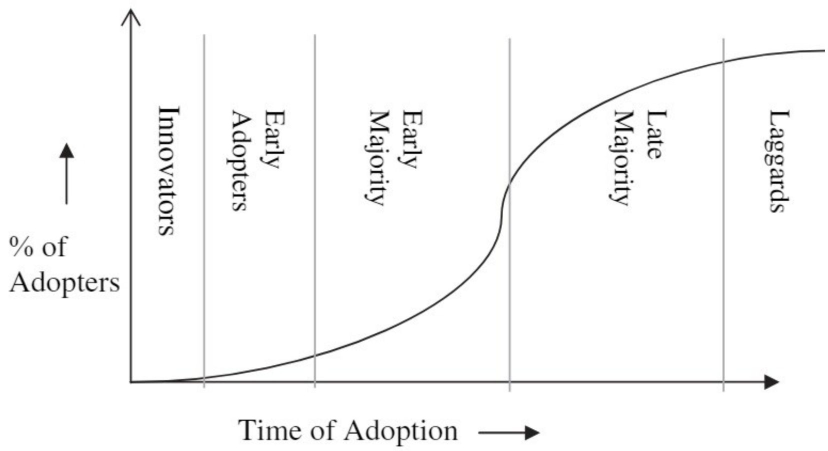


Figure 2.8: Technology rate of adoption

(Source: Balachandra *et al.*, 2010)

---

[28] Sustainable demand in the context of this research study is understood to mean a level of sufficient (annual) demand that warrants (investment in) significant manufacturing operations, R&D, and other activities to support the commercialisation of a technology.

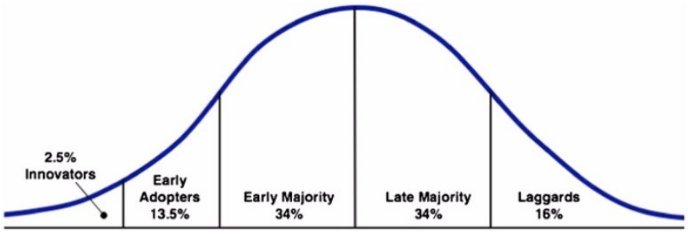


Figure 2.9: Bell curve categorising technology adopters

(Source: Balachandra *et al.*, 2010)

Given the boundaries established for the commercialisation process, it is reasonable to assume that the early and late majority adopter groups are the most relevant to the commercialisation process, given their relative size and time position on the s-curve, with the potential to rapidly increase the rate of commercialisation achieved. However, this view is disputed somewhat by Geroski (2000), who remarks that "*the most interesting and important users are the first users"*.

The first users are the innovators and early adopters, responsible for the initial concept, idea and early stages of technology R&D (Balachandra *et al.*, 2010). Classified together as 'potential adopters' in the commercialisation process, Balachandra *et al.* (2010) draw on the user-orientated instructional development (UOID) model of Burkman (1987) to recognise that the needs and views[29] of potential adopters form core catalysts in the adoption of (new) technologies. This perspective is shared by Rao & Kishore (2010), who state that "*the growth of a technology or an innovation is dependent on the total potential adopters"*. Cetindamar *et al.* (2010:65) also support the need to consider potential adopters, mentioning that "*trying to convince the mass market of a new controversial idea might be a waste of time and money*", and that it is necessary to first persuade innovators and early adopters about the strengths and merits of a new technology.

The development of a profile for potential adopters, and an understanding of the role they play in the commercialisation process, can assist initiatives aimed at mobilising these agents to act in the interests of a given technology. Arguably one of the most important components comprising such a profile are the factors that potential adopters use to assess (new) technologies, forming an integral part of the decision whether to adopt a (new) technology or not. Technology adoption is an uncertain process, regarding both the technology at hand, as well as potential future technologies which may be better suited for fulfilling the given need

[29] These needs and views vary based on differences in the size, structure, products, manufacturing processes, technological capabilities, management, relationship with other stakeholders, and current financial environment of potential adopters (Kemp & Volpi, 2008).

(Kemp & Volpi, 2008). From the UOID model by Burkman (1987), Balachandra *et al.* (2010) draw attention to the following factors used by potential adopters to assess (new) technologies:

1. Trialability, where a technology may be used and tested to a certain degree prior to adoption;
2. Observability, where a technology is able to produce visible results;
3. Relative advantage, the competitive advantage a technology possesses within the marketplace;
4. Complexity, the degree to which a technology can be easily understood; and
5. Compatibility, the degree to which a technology can be integrated with current practices, technologies and values.

Having examined how technology commercialisation occurs, we are now faced with the question of why, if knowledge of the fundamentals and different activities required for commercialisation exist, do many technologies never reach a commercialised state? This is a complex question, with no simple or easy solution. Balachandra *et al.* (2010) attempt to provide an answer by drawing attention to the so-called "*technology valley of death*" (see Figure 2.10), which refers to a transition period characterised by market uncertainty, large investment and production costs, low degree of manufacturing, and poor market penetration (Negro *et al.*, 2012). It is this period that is often responsible for the failure of many technologies to reach broad market adoption (Negro *et al.*, 2012). Hence, increasing the rate of commercialisation could be linked to overcoming this transition period in a shorter period of time, ensuring a commercialised state is reached, sooner.

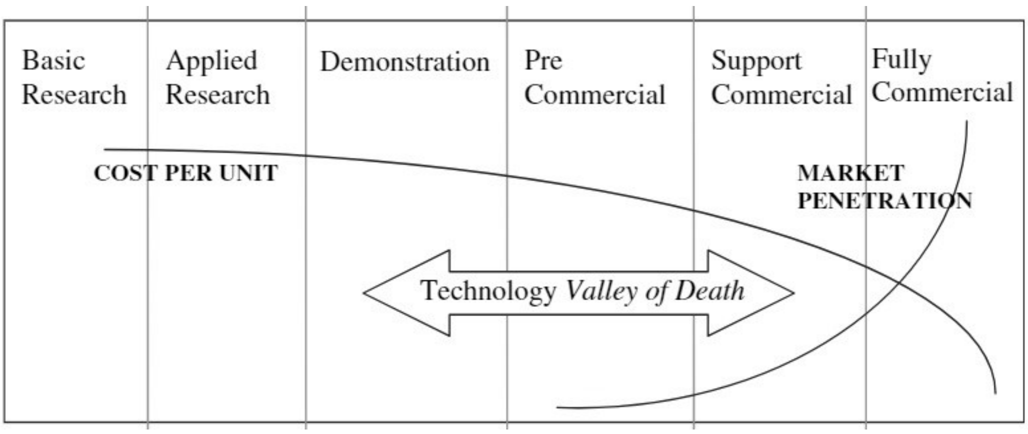


Figure 2.10: Technology valley of death

(Source: Balachandra *et al.*, 2010)

2.1.4 Who commercialises a technology?

Following the what, when, and how of technology commercialisation is the who. Who commercialises a technology? Perhaps the most obvious answer to this question is any entity, be it an individual, organisation, or other, who is able to identify a market need or want, and develop a (technological) solution to address the respective need or want. However, the complexities of the commercialisation process dictate that while a technology may be commercialised in-house, it is more likely that various actors and stakeholders in the technology's supply chain need to be involved in order for a technology to reach the market.

Yet, stakeholders differ from one technology's supply chain to the next, and within the developed versus developing country context (OECD, 2014). Furthermore, stakeholders enjoy differing degrees of power and influence based on their status in the supply chain, and society (OECD, 2014). As such, certain stakeholders may be better positioned than others to drive commercialisation efforts, and ensure that a technology reaches a state of maturity.

One solution to these issues is stakeholder mapping, an effective means of stakeholder identification, especially those individuals and organisations holding significant potential to manage and direct commercialisation efforts (BSR, 2011). However, considering that this question is unlikely to be answered further without knowledge of a respective technology and associated industries, the most suitable answer to be given at this stage is that various stakeholders of a technology's supply chain will play pivotal roles in the commercialisation process.

2.1.5 Where does technology commercialisation take place?

The next question to answer in our investigation into technology commercialisation is where does the process take place? This question can be answered in a number of ways. The first, and perhaps most obvious one, is on a geographic basis. Technologies are seldom limited to a single country, with their development taking place across international borders (Nepelski & De Prato, 2015). These sites of commercialisation are not random, and are often influenced by various environmental[30] and organisational[31] factors (European Commission, Idea Consult & Danish Technological Institute, 2014).

---

[30] Location characteristics, industry, sector, and value chain characteristics and dynamics, and market considerations (European Commission *et al.*, 2014)

[31] Strategic considerations, technology and innovativeness, and product and production complexity (European Commission *et al.*, 2014).

A second answer relates to technologies on a systematic basis. The multi-hierarchical nature of technological systems draws attention to the fact that not all components of a technology or product require the same degree of commercialisation, lying at different stages in their individual life cycles. Thus, when one speaks of the commercialisation of a given technology, it is necessary to specify on which level commercialisation is taking place. This question's difficulty is often directly correlated to the complexity of the relevant technology. However, it is expected that this question will be answered by those individuals actively involved in the commercialisation process, with a clearer idea of the market need or want identified. (Murmann & Frenken, 2006)

2.1.6 Why does technology commercialisation occur?

The final question of the 5W1H approach, why does technology commercialisation occur, is again not a simple one, varying from technology to technology. However, it is a subject which focuses on the role played by people, their decisions, interests, and agendas. While one answer may be that a technology is commercialised to fulfil a need, want, or problem of the target market, this neglects the other role players in the value chain. Another frequent answer is money (Apax Partners, 2005). In the interests of generality, a more appropriate answer may be to fulfil a personal need or desire of the individual involved in the commercialisation process, no matter their position in the chain of commercialisation activities, which, while it may be money, could also be for other reasons.

2.1.7 Summary: 5W1H model of technology commercialisation

Table 2.2 provides a summary of the different aspects of the commercialisation discussed so far, in accordance with the six questions of the model.

Table 2.2: Summary of 5W1H approach - technology commercialisation

5W1H question	Technology Commercialisation
What?	▪ The development of self-sustaining markets, which are able to compete in a level playing field with other competing technologies. The process by which a technology is introduced into the market, meeting expectations relating to performance and reliability, while being available at a cost the consumer is willing to pay.
When?	▪ Begins after the development and design step, and reaches completion once a technology enters the market and achieves a state of commercial maturity.
How?	▪ In-house development, joint commercialisation, technology transfer ▪ An operational plan comprising marketing, production, and finance components versus the licensing or transferal of IP rights.

5W1H question	Technology Commercialisation
Who?	▪ Stakeholders in the supply chain of a technology.
Where?	▪ Geographically, commercialisation is subject to environmental and organisational factors. ▪ Systematically, commercialisation depends on which components of a technology system are prioritised for commercialisation.
Why?	▪ To serve peoples' interests, agendas, and personal needs and desires.

2.2 Commercialisation of energy technologies

Following the establishment of a foundation in Chapter 2.1 for understanding the process of technology commercialisation, the focus now shifts to the context of energy technologies[32]. In the interests of consistency, the answers gained from the application of the 5W1H model to technology commercialisation will now be discussed in the context of energy technologies. The focus will be on MTRESs, which is the type of energy technology of interest in this research study.

2.2.1 What is the commercialisation of energy technologies?

The commercialisation of energy technologies differs from that of other technologies in several ways. Globally, energy markets are subject to a significant degree of government influence (IEA, 2016), who decide which technologies are incorporated into the national energy mix in order to meet the energy needs of its citizens (Tagotra, 2017). This has led to the energy sector developing a highly politicised nature (Krupa & Burch, 2011). Although embedded generation[33] and other sources of energy are beginning to challenge this model (Lopes, Hatziargyriou, Mutale, Djapic & Jenkins, 2007), it is still utility-scale demand through government policies that drives many energy markets today (Hannon, Foxon & Gale, 2015).

The reliance on government action and demand to drive the commercialisation of energy technologies is problematic, given the tendency of powerful political agents to favour certain energy technologies over others for a number of reasons (Wangler, 2012). Hence, considering the importance of self-sustaining markets in the standard commercialisation process, as highlighted by Balachandra *et al.* (2010), a valid question to ask is whether energy technologies ever truly achieve self-sustaining markets, given the need for political support? Hence, in the context of energy technologies, it may be more appropriate to pursue the formation of sustainable markets, rather than self-sustaining, as part of commercialisation efforts with respect to energy technologies.

[32] Defined as any technology that produces energy as an output in any form, typically for mass consumption.
[33] Also known as distributed generation, embedded generation refers to typically small-scale energy systems, such as residential solar PV, that differ from traditional large-scale and centralised sources of energy (Lopes *et al.*, 2007).

Yet what definition does the term ‘sustainable market’ warrant in the context of the commercialisation of energy technologies? Well, one first needs to be aware of the fact that it is typically government who decides which energy technologies to incorporate into the country’s energy mix on a large-scale, while being able to set regulations governing the energy sector and use of various energy technologies. Thus, in effect they have the ability to make or kill the market for any energy technology.

If we assume that an energy market exists, and that new energy technologies are being incorporated into the energy mix, then there needs to be a sufficient level of business afforded to a technology, and its associated industries, for entities to consider commercialising the respective energy technology (Kolk & van den Buuse, 2013). Consequently, perhaps the term ‘sustainable market’ should be associated with a minimum annual additional installed capacity, which would ensure a certain level of new business on an annual basis, in effect a pipeline of projects.

However, this scenario is based on the assumption that there exists a constant growing energy demand, which, while may be true in the long-term, is not always the case on a regular annual basis (Pfeiffer & Mulder, 2013). Many countries have experienced declining electricity sales in recent years, due to slowing growth and greater energy efficiency (REN21, 2017b). While one may argue that retiring old fossil-fuel technologies, such as coal power stations, can offset any potential oversupply of energy, it needs to be kept in mind that many of these technologies are debt free, and hence are able to supply energy cheaply. If they are retired, it is likely that the cost of electricity will rise in the short-term, a situation not favourable to government officials seeking re-election and popularity with voters. Therefore, if we consider the case of the electricity sector, the effect of new energy technology capacity on the overall national grid system cost needs to be evaluated carefully, together with any issues relating to grid stability.

If we assume that there is a growing electricity market, with a need for sustainable demand in the way of new build capacity, the question then becomes what should such a capacity value be? Capacity will likely vary from country to country, depending on factors such as the existing state of a nation’s electricity grid[34], projected future energy demand, composition of the current

[34] This refers in part to the extent to which the national grid is able to accommodate the inclusion of energy technologies such as MTRESs into the system, and the (potential) need for upgrading the grid infrastructure for improved transmission and distribution of electricity.

energy mix, the capacity credit[35] of the respective energy technology, and the (preferred) inclusion of other energy technologies into the national energy[36] mix in the future.

Adding to the difficulty of this question are the complexities of the modern-day energy sector, with different energy technologies able to supply electricity at different times of the day, and at significantly different costs, in order to meet changing demand curves (Matek & Gawell, 2015). Furthermore, the use of different methodologies, assumptions, and energy data may yield different answers regarding a suitable capacity figure (SQWenergy, 2010). As such, the recommendation is made that the establishment of any annual additional installed capacity, representing sustainable demand, be based on a given energy technology, and the needs of the energy sector of a respective country. Furthermore, the engagement with relevant experts in the energy sector can also be of use towards identifying what such a capacity figure should be.

The subject of political support for a given energy technology has a strong effect on the possibility of the existence of a level playing field within the energy sector (Eyre, 1998). Furthermore, one needs to consider the past history of the global energy sector (Power, Newell, Baker, Bulkeley, Kirshner, *et al.*, 2016). Established fossil-fuel based energy technologies have benefitted from decades of infrastructure development, aiding their market expansion (Lohmann, 2009). In addition, these technologies have enjoyed easy access to capital, strong supplier networks, significant consumer awareness (of the technology), established technical standards and skills transfers programmes, and compliance with, and support from, current regulation (Meadowcroft, 2009).

This set of circumstances has led to fossil-fuel technologies dominating the energy mixes of many countries (International Energy Agency, 2016). Hence, a significant barrier to the commercialisation of new energy technologies is the bias within existing energy infrastructure towards established energy technologies. Indeed, it can be said that energy infrastructure is always likely to favour one type of energy technology over another, in part due to political

[35] "*The capacity credit is the peak demand less the peak residual demand, expressed as a percentage of the variable renewables installed"*. An example of capacity credit may be demonstrated by wind power technologies. If 10 GW of wind power plants are installed, and their capacity credit is 10%, then there will be a reduction of 1 GW in the amount of other power plants required in the system, compared to a case where no wind power plants were built. (IEA, 2011)

[36] Although the primary function of many energy technologies, is to produce electricity, certain energy technologies, such as coal and CSP, are also able to produce thermal heat for independent use, in addition to its role as an intermediate step for the production of electricity. Thus, when reference is made to a country's energy demand or mix, such demand will likely be dominated by electricity, but may also contain thermal heat, oil, and other energy types.

support. Therefore, it is unlikely that a level playing field will ever exist, given the intrinsically political nature of the energy sector worldwide.

The second aspect to be addressed is the expectations relating to the performance and reliability of energy technologies. Discussion of this aspect is centred around two questions: (1) Whose expectations are being referred to? and (2) What connotations do we attach to the performance and reliability of energy technologies?

Expectations regarding an energy technology are typically attributed to the consumer of the technology (Popp, Newell & Jaffe, 2010). However, it is not always clear who this consumer is. Is it the end-user of the energy good produced by the energy technology? Is it the government or energy utility, who make use of energy technologies to ensure a nation’s energy demand is met? Or should we also consider other actors in the supply chain, such as the developers of energy technologies, who expect that by meeting a certain standard of performance and reliability in the energy technology in question, they will be able to earn a suitable profit?

Considering the role played by various stakeholders throughout the commercialisation process, it is difficult to rank the expectations of different individuals and groups in order of importance. To avoid any potential bias, it is recommended that the relevant entity be specified on a case-by-case basis, though it is expected that expectations of performance and reliability will typically refer to the individual or entity sharing a direct relationship with a respective energy technology for the purposes of energy generation. These entities could be one of the following: (1) government or a state utility, who generates energy from their own energy technologies, or relies on independent power producers (IPPs) to supply the required energy; (2) IPPs, who expect that the energy technologies they develop will be able to supply the energy required; or (3) embedded generation users, who make use of energy technologies to generate their own energy. We now turn to the second question to be answered concerning the connotations attached to the performance and reliability of energy technologies.

In order to assist national governments, energy utilities, and large industrial firms with their energy planning, energy technologies need to be able to supply energy when they say they can. The supplied energy can be in the form of electricity, heat, or other. This requires a certain level of performance and reliability in order to generate a specified energy output (Jackson, 2016a). Although the quantification of performance and reliability are technology-dependent to a large extent, (King, Boyson & Kratochvil, 2002), there are several comments we can make on the subject. The scope of this discussion is limited to energy technologies themselves, and not the wider energy systems, such as national electricity grids, which they typically form a part of. However, mention is made of the wider energy system where necessary.

If we consider that the primary goal of an energy technology is to produce energy, then its performance can be linked to the quantity (King *et al.*, 2002) and quality of energy generated (Jackson, 2016a). As an example, in the case of electricity this refers to the amount of electricity produced, typically on an annual basis (King *et al.*, 2002). Moreover, it refers to the nature of the electricity in terms of frequency, voltage and current levels, and their variations (Jackson, 2016a).

The variations need to remain within certain limits set by the energy regulator and national grid code, to limit potential damage caused to national grid infrastructure (Passeya, Spooner, MacGill, Watt & Syngellakis, 2011) and household appliances (Jackson, 2016a). While an in-depth analysis of energy quality is beyond the scope of this literature review, ensuring quality of supply highlights the important role played by the management of these technologies, and the wider systems and networks they form part of (Jackson, 2016a).

Continuing with the premise that the primary goal of an energy technology is to produce energy, the reliability of energy technologies can be said to describe the security of energy supply one receives from these technologies, referring to their ability to produce energy when expected (Jackson, 2016b). This ability differs between energy technologies due to the source from which they derive their power. An example is certain MTRES which generate energy from intermittent sources, such as the sun and wind (Klein & Rubin, 2013).

There are several solutions available in response to the problem of reliability. Modern energy systems and networks have taken on new designs to accommodate this variability in supply (Jackson, 2016a). These designs typically take a hybrid form, consisting of different types of complementary energy technologies (Jackson, 2016b). An example is the use of wind turbines with solar photovoltaic (PV), mini-hydro, the national grid, and/or diesel generators to meet the required energy needs (Jackson, 2016b). ESTs are also an option, especially flow batteries and flywheels (Jackson, 2016b).

Effective management of technologies is also able to address the issue of reliability (Jackson, 2016b). A diverse range of tools are available, including forecasting tools (for fuel source considerations), and probability metrics, namely: P50, P90 and P99[37] (Jackson, 2016c).

---

[37] These metrics represent the quantity of energy produced on an annual basis that can be expected with a 50%,

Furthermore, it is important to manage the supply of energy from multiple energy technologies as effectively and efficiently as possible to maintain grid stability (Matek & Gawell, 2015). As such, other suitable tools and concepts include: capacity credit, the level of penetration[38] in the system, dispatchable reserve capacity, and storage (Jackson, 2016b).

A final comment concerns the management of expectations regarding the performance and reliability of energy technologies. People often expect access to energy whenever needed, (Jackson, 2016a), resulting in a demand profile which typically exhibits a morning and evening peak (Anderson, Lin, Newing, Bahaj & James, 2017). Ensuring that there is sufficient supply to meet this demand at all times highlights the role played by baseload energy technologies, ESTs, and complementary hybrid systems (Jackson, 2016b). In order to improve the ability of utilities to manage these expectations, engagement with all relevant stakeholders is required, gaining further knowledge of the concerns that individuals have, and educating them about the different tools and techniques available to address these problems (The National Archives, 2013).

The third aspect regarding our definition of the commercialisation of energy technologies is the cost[39] that consumers are willing to pay for energy technologies. The first thing to be addressed is our understanding of the consumer. Is the consumer the end-user, who pays for a unit of energy produced by such technologies through the national grid? For example, the end-user may be a residential household or an industrial user. Or is the consumer the entity who pays for the entire energy technology in order to use it to meet their energy needs directly? For example, the entity may be government, who supplies energy to the nations citizens, or an industrial user, who wishes to generate their own energy independent from the national grid. The answer to this question is likely to lead to a different understanding of the final cost consumers are willing to pay for an energy technology. Thus, it is worth examining both cases before a final decision is made.

Given that the majority of energy technologies are used to produce electricity on a large-scale (Kosmadakis, Karellas & Kakaras, 2013), let us focus on utility-scale electricity production. Next, while different metrics exist to quantify the cost paid for electricity from different energy technologies, one of the most widespread and popular ones is the levelised cost of electricity

90%, and 99% confidence level (Jackson, 2016c).

[38] Can be measured in two ways: (1) instantaneous power penetration, the ratio of instantaneous power output to the instantaneous energy load, and (2) average energy penetration, the ratio of energy output to energy load , both measured over a year (Jackson, 2016b).

[39] Although cost and price are different economic terms, in the context of this discussion, the term cost is taken to mean the final figure paid by the consumer, inclusive of any margins that may have added on through the supply chain up to that point in the chain.

(LCOE)[40], partly as a result of its simplicity (Sklar-Chik, Brent & De Kock, 2016). Hence, the decision was made to use the LCOE as a base metric, to assist the discussion of both cases. However, it is important to realise that the metric is subject to many assumptions and variables, which influence the final value obtained (Sklar-Chik *et al.*, 2016). As a result, the LCOE is frequently presented as a range of values, rather than a single one, to account for these differences (Sklar-Chik *et al.*, 2016).

The first case identifies the consumer as the end-user of the electricity good produced by the respective energy technology through the national grid. There are several issues regarding this definition of the consumer. The cost paid by the consumer for electricity is indicative of the overall system cost, which is determined through a number of factors, such as the cost of fuel, grid systems, regulations, and periods of peak demand (United States Energy Information Administration, 2017). This complicates the discussion on the commercialisation of energy technologies, as the cost of an energy technology may not be the final cost which the consumer ends up paying. Furthermore, it highlights the need to consider in which country a technology is being commercialised, or in which nation the technology is targeting, and the state of the accompanying national grid.

In the past, end-user consumers have had little influence over the price charged for electricity by energy utilities, due to the monopoly such utilities have over the generation, distribution, and transmission of energy (Painuly, 2001). The liberalisation of several energy markets (IEA & OCED, 2005), and increase in the adoption of embedded generation and small-scale energy systems, have begun to change this model (Richter, 2012), as end-user consumers now enjoy greater control over the cost they pay for electricity (IEA & OCED, 2005; Richter, 2012). The same is true of other energy needs, with growing residential use of solar-water heaters and solar-pumps (IRENA, 2015).

It is here that complexities begin to emerge. Based on the assumption that the consumer is the end-user, it is to be expected that the consumer will always choose the energy technology with the lowest LCOE, considering that there is no real difference between the units of electricity produced by different energy technologies, apart from the means by which they do so (Craig, Brent & Dinter, 2017). However, basing a decision purely on the cheapest LCOE neglects the different value propositions of different energy technologies currently available.

---

[40] The cost to produce one kilowatt hour of electricity from a given energy technology (IRENA, 2016). Can also be used to describe the levelised cost of energy.

Energy technologies typically provide energy at different times of the day, under different conditions, and at different costs (Diesendorf, 2016). One example is solar PV, which, while currently one of the cheapest sources of energy, is only able to produce electricity when the sun is shining, and typically only during the day when the majority of sunlight is received (Department of Energy, Department of National Treasury & Development Bank of Southern Africa, 2017). Electricity demand also plays a key role in the choice of energy technology, given the need to match demand and supply to prevent oversupply (Banks & Schäffler, 2006).

These complexities provide a useful introduction to the second case, where the consumer is defined as the entity who purchases an entire energy technology in order to meet their energy needs, be it government or a state utility who need to provide the nation's citizens with electricity (Wee, 2017), or a firm requiring electricity to power their (industrial) processes (Selko, 2012). The cost paid by the consumer in this case is a more accurate representation of the true cost of each individual energy technology, as opposed to the entire system cost.

In light of all the factors discussed above, the consumer is defined as the entity who makes use of the electricity produced directly from an energy technology. As such, the cost refers to the LCOE of the respective energy technology. Moreover, given the focus on the utility-scale market in many RE reports and publications, and that large power plants are able to achieve lower LCOEs (Kosmadakis *et al.*, 2013), the metric is associated primarily with energy technologies developed on a utility-scale. However, care needs to be taken when using a LCOE value, making sure any figure determined is compared with other energy technologies on a like-for-like basis, with new-build energy technologies operating in the same demand[41] category, and under the same set of assumptions.

2.2.2 When does the commercialisation of energy systems take place?

The duration of the commercialisation of energy technologies is understood to be the same as that established in Chapter 2.1.2. The process begins once an energy technology has progressed beyond the development and design phase, and ends once it reaches the market and achieves a commercial state. In terms of assessing the state of commercialisation, while we have already discussed the LCOE metric used to quantify the costs of energy technologies, it is worthwhile mentioning several other metrics also used to measure the performance and progress of energy technologies through the commercialisation process. These include: annual energy or electricity production (Edkins, Winkler & Marquard, 2009), used to track the (change in) contribution of different energy technologies to a country's energy supply, and new

[41] Historically baseload, mid-merit, or peaking.

and cumulative installed capacity of an energy technology (Haas, Panzer, Resch, Ragwitz, Reece, *et al.*, 2011), used to assess the addition to, and change in composition of, a nation's existing energy mix. The choice of which metric to use is dependent on factors such as the availability of data, means of implementation, and inherent metric complexity (Rademaekers, Yearwood, Ferreira, Pye, Hamilton, *et al.*, 2016).

2.2.3 How does the commercialisation of energy systems occur?

Similar to the discussion on how technology commercialisation takes place, the commercialisation of energy technologies has been addressed to a certain extent by Figure 2.3, providing guidance on which activities are needed at different stages of the commercialisation process. It should be noted that the model in Figure 2.3 is based on an idealised energy system, and does not factor in the multi-technology hierarchical nature inherent to technologies such as MTRESs (Lund, 2009). However, apart from the fact that certain activities may not be relevant to all the components of MTRESs, the chain of activities is unlikely to differ significantly, apart from the fact that it is governments who typically decide the level of demand afforded to different energy technologies on a local basis.

Revisiting the discussion on potential adopters, specifically the profile established in Chapter 2.1.3, Peter, Ramaseshan & Nayar (2002) devised a conceptual framework (see Figure 2.11) consisting of various socioeconomic and technical factors. The framework is used to gain an understanding of the set of factors that influence the decision of potential adopters to adopt energy technologies, with a focus on solar technologies. The framework lists the factors identified, while also displaying the interrelationships that exist by means of a network, culminating in the final decision of whether or not to adopt the technology.

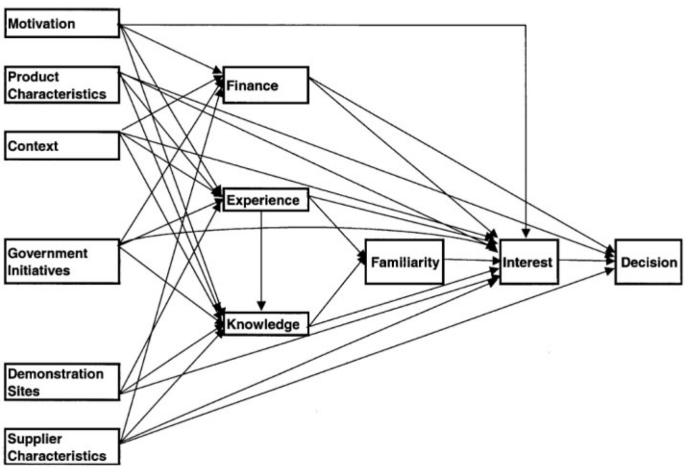


Figure 2.11: Framework of factors influencing the adoption of solar technologies

(Source: Peter *et al.*, 2002)

Comparing these technology adoption factors to those of the potential adopters' profile established in Chapter 2.1, it is clear that a more comprehensive list of factors is presented here. In addition, the illustration of the interrelationships that exist between the different adoption factors improves our understanding of how such factors interact with each other. By integrating the factors and relationships of Figure 2.11 into the potential adopters' profile, the existing profile can be strengthened, providing greater clarity on the type of individual to be mobilised. The clarity will assist efforts associated with the commercialisation of energy technologies, and how this may be achieved in practice.

One of the key subjects of interest in this study concerns the slow rate of commercialisation of energy technologies, in particular that of MTRESs. Currently, the commercialisation of MTRESs is achieved chiefly through government-related efforts, with little input from the private sector (Balachandra *et al.*, 2010). Aslani (2015) identified a number of initiatives used by governments globally for driving the commercialisation of MTRESs. These initiatives include: feed-in tariffs (FITs), R&D support, tax incentives, and international cooperation between different industry players (manufacturers, businesses, consultants etc.). However, the slow rate of commercialisation of MTRESs achieved thus far raises serious questions as to the effectiveness of these measures (Balachandra *et al.*, 2010). Moreover, many MTRESs are yet to achieve a state of maturity in their life cycles (Grobbelaar *et al.*, 2014).

Many technologies, such as automobiles, the internet, and cell phones, have achieved rapid economic growth in relatively short periods of time (Balachandra *et al.*, 2010). The growth realised by these technologies stands in stark contrast to that experienced by MTRESs, despite the existence of similar limitations[42] (Balachandra *et al.*, 2010). Such differing levels of market growth warrant an investigation into the aspects responsible for the slow the rate of commercialisation of MTRESs.

Negro *et al.* (2012) identified two scientific paradigms to explain the slow rate of commercialisation, and by extension diffusion, of MTRESs:

1. A neo-classical economic paradigm focusing on market failures as the chief barrier; and
2. The systematic nature of the environment in which innovation takes place, with the environment commonly termed, an "*innovation system*[43]*, technological system or innovation ecosystem"*.

---

[42] Low levels of public adoption, poor sales, and absence of government regulation (Balachandra *et al.*, 2010).

[43] Defined by Negro *et al.* (2012) as: *"socio-technical configurations of actors, rules, physical infrastructures and their relations"*.

The innovation system paradigm highlights the fact that market failures may not be solely accountable for the slow rate of commercialisation realised, and that other system failures may also bear responsibility (Markard *et al.*, 2012). Given the multi-faceted nature of the commercialisation process, the ability of the innovation system's paradigm to identify all systematic failures currently obstructing the commercialisation of MTRESs mark it as a superior paradigm to the neo-classical economic approach (Negro *et al.*, 2012). Knowledge of these failures is crucial to the development of a systematic solution to the slow rate of commercialisation.

While it is acknowledged that market-related failures are not the sole factor responsible for the current slow rate of commercialisation of MTRESs (Negro *et al.*, 2012), they nonetheless form one of the largest types of barriers encountered (Balachandra *et al.*, 2010). To provide insight into the poor market performance of MTRESs, Balachandra *et al.* (2010) investigated the underlying causes behind such behaviour. Their findings are summarised in Table 2.3.

Table 2.3: Market behaviour of MTRESs

Market behaviour	Description
Energy efficiency is insufficient as the sole element of competitive advantage	The commercialisation process requires a technology to be superior to the competition in multiple facets (performance, cost, quality, reliability, user friendliness). Advocating energy efficiency alone as an advantage over competitive energy technologies is unlikely to be sufficient in the medium- to long-term.
Competition from industry incumbents	Established and mature forms of energy production, such as coal and oil, have achieved economies of scale and vast distribution networks, and amassed great knowledge from their learning curves over time. This provides stiff competition to the relatively new RE industry.
Lessor importance of environmental and social issues in the business world.	The initial development of MTRESs was in response to environmental and social issues. The allocation of financial capital by investors (entrepreneurs, venture capitalists) is typically done with an acceptable ROI in mind, something MTRESs have not always been able to provide.
Time period	The individual benefits of MTRESs are only applicable to long-term use, thus marking any (solely) short-term market penetration efforts largely ineffective.
Scale	Societal benefits of MTRESs are only applicable to large-scale use, thus marking any (solely) short-term market penetration efforts largely ineffective.

Market behaviour	Description
Intermittent nature	RE sources are commonly characterised by a lack of consistency in supply, as the sun does not always shine and wind does not always blow, as well as possessing a dispersed distribution, as opposed to concentrated oil and coal energy sources.
Short-term focus	Many MTRESs tend to focus on displaying they can work only once, without consideration for continued use which requires maintenance, viable markets for future adoption, and infrastructure for duplication (additional MTRES projects).
Uncertainty and interdependence	A lot of uncertainty surrounds MTRESs, particularly concerning which aspects, such as knowledge, methods, and hardware, should be commercialised. In addition, MTRESs are complex systems, involving a significant degree of interdependence between the decisions made regarding resources, technology transition processes, and component transportation, with many of the decisions made being site-specific.
Lack of capability and effort	Many government-led initiatives implemented to assist the market penetration of MTRESs have been met with low levels of success. Lack, and conflict, of interest has played a large role in this slow rate of commercialisation, with the potential for disruption of existing political-business relationships also undermining commercialisation efforts.

(Source: Balachandra *et al.*, 2010)

These market factors highlight a few of the unique limitations encountered by MTRESs in the commercialisation process, promoting awareness of the barriers preventing MTRESs from realising commercial status. Given that the primary competitive advantage of MTRES, being environmentally friendly, is not sufficient to guarantee a rapid rate of commercialisation, such technologies need to be able to compete on other properties, such as cost, especially in the mid- to long-term (Balachandra *et al.*, 2010). The issue of reliability, attributable to the intermittent nature of MTRESs, is also problematic, as customers are reluctant to purchase a technology they cannot use when needed (Balachandra *et al.*, 2010).

The significant uncertainty faced by MTRESs may be attributable to a range of factors, such as political instability, lack of sufficient investment, and intermittent nature (Negro *et al.*, 2012). Confidence in new MTRESs may be fostered by developing a transparent timeline mapping the future of the industry, one enforced through policy. Such a roadmap could assist in the creation of a sustainable market, creating certainty that may act to mitigate the strong opposition forces likely to be encountered from industry incumbents, especially those inclined to protect their own interests, and maintain the existing status quo of energy production.

Established energy technologies also face the challenge of being typically large-scale (Balachandra *et al.*, 2010). This limits the market segments in which energy companies have been able to operate, although new energy technologies, such as solar (PV), which can be deployed in multiple market segments, are beginning to change this fact (Stapleton, 2009). However, issues still exist with respect to the integration of MTRESs into electricity grids, and accompanying regulations (Abdmouleh, Alammari & Gastli, 2015).

The market factors identified above serve to indicate the shortcomings of government-related efforts thus far. The investment potential and expertise of the business sector need to be harnessed in a similar way to that of successful technological industries (automobiles, cellular phones and internet). In these industries, progress is driven predominantly by the business sector. Without a significant shift in the degree of involvement of the business sector, the rate of commercialisation of MTRESs may remain low. One need only look at the existing structure of energy industries worldwide as an example of where the private sector has successfully assumed a strong position in such technologies. (Balachandra *et al.*, 2010)

Having an understanding of the key elements that determine progress in the commercialisation process is useful, but implementing this knowledge is another matter entirely. To examine how commercialisation has been achieved in the past, a number of different strategies, approaches, and techniques were evaluated. This evaluation is summarised in Chapter 4, with the full copy available in Appendix A, with reference to MTRESs.

2.2.4 Who commercialises an energy technology?

Although the prominent role played by the government in the commercialisation of energy technologies cannot be denied, they are not the only role players involved in the process. Building on the identification of the stakeholders in a technology’s supply chain who commercialise it (see Chapter 2.1.4), Balachandra *et al.* (2010) recognise the different stakeholders involved in the commercialisation of energy technologies (see Table 2.4), with a focus on MTRESs. The list categorises stakeholders based on the role they play within the commercialisation process, providing greater detail on the potential adopter profile established so far.

Table 2.4: Stakeholders in the commercialisation of MTRESs

Stakeholder	Role in commercialisation process
Technology developers	Conduct R&D into MTRESs. Includes scientific research institutions, R&D divisions (public & private firms), government-supported research facilities, and universities.
Owners & suppliers of technology	Represents private companies and state-owned entities. Technology is often developed in the public sector and then transitioned to the private sector, due to the perceived superior capabilities of exploiting a technology's market potential.
Entrepreneurs	Potential adopters supported by government and financial institutions. Understand customer needs and the market environment. Responsible for small-scale firms in order to develop, market, and sell MTRESs.
Buyers & final-users	Principal stakeholders in commercialisation process. Large buyers (public & private entities) purchase MTRESs from suppliers; small buyers (households, communities, non-government organisations (NGOs)) purchase from entrepreneurs.
Financial backers	Provide financial support to entrepreneurs to obtain technology from suppliers. Includes mainstream banks, non-banking financial institutions, and individual or institutional investors.
Information providers	Organisations (such as UN, government entities, technology clearing houses) who provide independent information (such as menu of technology options, technology sources, case studies, databases) to assist in connecting the needs of buyers to the capabilities of suppliers.
Market intermediaries	Affect buyers' decision-making process by offering information regarding MTRESs. Aid entrepreneurs with business plans, prospective partnerships, intellectual property rights and licenses, technology education programmes and investment proposals. Includes consultants, NGOs, media, trade associations.
Governments	Establish the regulatory, legislative, and policy framework for technology and monetary transfers, economic tools (taxes and subsidies), and entrepreneurship development. Often responsible for the majority of energy generation, particularly in developing countries.

(Source: Balachandra *et al.*, 2010)

Aslani & Mohaghar (2013) acknowledge a similar set of stakeholders, while also investigating the network that exists between the various stakeholders (see Figure 2.12), characterised by a flow of services, products and information. This network provides clarity on the interrelationships which exist between stakeholders, highlighting which bonds can be fostered and strengthened over time to increase the rate of commercialisation achieved.

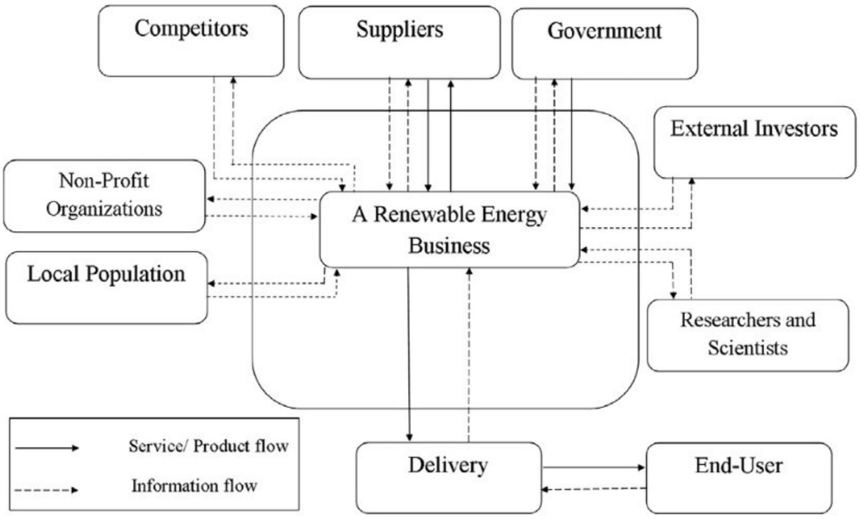


Figure 2.12: Stakeholder network

(Source: Aslani & Mohaghar, 2013)

Engagement with multiple stakeholders is crucial to establish credibility and legitimacy in a new technology, both of which are powerful forces in the commercialisation process (McDowall, 2012). People form an integral part of the commercialisation process, responsible for making the decisions that affect the rate of commercialisation achieved (Minoja, 2012). While it is true that some stakeholders may attain 'prime mover[44]' status based on their knowledge, expertise, and influence (Jacobsson & Johnson, 2000), and thus be more relevant to the commercialisation process than others, neglecting a stakeholder group has the potential to result in an unanticipated backlash in the future, such as the case of the Brent Spar oil storage platform disposal in 1994 (Löfstedt & Renn, 1997).

By incorporating all stakeholders in the commercialisation process, a real sense of ownership (of a MTRES) can be nurtured, especially among the local community, improving the social acceptance of the respective technology (Wustenhagen, Wolsink & Burer, 2007). By fostering favourable public perception, additional support for a new technology can be generated (Isabella, Yu, Silva & Pegetti, 2017). That being said, it is almost inevitable that resistance of some form will emerge from certain stakeholder groups (Huijts, Molin & Steg, 2012). The ability to manage such resistance, and subsequent degree of success achieved in overcoming it, will have a significant influence of the rate of commercialisation realised (Huijts *et al.*, 2012).

[44] Prime movers are associated with four primary tasks in the promotion of a new technology: (1) raising awareness, (2) investment, (3) legitimisation, and (4) diffusion (Jacobsson & Johnson, 2000).

2.2.5 Where does the commercialisation of energy technologies take place?

Chapter 2.1.6 mentions several spatial elements that address the question regarding where does technology commercialisation take place. Continuing from that, the complexity of energy technologies, with their large numbers of components, means that there is a greater tendency for commercialisation to take place across international borders in order to harness the technical expertise of different nations (Smith, 2011), and shift production to where it is cheapest in order to reduce costs (Ferdows, 1997). The incorporation of a global dimension also has an effect on the development of sustainable industries, while the expectations relating to the technology's performance and reliability encompass a wider range of stakeholders.

Another possibility, if we consider the question from a spatial viewpoint, is that the commercialisation of energy technologies takes place in the country where such technologies are to be constructed (Murphy, Jennings, Hughes, Ashcroft, Burke, *et al.*, 2014). This is valid if we consider that energy technologies such as MTRESs have to be constructed in proximity to RE sources, (National Academy of Sciences, National Academy of Engineering & National Research Council, 2010), while also taking into account grid infrastructure constraints (Nogee, Clemmer, Paulos & Haddad, 1999). Finally, it also needs to be noted that it is the citizens of a country who make use of the final energy good (Ahuja & Marika, 2009).

Lastly, there is the question - on which system hierarchy level of an energy technology does commercialisation take place? This question was discussed in Chapter 2.1.6, with the same outcome being applicable here. Hence, no further discussion is deemed necessary.

2.2.6 Why does the commercialisation of energy technologies occur?

There are several answers to the reason behind the commercialisation of energy technologies. While money is always a core motive (Apax Partners, 2005) , on a higher level it is to produce technologies which are able to meet the energy needs of a nation's citizens at an acceptable cost (Ahuja & Marika, 2009). Furthermore, through the development of associated sustainable industries (Hartmann & Huhn, 2009), commercialisation can benefit job creation, and lead to increased socio-economic growth (Balachandra *et al.*, 2010).

Security of energy supply is another reason behind the commercialisation of energy technologies (Aslani *et al.*, 2013), with energy considered to be of immense strategic importance in the modern era (Hajiyeva, 2016). Increasing fuel prices and finite fuel supplies have highlighted the need for diversity in the use of energy technologies (Rao & Kishore, 2010). In addition, governments may wish to reduce their reliance on foreign sources of energy (Solomon & Krishna, 2011). The problem of energy security is typically of greater urgency in developing countries, which face significant grid instability, and a lack of capital to finance grid extensions to the entire population (Thiam, 2011).

Having discussed the political nature of the energy sector in Chapter 2.2.1, the subject won't be repeated apart from acknowledgement of the role that agency and power play in the commercialisation of energy technologies. These roles are represented by the conflicting interests and agendas of powerful agents within the energy sector (Markard *et al.*, 2012).

In the case of MTRESs, there are additional reasons to favour the commercialisation of these technologies. First, they offer environmental benefits, (Blazejczak *et al.*, 2014), generating significantly less GHG emissions into the earth's atmosphere, and mitigating the effects of global warming, acid raid, and air pollution on the natural environment (Akella *et al.*, 2009). Secondly, they possess a near infinite fuel supply from energy sources, such as the sun and wind (Department of Energy, 2015a). Finally, they are able to address multiple energy needs, such as CSP, which can supply both electricity and thermal heat (Gauché *et al.*, 2017).

2.2.7 Summary: 5W1H model of the commercialisation of energy technologies

Having addressed each of the questions of the 5W1H model, the foundation for the process of technology commercialisation has now been strengthened through an understanding of the process in the context of energy technologies, particularly that of MTRESs. Table 2.5 summarises the different aspects of the commercialisation of energy technologies, as per the 5W1H model.

Table 2.5: Summary of 5W1H approach – commercialisation of energy technologies

5W1H question	Commercialisation
What?	▪ Sustainable markets, with an additional annual installed capacity dependent on expert input, as well as the status and history of the energy sector of the respective country. The meeting of expectations relating to performance and reliability of energy technologies. Available at a suitable LCOE comparable to other competitive energy technologies in same market bracket.
When?	▪ Begins after the development and design step, and reaches completion once a technology enters the market and achieves a state of commercial maturity.
How?	▪ Through government-related efforts. ▪ In-house development, joint commercialisation, technology transfer ▪ An operational plan comprising marketing, production, and finance components versus the licensing or transferal of IP rights.

5W1H question	Commercialisation
Who?	▪ Various stakeholders throughout the supply chain of the energy technology, with government possessing the most important position.
Where?	▪ Geographically, commercialisation is subject to environmental and organisational factors; across international borders, in the country where the technology is to be built ▪ Systematically, commercialisation depends on which components of a technology system are prioritised for commercialisation.
Why?	▪ To serve peoples' interests, agendas, and personal needs and desires. ▪ To meet the energy needs of a nation's citizens at least cost. ▪ Security of energy supply ▪ Environmental benefits

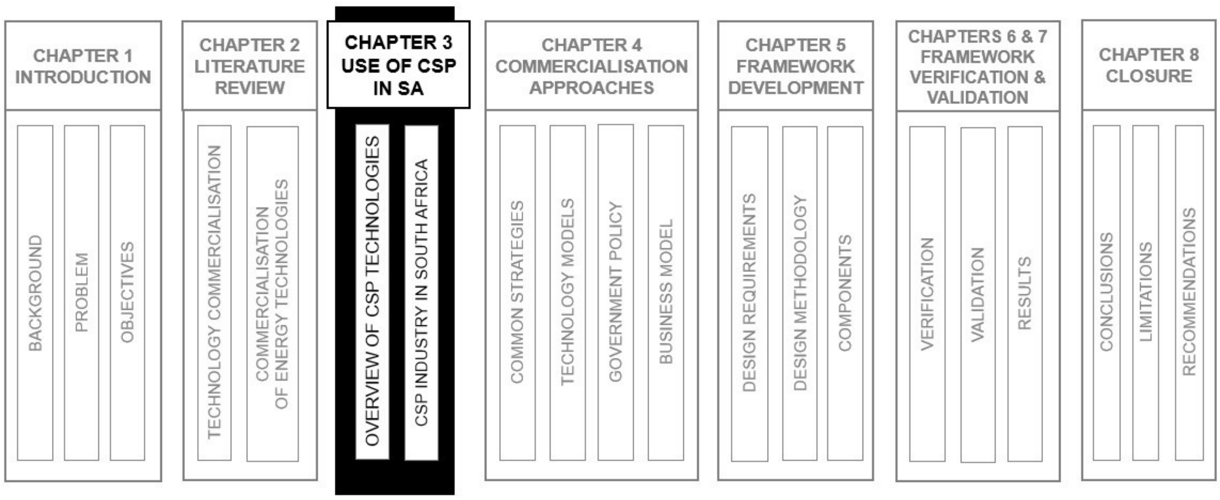
2.3 Summary: Literature review

Chapter 2 presented the first part of the literature review conducted as part of the research study. The field of technology commercialisation was explored using the 5W1H model, following which the focus was narrowed to the commercialisation of energy technologies, in particularly MTRESs. The use of the 5W1H model served as a useful starting point to guide the literature review, answering the most prevalent questions associated with the field of technology commercialisation, and that of energy technologies. The literature review continues in Chapter 4, with an evaluation of existing strategies, approaches and techniques for the commercialisation of MTRESs.

Chapter 3

The use of CSP in South Africa

Chapter 3 continues the review of the literature with an analysis of the use of CSP in South Africa. First, an overview of CSP technologies is provided based on their elementary operation, strengths and weaknesses, as well as current state and future prospects. This is followed by an evaluation of the CSP industry in South Africa, consisting of (1) of the value proposition of CSP technologies and the dominant barriers limiting their commercialisation within South Africa, (2) the activities comprising the technology's supply and value chains, (3) a set of demand- and supply-side measures aimed at strengthening the CSP industry in South Africa, and (4) future prospects relating to the industry's development within South Africa, and the role that CSP may play within the country's energy mix.



3.1 Overview of CSP technologies

There are presently four different types of CSP technology (Gauché, Brent & von Backström, 2014), illustrated in Figures 3.1 - 3.4 and summarised in Table 3.1. It is still uncertain which one may emerge as the dominant design (see Chapter 2.1), both globally and in South Africa. As such, it would be unwise to focus on a single CSP type until more is known about the value proposition of all four. For the foreseeable future, the parabolic trough collector (PTC) is seen as the most likely contender, while the solar tower central receiver (CR) type has the potential to produce a significant amount of electricity at low cost. On the other hand, Linear Fresnel collector (LFC) technology is favoured over PTC for smaller, lower temperature uses, such as industrial process heat and small-scale power. (Grobbelaar *et al.*, 2014)

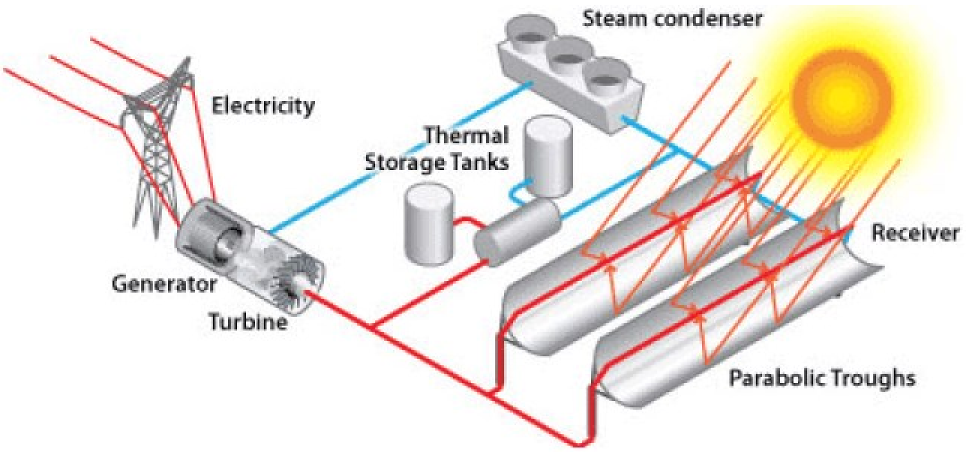


Figure 3.1: Parabolic trough collector

(Source: Mendelsohn *et al.*, 2012)

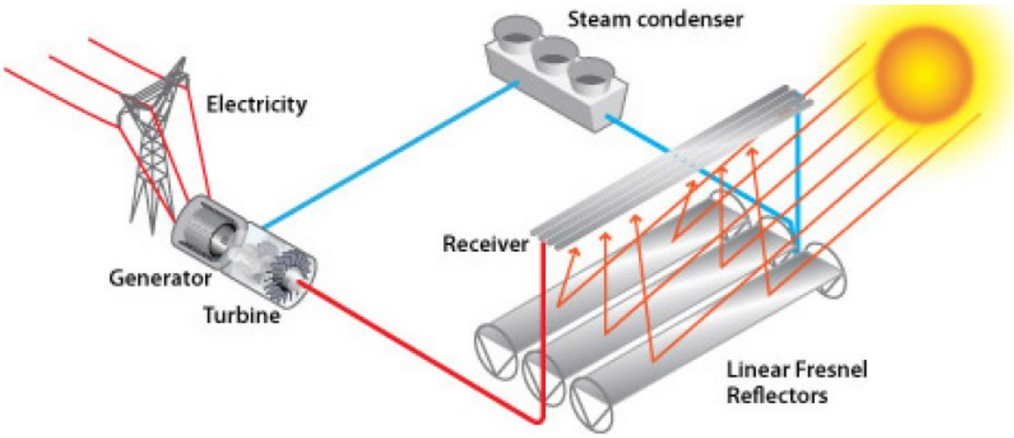


Figure 3.2: Linear fresnel collector

(Source: Mendelsohn *et al.*, 2012)

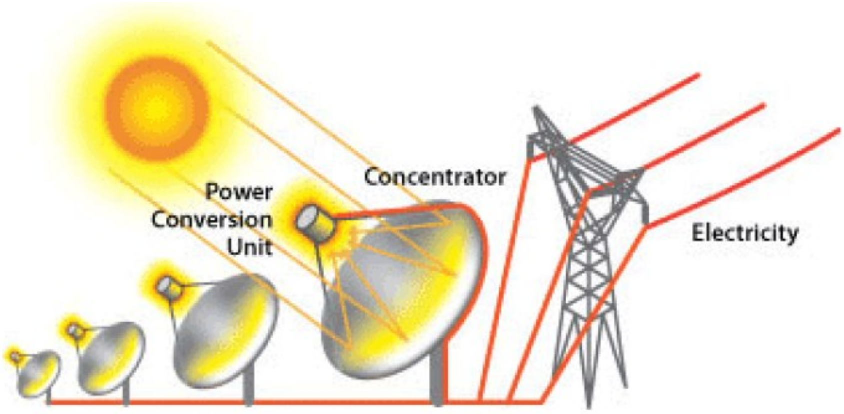


Figure 3.3: Parabolic dish stirling

(Source: Mendelsohn *et al.*, 2012)

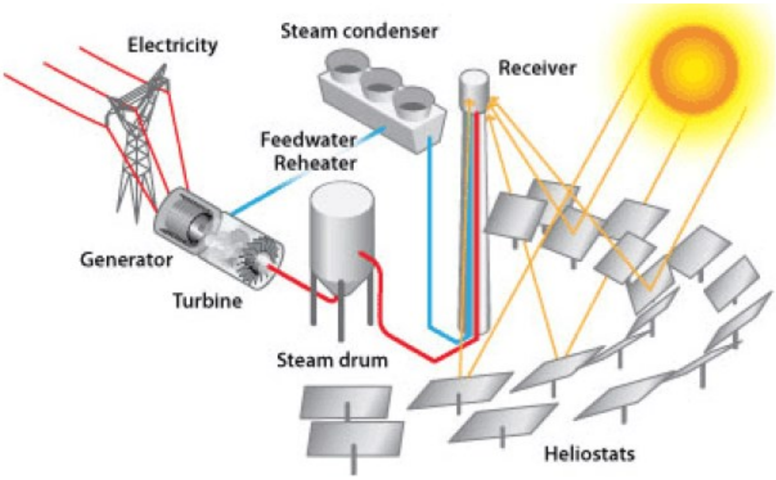


Figure 3.4: Central receiver

(Source: Mendelsohn *et al.*, 2012)

Table 3.1: Overview of CSP technologies

CSP technology	Description	Strengths	Weaknesses	Current state and future prospects
Parabolic trough collector (PTC)	Line focused. Parabolic-shaped mirrors concentrate sunlight onto a central receiver tube in the focal line of the collector. Single-axis tracking mechanism.	▪ Most mature of the four CSP technology types. ▪ Good level of optical efficiency (geometric properties).	▪ Use of thermal oil, molten salts and steam loops. ▪ Maximum permissible temperature < 400°C → reduced efficiency & greater water usage ▪ Evacuated tubes and mirrors likely to be imported into South Africa	▪ Most commercially advanced and profitable CSP technology. ▪ R&D success may improve this model
Linear Fresnel collector (LFC)	Line focused. Series of long, flat mirrors to concentrate sunlight either side of a central receiver tube. Single-axis tracking mechanism.	▪ Use of molten salts or direct steam as a heat transfer fluid (HTF) is a more feasible option. ▪ More efficient land use; less steel & concrete needed, cheaper flat glass mirrors, greater mirror surface per receiver.	▪ Greater number of mirrors required for equivalent energy production as other models. ▪ Lack of experience	▪ Potential to yield profits faster if adapted to a similar complexity as the parabolic trough. ▪ Higher local material use possible.
Parabolic dish / Dish stirling (PD)	Point focused. Parabolic-shaped dish that reflects sunlight onto receiver at focal point. Dual-axis tracking mechanism.	▪ Greatest thermal efficiency of CSP technologies. ▪ Small modular capacity, high degree of scalability, adaptable to slopes (hills, mountains). ▪ Dry cooling → doesn't require big cooling systems, low water usage.	▪ Scalability only possible through modularity. ▪ Lack of suitable storage. ▪ Lack of acceptable commercial success.	▪ Remote and rural application in arid areas.
Central receiver / solar tower (CR)	Point focused. Ground-based field of heliostat mirrors that reflect sunlight towards solar tower central receiver to heat fluid; sunlight → heat → steam for power generation. Dual-axis tracking mechanism.	▪ Point focused; no scalability issues → increase field size per electricity demand. ▪ Flat mirrors & high concentration simplifies parts. ▪ Higher temperatures → greater efficiency for power, storage and dry cooling. ▪ Greatest potential for cost reduction.	▪ Lifecycle (lack of significant operating experience). ▪ Maturity: still in developmental phase.	▪ Optimal for CSP dispatch in a grid-connected system. ▪ Large scale possible in regions with clear skies. ▪ Low water consumption. ▪ Highest local content.

(Source: Adapted from Gazzo, Kost, Ragwitz, Govindarajalu, Roos & Hassan, 2010; Müller-Steinhagen & Trieb, 2012; Thompson-Smeddle, 2012; Gauché *et al.*, 2014)

3.2 The CSP industry in South Africa

The CSP industry in South Africa is currently in an early stage of development, with some questioning its relevance in the country's energy supply (Grobbelaar *et al.*, 2014). Gauché, Backström & Brent (2013) claim that CSP technology *'is the ideal future dispatchable power technology for South Africa in the broadest context in that it can dispatch power to demand and can enable a very high degree of local inclusion'*. The ability to provide electricity on demand is vital within any economy to assist with socio-economic growth (Brent & Pretorius, 2011), and provides a measure of flexibility within the national electricity grid (Gauché *et al.*, 2014). However, the fact that CSP is able to produce dispatchable electricity, and has the potential for increased local socio-economic development, raises the question as to why the level of penetration in the South African energy industry remains at such a low level.

Following an extensive analysis of both traditional and RE sources, Gauché *et a*l. (2013) expanded on their initial claim, presenting a list of secondary propositions with respect to the deployment of CSP technology over alternative energy technologies in South Africa:

- CSP is the optimal energy technology with respect to long-term sustainability and deployment in South Africa, especially as the supply of fossil fuels diminishes with increased consumption.
- The existing resources, skills, and infrastructure are well positioned to be utilised together with CSP equipment, skills, and associated project risks.
- The costs associated with a national CSP rollout are significant, yet provide a number of socio-economic benefits for SA, together with a more diverse energy supply. However, before such a rollout takes place, it is necessary to learn more about the technology through construction of smaller CSP experimental plants to be used for research and learning purposes.
- The future CSP technology for bulk power production will be a CR type, one that is flexible in size in order to increase or decrease electricity production. An additional benefit is the greater efficiency of the model with respect to plant area requirements, cost, and reduced water usage.
- CSP technology can be harnessed for distributed power production, in turn providing reduced transmission risks, and greater value to the local population and natural environment.

This list of secondary propositions provides some answers regarding the lack of roll out of CSP, with cost being recognised as the largest barrier currently faced by the CSP industry (Grobbelaar *et al.*, 2014). However, these costs need to be placed into context when considering CSP's potential for dispatchability, which allows the technology to be integrated with other energy resources into a more diverse mix.

A lack of knowledge of CSP technologies is also highlighted as being a prominent issue in South Africa, with the need for the development of small-scale experimental CSP power plants to learn more about the technology, and identify subsequent issues and areas for future investigation and research (Gauché *et al.*, 2013). Furthermore, the fact that South Africa currently possesses the necessary resources, skills, and infrastructure to aid the construction of such plants, and advance the CSP industry (Sager, Ellen, Ritchken & Osborne, 2015), points to a lack of willpower to utilise these assets to achieve progress in the learning process of CSP technologies.

Moving beyond the barriers of cost and knowledge, it is worthwhile delving deeper into the South African CSP industry, analysing the measures aimed at promoting and expanding the existing market for such technologies. This analysis includes the supply and value chains, demand- and supply-side management (of the industry), and prospects for the future development of the industry. However, it may be beneficial to first examine the CSP projects developed under the country's REI4P programme, and the cost reductions have taken place.

3.2.1 CSP under the REI4P Programme

A number of CSP projects in South Africa have been commissioned through REI4P, the country's utility-scale power procurement programme. Table 3.2 presents an overview of these projects, detailing their current status, type of technology used, TES capacity, bid window round commissioned, and the respective developer and engineering, procurement, and construction (EPC) firm used. The introduction of a two-tier time-of-day (TOD) tariff multiplier of 2.7 from bid round 3 recognizes the dispatchable value of the technology, able to provide energy on demand during peak demand periods. (Relancio, Cuellar, Walker & Ettmayr, 2016)

Table 3.2: CSP projects under the REI4P

Project	Capacity	Bid round	Status	Technology	TES capacity	Developer	EPC
Kaxu	100 MW	1 (single tariff)	Operation	PT	2.5 h at full load	Abengoa/IDC	Abeinsa
Khi	50 MW	1 (single tariff)	Construction	CRS	2 h at full load	Abengoa/IDC	Abeinsa
Bokpoort	50 MW	2 (single tariff)	Construction	PT	9 h at full load	ACWA	Acciona/ Sener/TSK
Xina	100 MW	3 (TOD tariff)	Construction	PT	6 h at full load	Abengoa/IDC	Abeinsa
Ilanga	100 MW	3 (TOD tariff)	Construction	PT	5 h at full load	Cobra/Emvelo	Cobra
Redstone	100 MW	3.5 (TOD tariff)	Development	CRS	12 h at full load*	ACWA/Solar Reserve	TDB
Kathu	100 MW	3.5 (TOD tariff)	Development	PT	4-6 h at full load*	GDF	Acciona/ Sener

* Subject to be confirmed by bidders at Financial Close

(Source: Relancio *et al.*, 2016)

It is also worth comparing the cost of CSP technologies to other energy technologies in South Africa under the REI4P. Figure 3.5 compares the reduction in average tariffs under the REI4P for solar PV, CSP and wind technology, while Figure 3.6 compares the lifetime cost per energy unit of various energy technologies, based on new build capacity values. While it interesting to assess how CSP compares to other energy technologies on a cost basis, one must be careful when making any decisions based on the data, taking into account additional factors such as the capacity factor[45] of the different technologies, value propositions, and energy demand patterns.

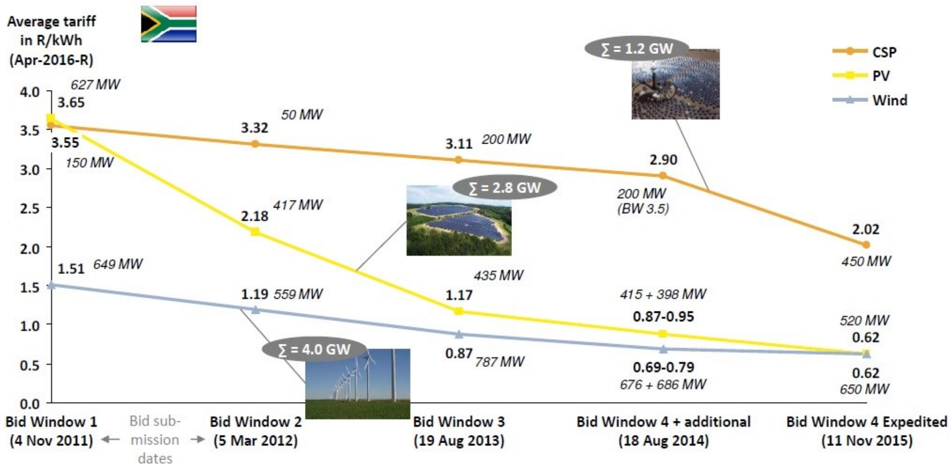


Figure 3.5: Solar and wind cost reduction trends under the REI4P

(Source: CSIR Energy Centre, 2017)

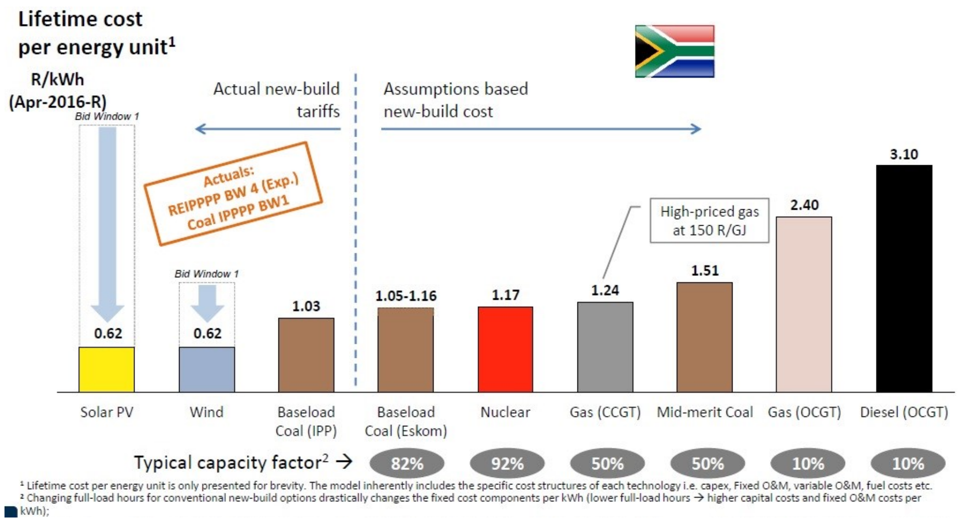


Figure 3.6: Lifetime cost comparison of energy technologies

(Source: CSIR Energy Centre, 2017)

---

45 A capacity factor is the ratio of actual power generated to the maixum possible power output (rated power output) from a technology over the same time period (Troldborg *et al.*, 2014).

3.2.2 Supply chain and value chain

The supply chain and value chain both play an important role in a technology's progress towards a commercialised state. Both chains aid the development of strong (associated) industries that support a technology (Frederick, 2009), greater adoption of a technology within the market and society (Amarender Reddy, 2013), as well as increased cost reduction, economic growth, and consumer satisfaction (Amarender Reddy, 2013; Economic Development Board of South Australia, 2015). Hence, strengthening both chains is vital for increasing the rate of commercialisation.

Confusion often exists regarding the differences between the supply chain and value chain. The boundaries between the two chains are frequently blurred over time, in part due to that fact that they share many common activities, such as manufacturing-related tasks, which add value to a technology (value chain) while also ensuring it is ready for consumer use (supply chain) (Daidj, 2015). Surbhi (2015) attempts to clarify the difference between the two chains, describing the supply chain as: '*the interconnection of all the activities that starts from the manufacturing of raw material into the finished product and ends when the product reaches the final customer*', and the value chain as: '*the set of activities that focuses on creating or adding value to the product'*. Amarender Reddy (2013) offers a similar view, stating that the supply chain consists of '*stages that transform a raw material into a finished product or service, and delivers it to the ultimate customer*', while the value chain is focused on '*value addition at different stages of transfer'* for the purposes of maximising the final technology's value at the lowest possible cost.

Expanding on these definitions, Surbhi (2015) states that the supply chain represents an operational management tool to transform businesses, reducing expenses while increasing consumer happiness. The value chain, on the other hand, is a business management tool aimed at gaining a competitive advantage of other firms in the respective industry, while meeting consumer needs satisfactorily (Surbhi, 2015). Comparing the two chains, the decision was made to focus attention on the value chain, namely: those activities used to create additional value within South Africa's CSP industry, and thus considered of greater interest for efforts aimed at improving the rate of commercialisation of CSP technologies in South Africa.

Delving deeper into the value chain, Pearce II & Robinson Jr. (2009:164) define it as: '*a chain of activities that transforms inputs into outputs that customers value*'. This conceptualisation draws attention to the various inputs and outputs of the different value chain activities, be they materials, labour, services or other, while also highlighting the role played by the consumer. These activities may vary between businesses and organisations, but have the same fundamental focus of creating and/or adding value to the respective offering, be it a product or service, until it reaches the consumer. Thus, analysis of the CSP value chain needs to consider the required input and outputs, together with the needs and profile of CSP users and stakeholders.

The activities of a value chain are commonly divided into two categories: primary and support. Primary activities describe those relating to the actual product or service itself offered by an organisation, such as manufacturing, marketing, or post-sales support. Support activities refer to those activities that aid an organisation through the provision of infrastructure and other services, such as administration, human resources and R&D, that allow for the primary activities to occur on a continual basis. This categorisation provides more detail about the role played by different activities within the value chain, and broader commercialisation process, and may assist focus efforts aimed at increasing the existing rate of commercialisation. (Pearce II & Robinson Jr., 2009:164)

The value chain of many energy-producing technologies often focuses on the chain of activities used to generate electricity (see Figure 3.7), the primary form of energy desired (Richter, 2012). However, this chain neglects consideration of the ability of energy technologies to produce other forms of energy, such as solar thermal heat in the case of CSP technologies. Thus, it may be more appropriate to devise an energy value chain, one that considers the diverse applications of CSP, and that can be used to clarify the (commercialisation) activities needed, together with the skills and capabilities of the various parties.

Figure 3.7: Electricity value chain

(Source: Richter, 2012)

A detailed breakdown of the CSP value chain is presented in Figure 3.8. The core activities of the value chain are recognised, with consideration given to the inputs and outputs of each activity, such as the materials required by the various components of a typical CSP system. In contrast to the generic electricity value chain of Figure 3.7, the activities of Figure 3.8 are supported by a list of elements, providing greater information on the nature of each activity. The inclusion of the essential partners of the value chain is also useful, acknowledging those responsible for the implementation of each activity in the chain. Finally, four aspects required in the analysis of the value chain are highlighted, offering value for those management practitioners and other organisational leaders interested in strengthening the value chain.

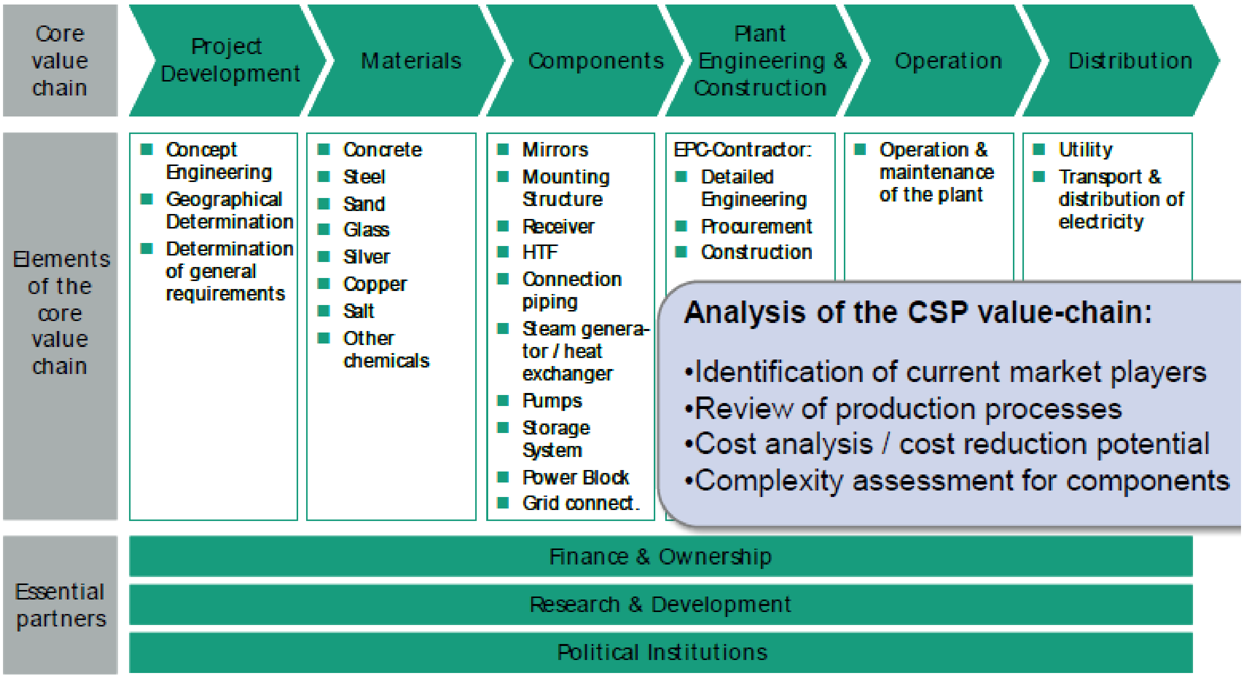


Figure 3.8: CSP value chain

(Source: Eichhammer & Morin, 2010)

Lund (2009) proposes an alternative value chain for the CSP, and RE, industry, one that is more aligned with the activities that form part of both the value chain and the supply chain. Rather than illustrate the value chain in a linear form, as in Figure 3.8, Figure 3.9 shows the interconnectedness of the different activities, demonstrating the various relationships that exist. In particular, it elaborates on the activity of system integration, one that is especially important in the case of CSP and MTRESs. However, the focus on a generalised supply/value chain for all energy systems fails to provide an adequate description for the specific case of CSP technologies. As such, the CSP value chain of Figure 3.8 proves a superior model for understanding the different activities that comprise the CSP industry.

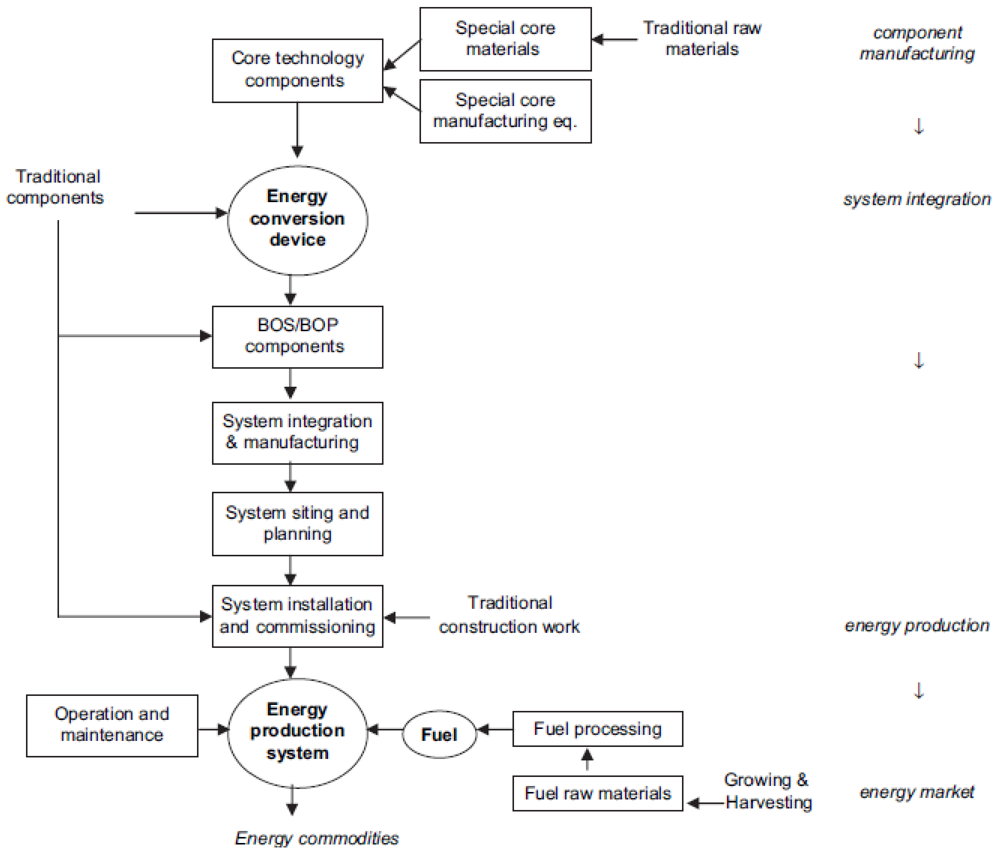


Figure 3.9: Energy systems supply/value chain

(Source: Lund, 2009)

3.2.3 Supply-side management

The supply-side management (SSM) of the CSP industry in South Africa focuses primarily on technology-push initiatives, that is, means of aiding technological progress in order to improve the supply of high-quality, low-cost technologies, products and services (Grobbelaar *et al.*, 2014). Grobbelaar *et al.* (2014) proposed a number of measures (see Table 3.3) aimed at strengthening the supply of CSP technologies in South Africa, with the potential to position South Africa as the leading CSP technology producer in Southern Africa.

Table 3.3: CSP supply-side measures for South Africa

Supply-side measure	Implementation in South Africa
The development of a local manufacturing hub	The development of a local CSP manufacturing hub, one flexible in scope and size, could greatly enhance efforts to lower the costs relating to CSP technologies and components in South Africa. Without such a hub, components for CSP plants will need to be imported from overseas, likely at a higher cost. The hub would also contribute to local socio-economic growth, thus meeting government criteria for domestic industrial development. Government can assist the hub's

Supply-side measure	Implementation in South Africa
	development through supply-side policies, such as those which safeguard domestic goods against the introduction of significantly cheaper technologies developed elsewhere (China) into the South African market.
Greater involvement of government in selection of CSP technologies.	Governments tend to show reluctance to intervene in picking a 'technology winner[46]', preferring for the private sector and market forces to be responsible for such a selection. However, government action in this regard can increase the rate of commercialisation, as a dominant design would emerge sooner than expected, benefitting the industry.
Expansion of South Africa's innovative capacity and R&D investment	South Africa lacks sufficient technical expertise in CSP technologies. However, despite the lack of such specialist knowledge, and the complex nature of such technologies, many of the components and materials required are standard parts readily available on a local basis. Improvements in the country's (CSP) innovative capacity, leverage of capacity in similar industries (automobile industry), and greater R&D investment, can have a significant impact on its ability to utilise CSP technologies to diversify the existing energy supply.
Take advantage of international supply-structure constraints	The manufacturing sector in South Africa is an established one. It is recommended that the sector's capabilities be harnessed as a means of competitive advantage with respect to the production of CSP-related components. The elementary nature of the international global CSP supply chain presents an opportunity for first-movers to gain market share through exporting supply structures for the global market.

(Source: Grobbelaar *et al.*, 2014)

3.2.4 Demand-side management

Demand-side management (DSM) is defined by Behrangrad (2015) as*: "modifications in the demand side energy consumption pattern to foster better efficiency and operations in electrical energy systems.*" Although broken up into its various activities in Figure 3.10, management of energy, and electricity, demand is no simple task. To improve DSM, energy utilities seek to modify existing energy demand patterns through energy efficiency and demand response (DR) operations. These operations have received greater prominence due to the introduction of smart grid technology, rising electricity prices, and deregulation of electricity markets worldwide. (Behrangrad, 2015)

[46] See Chapter 2.1 for discussion on dominant design.

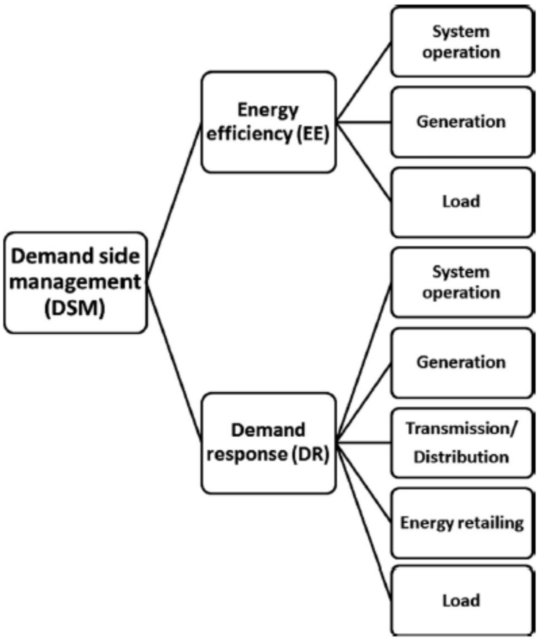


Figure 3.10: Demand-side management activities

(Source: Behrangrad, 2015)

Although EE measures[47] are important in the DSM of South Africa's energy industry, maximising the use of electricity in a variety of applications, they have little relevance for the CSP industry, where the objective is to maximise the quantity of electricity sold and thus earn a higher profit. Indeed, one could argue that EE initiatives act to the detriment of energy producing technologies, limiting the demand for their product. Thus, the DSM of the CSP industry in South Africa should focus primarily on DR operations, namely: system operation, energy generation, energy transmission and distribution, energy retailing, and the energy load. Table 3.4 presents a number of initiatives aiming at improving the demand for CSP technologies in South Africa.

Table 3.4: Demand-side initiatives for South Africa

Demand-side initiatives	Implementation in South Africa
Development of suitable financial mechanisms	The CSP industry in South Africa currently faces large initial costs, with a significant financial shortfall contributing to a higher LCOE than other energy technologies. Innovative financial mechanisms are required to secure the investment needed for such projects, together with a change in will from political leaders and key financial institutions.

[47] Note that these EE measures refer to the management of the entire energy sector, and do not refer to the efficiency of the respective energy technology itself.

Design of a voluntary green energy market	In order to develop a green market, appropriate incentives need to be put in place to ensure behavioural changes and market shifts. Experience has shown that such changes cannot be stimulated by the voluntary nature of the market alone.
Formation of a market for South African technology	Promoting demand for CSP technologies from South Africa can assist the development of a local CSP manufacturing industry, and ensure a sustainable market for such technologies, both domestically, regionally (Southern Africa) and internationally.
Update of the IRP	The 2010 IRP (and updated 2011) IRP document is now widely considered out of date, especially considering it is meant to be revised once every two years. Hence, there is an urgent need to produce an updated version regarding South Africa's energy policy going forward. Ambitious targets are needed to promote investment in the CSP industry and lower costs.

(Source: Grobbelaar *et al.*, 2014)

3.2.5 Future industry development

As stated previously, arguably the most critical goal of both supply- and demand-side management presently is the need to reduce the costs involved with CSP technologies (Grobbelaar *et al.*, 2014). Figure 3.11 expands on those measures introduced in Tables 3.3 and 3.4 to focus on how such interventions may be applied to achieve cost reductions. Strong consideration should be given to these interventions for inclusion in any approach aimed at commercialising CSP technologies in South Africa.

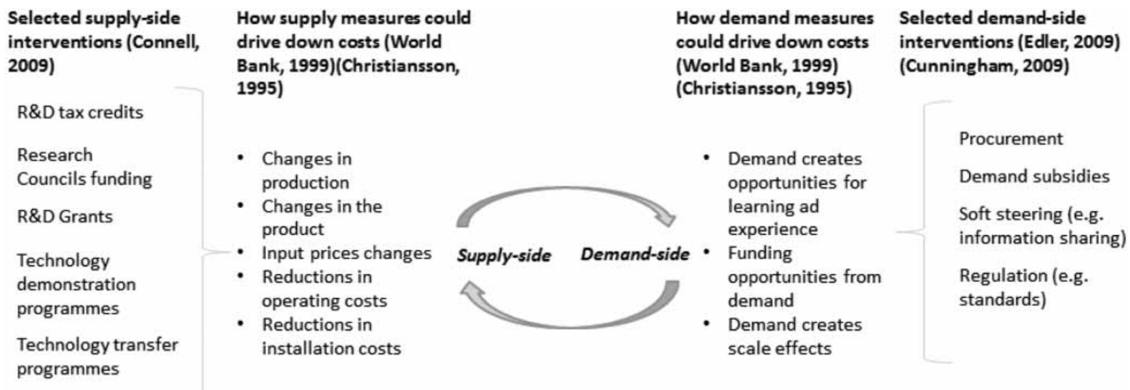


Figure 3.11: Supply-side and demand-side measures for technology cost reduction

(Source: Grobbelaar *et al.*, 2014)

Although the measures discussed are important for the development of a sustainable market for CSP technologies in South Africa, it is necessary to position these measures in the broader context of industry growth. Grobbelaar *et al.* (2014) present a CSP industry roadmap (see

Figure 3.12), locating various measures and activities (supply, demand, and non-economic) based on their time period of use, and respective state of the industry (establishment, growth and maturity). The roadmap offers insight into the interactions between supply- and demand-side measures in fostering a sustainable CSP market in South Africa. However, due to the date of publication, it lacks a certain degree of relevance in terms of current government policy, given that the REIPPP Programme has replaced the REFIT. Nonetheless, it still holds value as a source for growing the CSP industry in South Africa.

	Industry establishment (2011 to 2015)	Growth (2016 to 2030)	Maturity (2031 to 2050)
	• *Focus on cost reduction*	• *Focus on cost reduction and large scale roll-out* • *Explore export opportunities*	• *Focus on stimulating demand and implementing water saving technology*
Non-economic	*Non economic:* • Initial grid expansions (Edkins, 2009)(Primary interviews) • Improved coordination and communication for renewable energy policy making and industry development (Primary research)	*Non economic:* • Further Grid expansions with grid wide storage (Edkins, 2009)(Primary interviews)	*Non economic:* • SAPP day-ahead market (Edkins, 2009)
Demand	*Demand:* • Implementation of technology demonstration programmes (Primary interviews) • REFIT implemented (Edkins) • Planned build of 100 MW per year	*Demand:* • REFIT but to expire at some point (Edkins, 2009) • Scale up of planned build from 100 MW to 300 MW per year or more (to support full manufacture locally)(Primary interviews) • Explore export opportunities for certain components	*Demand:* • Policies geared towards stimulating demand locally – cost efficiency achieved and compares with PV or wind (IEA, 2009) • South Africa manufacture and export CSP technology globally (Primary interviews)

Supply	*Supply:*
	• ***R&D:*** Align R&D funding to address SA based technology development e.g. water saving technology (Primary interviews)
	• ***Technology:*** Technology transfer programmes – attract Multi nationals to set up operations in SA (Edkins, 2009)(Primary interviews)
	• ***Manufacturing:*** Self-exploration activities to determine which component and sub-systems could cost effectively be manufactured in SA (primary research)
		Supply:
		• Test centre established to keep close track of most efficient ways of achieving cost efficiencies
		• ***R&D:*** SA specific technology for certain components
		• ***Manufacturing:***
		  • Establishment of manufacturing capabilities by related SA industries (Primary Interviews)
		  • Scale up capabilities in manufacturing (Primary Interviews)
			Supply:
			• ***Innovation:*** Water saving technology implementations (Edkins, 2009)
			• ***Manufacturing:***
			  • Standardisation of components and manufacturing processes;
			  • South Africa able to fully manufacture part or whole of CSP plant

Figure 3.12: Measures for developing the CSP industry in South Africa

(Source: Grobbelaar *et al.*, 2014)

The development of South Africa's CSP industry is also subject to the influence of other electricity-producing technologies within the country's energy mix (Baker, 2015). Figure 3.13 presents a qualitative positioning of the different types of future electricity production in South Africa, leading up to 2030. The horizontal axis classifies each type of electricity generation as intermittent, base-load, or dispatch/peaking, while the vertical axis describes the localisation potential of each type, namely: their usage of content local to South Africa in the way of resources, such as skills, knowledge and materials. The acronyms CCGT and OCGT represent combined cycle gas turbine and open cycle gas turbine respectively. (Grobbelaar *et al.*, 2014)

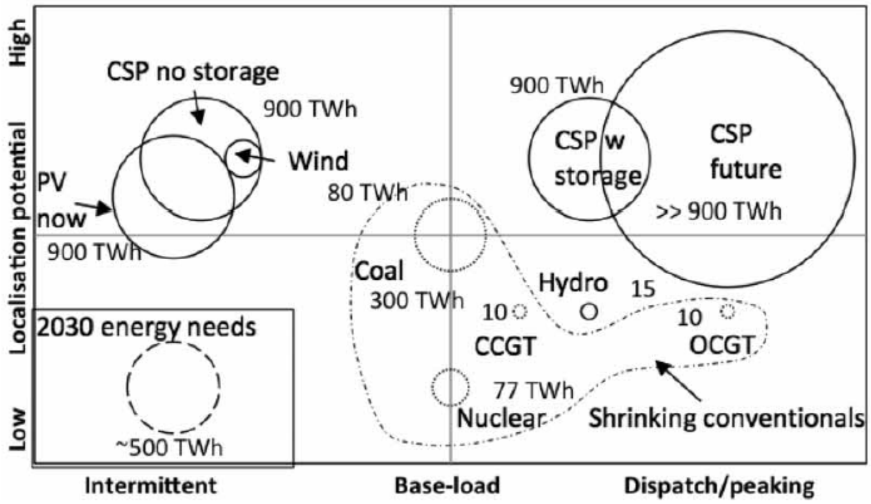


Figure 3.13: Comparison of future electricity generation technologies in South Africa

(Source: Grobbelaar *et al.*, 2014)

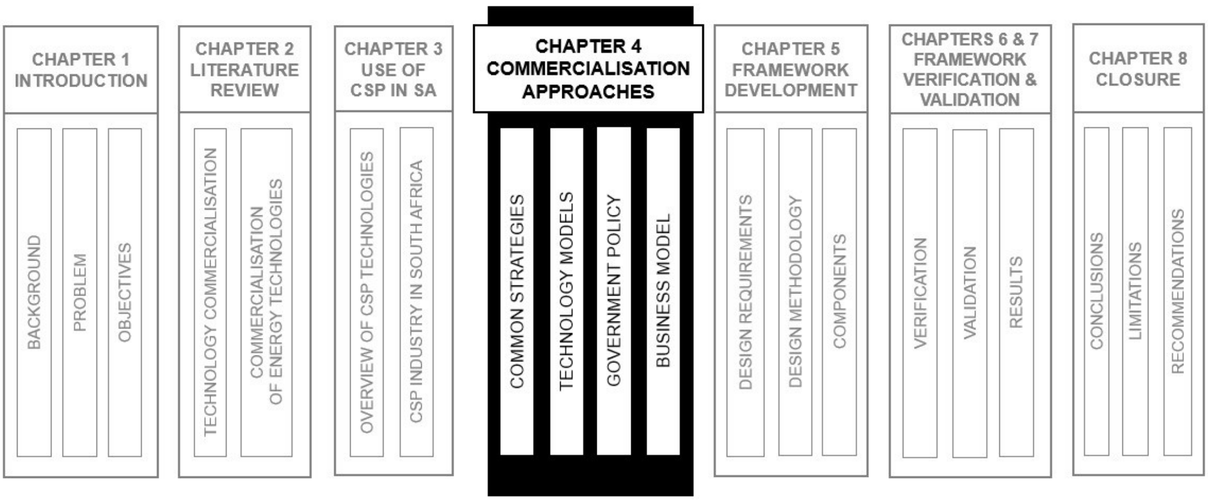
The inclusion of storage with CSP technologies allows them to operate as dispatch technologies (as opposed to intermittent) (Baharoon *et al.*, 2015). This ability to store thermal energy increases the time period of energy output (Baharoon *et al.*, 2015). Although it is possible that CSP alone could meet South Africa's projected energy needs in 2030, the costs involved will be excessive, marking such an option infeasible (Grobbelaar *et al.*, 2014). A more practical solution involving RE sources would be an energy mix of solar PV, wind and CSP (Grobbelaar *et al.*, 2014). However, much progress needs to be made in each of the three technology types before such a scenario could be considered realistic (Grobbelaar *et al.*, 2014) In addition, the future of South Africa's energy mix is the responsibility of the national Department of Energy (DoE) (Department of Energy, 2016), which presently seems inclined to favour the use of coal and nuclear technologies over MTRESs (Wright, Bishof-Niemz, Calitz, Mushwana, Heerden, *et al.*, 2017).

Concluding the examination of the use of CSP in South Africa, it appears that the CR type may emerge as the dominant design of the future from the four existing CSP technologies. Cost is currently the largest barrier to the roll out of CSP technology, with a number of measures being introduced to address cost reduction as well as the shortage of practical knowledge and skills. Investigation of the value chain provides greater awareness of which activities should be prioritised in the short-, medium- and long-term, while the necessary SSM and DSM measures to assist industry growth through means of a roadmap were also investigated. Finally, following comparison of the prospects of various electricity-producing technologies in South Africa, it was found that CSP technology possesses the potential to form part of a future RE mix, together with wind and solar PV, to meet South Africa's energy demand by 2030.

Chapter 4

Strategies, approaches, and techniques for the commercialisation of MTRESs

Chapter 4 concludes the literature review conducted in this research study. It builds on the understanding of the commercialisation process established in Chapter 2, with an evaluation of existing strategies, associated approaches, and techniques[48] for commercialising MTRESs to determine their strengths and weaknesses. The purpose of the evaluation is to investigate what is required to increase the rate at which the commercialisation of MTRESs takes place. In practice, the methods evaluated in this section may not be used exclusively; the purpose of this evaluation is to analyse each method separately. The complete evaluation conducted can be found in Appendix A; Chapter 4 merely provides a summary of each strategy, approach, and technique evaluated.



[48] The researcher acknowledges the argument that any commercialisation approach can be broken down into activities such as design and development, engineering and manufacturing, marketing, and finance. This section analyses a range of strategies, approaches, and techniques on a variety of levels, some of which may make use of these different activities in order to commercialise MTRESs.

4.1 In-house development

Table 4.1 summarises the evaluation of the in-house development strategy from Appendix A.1.

Table 4.1: In-house development evaluation

Description	Strengths	Weaknesses
The internal commercialisation of a technology by an organisation's own competencies and processes (distribution, production etc.).	Allows an organisation control over the entire commercialisation process, as well as retaining the IP rights relating to the specific technology.	An organisation may not enjoy sufficient strength of operations and finance, or possess sufficient strength in the capabilities and sub processes required for commercialisation, resulting in the technology failing to reach commercial status.

4.2 Joint commercialisation

Table 4.2 summarises the evaluation of the joint commercialisation strategy from Appendix A.2.

Table 4.2: Joint commercialisation evaluation

Description	Strengths	Weaknesses
A strategic alliance or partnership between one or more entities with a common interest in the commercialisation of a given technology.	Allows organisations to complement their strengths and expertise with that of other organisations, in order to realise a more rapid commercialisation of a given technology.	Questions may emerge over the degree of benefits each party receives during the commercialisation process. Potential for conflict and breakdown of trust between partners, threatening the event that a technology reaches a commercialised state.

4.3 Technology transfer

Table 4.3 summarises the evaluation of the technology transfer strategy from Appendix A.3.

Table 4.3: Technology transfer evaluation

Description	Strengths	Weaknesses
The transfer of IP rights relating to a specific	▪ Can be implemented at any phase in the commercialisation process.	▪ Narrow application ▪ Number of entities involved in the transfer of technology

Description	Strengths	Weaknesses
technology in the way of licensing, technology exportation etc.	▪ Can present a cost-effective option for firms facing a competitive business environment ▪ Presents an alternative commercialisation avenue for firms who may developed a technology not in line with their core businesses.	towards commercialisation represents a greater possibility for gaps in the chain to exist, with the technology failing to reach commercial maturity.

4.4 Technology life cycle analysis

Table 4.4 summarises the evaluation of the TLC analysis approach from Appendix A.4.

Table 4.4: Technology life cycle analysis evaluation

Description	Strengths	Weaknesses
Analysis of a technology's life cycle, the factors responsible for its progression up the s-curve, and its (potential) impact on the external environment.	▪ Allows for effective technology management through identification of a technology's present life cycle stage, and the stage's implications with respect to decision-making. ▪ Easy to understand.	▪ Discrepancies/confusion exist between use of the terms TLC, product life cycle (PLC), and industry life cycle (ILC). ▪ Lack of a common TLC viewpoint (macro view vs s-curve) ▪ Requires integration with other methods and data for practical use.

4.5 Technology assessment

Table 4.5 summarises the evaluation of the technology assessment (TA) approach from Appendix A.5.

Table 4.5: Technology assessment evaluation

Description	Strengths	Weaknesses
A broad range of analytical tools and methods with which to conduct a thorough assessment of a given technology.	Yields a systematic and holistic view of the respective technology to assist the decision-making process.	▪ Lack of a standardised and systematic TA methodology for energy technologies. ▪ Predominant focus on energy policy and strategy, as opposed to technology management. ▪ Large data requirements

4.6 Government action and policy

Table 4.6 summarises the evaluation of government action and policy from Appendix A.6.

Table 4.6: Government action and policy evaluation

Description	Strengths	Weaknesses
Policies, initiatives, and other actions performed by government to assist the commercialisation of new technologies, and meet objectives.	▪ Provides incentives for the business sector and consumer to invest in, and adopt, a new technology. ▪ A key driver of demand for MTRESs. ▪ Creates the regulatory environment necessary to drive investment and socio-economic growth.	▪ Frequently used for the personal interests and agendas of powerful political agents, instead of the 'common good'. ▪ Policy uncertainty and ambiguity; lack of coordination between different departments. ▪ Political interference often has a detrimental effect on the implementation of sound policies. ▪ Policies are not often technology-specific, or provide insufficient clarity regarding their implementation. ▪ Insufficient involvement of other stakeholders; government is unable to manage and finance entire industries by themselves.

4.7 Technology roadmap

Table 4.7 summarises the evaluation of the technology roadmap (TRM) approach from Appendix A.7.

Table 4.7: Technology roadmap evaluation

Description	Strengths	Weaknesses
"*A medium to long term action plan to forecast the direction of future markets and developments in technology and help make strategic decisions, providing a critical link between technology investment decisions and business planning, and providing a structured approach for mapping the evolution and development of complex system*" (Jeffrey, Sedgwick & Robinson, 2013).	▪ Integration of business thinking with science and technology into the development of complex systems. ▪ Can be combined with different management techniques to solve complex issues in all industries and technologies. ▪ Platform for the engagement of multiple stakeholders.	▪ Many energy TRMs lack frequent revision and updating to ensure they remain relevant. ▪ Insufficient mention of organisational capabilities required for commercialisation. ▪ Little focus given to improving social acceptance of new technologies (overcome local opposition).

4.8 Architecture framework

Table 4.8 summarises the evaluation of the architecture framework from Appendix A.8.

Table 4.8: Architecture framework evaluation

Description	Strengths	Weaknesses
A systems engineering tool used to analyse complex systems. Focuses on the components and functions contained within a system, as well as the interfaces which exist within the system, and between the system and external environment.	▪ Ability to handle problems containing inherent uncertainty and poor organisation. ▪ Includes consideration of the interfaces which exist both within systems, and between the system and the external environment. ▪ Iterative nature; able to accommodate and organise new data while recognising the ongoing structural evolutions experienced by the technological system with reference to the existing technological system (socio-technical transition). ▪ Forward looking nature allows for setting of short-, medium-, and long-term goals.	Lack of mention given to organisational capabilities required for the commercialisation process.

4.9 Business model

Table 4.9 summarises the evaluation of the business model approach from Appendix A.9.

Table 4.9: Business model evaluation

Description	Strengths	Weaknesses
A model for businesses wishing to commercialise MTRESs.	▪ Acknowledges importance of stakeholder partnerships. ▪ Innovative financial, marketing, and incentive schemes.	▪ Lack of a comprehensive TA component to fully understand the respective technology. ▪ Focus on ROI conflicts with certain goals and activities required for technology commercialisation. ▪ Lack of measures to improve social acceptance of MTRESs. ▪ Lack of mention of the interfaces between the different components of the model.

4.10 Summary: Strategies, approaches, and techniques for the commercialisation of MTRESs

Chapter 4 concluded the literature review with a summary of the evaluation of strategies, approaches, and techniques for the commercialisation of MTRESs, comprising a description of each strategy along with its relevant strengths and weaknesses. While each of the strategies evaluated has value, it is likely that an integrated tool may prove to be the most effective, especially given the macro-level focus of the research study. Such a tool could utilise the architecture framework as base, and contain elements of government policy and TA, together with the basic building blocks to construct TRMs. Moreover, it should also make provision for the three most common technology commercialisation strategies (in-house development, joint commercialisation, technology transfer).

The keywords used during the search of the relevant literature are presented in Table 4.10, with various combinations applied to the existing theory. Online academic sources were primarily utilised, such as Google Scholar, and the Web of Science.

Table 4.10: Literature search keywords

Keywords			
Multi-technology	Commercialisation	Adoption	Strategy
Stakeholder	Renewable energy	Business	Management
Technology (cluster)	Obstacles/barriers/challenges	Adoption	Diffusion
Investment	System	Hybrid	Innovation
Socio-technical transition	Technology roadmap	Social acceptance	Government

Deciding which articles are most relevant to a study is never simple when considering the vast number of publications available. Any selection of articles may rightly be considered subjective to a certain degree. The boundaries of the literature search were extended to include all technologies of a RE nature, as well as all forms of technology commercialisation, to create as large a sample pool as possible. Articles were subsequently chosen based on their merits, number of citations in other articles, and relevance to the research study.

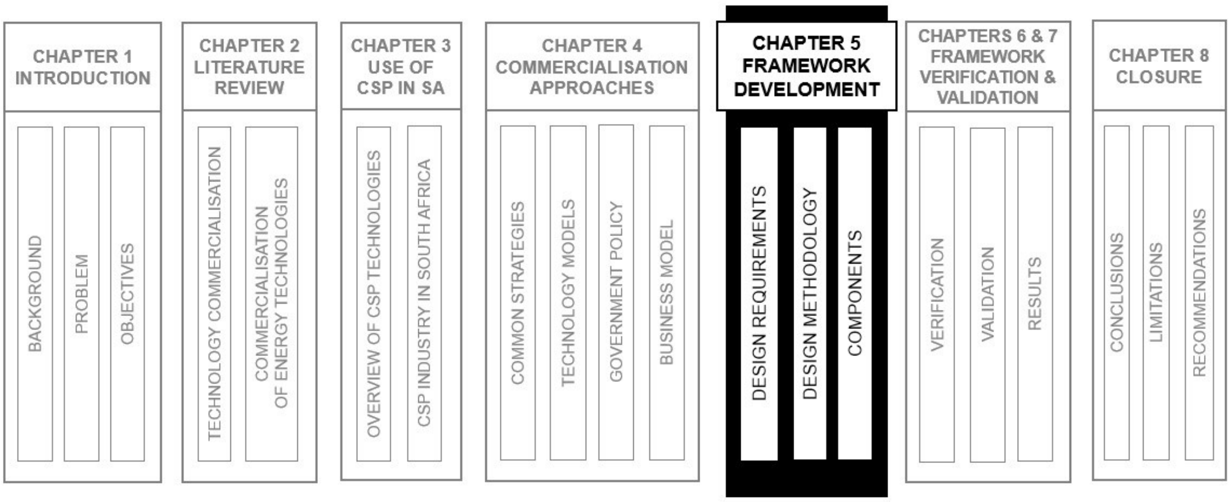
An important factor to mention in the choice of articles based on the number of citations is the Matthew effect. In the context of literature reviews, this effect refers to the natural occurrence whereby older articles tend to have a higher number of citations, as do well-known authors or papers that already possess a high number of citations (Mahbuba & Rousseau, 2011). As such, the number of citations an article possesses is not necessarily an indication of the quality of the research contained within. In an attempt to mitigate the impact of the effect, and limit the possibility of missing articles relevant to the research topic, articles published more recently were given a higher weighting.

The following chapter, Chapter 5, describes the development of a conceptual model to increase the rate of commercialisation of CSP technologies in South Africa.

Chapter 5

Development of the Strategic Management Framework

Chapter 5 documents the development of a strategic management framework for the commercialisation of MTRESs. While this research study focuses on the commercialisation of CSP technologies in South Africa, the decision was made to design the framework to be as generic as possible - in order to facilitate (possible) future use with other MTRESs. The contribution of literature sources to the conceptualisation of the framework are acknowledged, together with a list of the core assumptions held by the author during the framework's development. The structure of the framework is explained, followed by an in-depth discussion of each component and its contribution to the overall commercialisation process, with reference to additional supportive material in the research study's appendices.



5.1 Selection of a conceptual model

In order to address the primary goal of the research study, an approach to increase the rate of commercialisation of MTRESs, utilising CSP technologies in South Africa as a case study, there was a need to select a suitable type of model. Following an evaluation of strategies, approaches and techniques used for the commercialisation of MTRESs (as seen in Appendix A, and summarised in Chapter 4), it was determined that a suitable approach would be one similar to the architecture framework. The model should be able to incorporate multiple components, in order to address the many elements of the commercialisation process. As such, the choice of a framework was deemed an appropriate starting point.

A brief review of literature revealed that there are many different types of framework (summarised in Table 5.1), the majority of which are used for monitoring and evaluation purposes. Frameworks are typically used to understand programme or project goals, as well as measurable targets in the short-, medium-, and long-term (Measure Evaluation, n.d.). In addition, they allow for clarification on the relationships which exist between various inputs, processes, and outputs, influential internal and external elements, and the implementation of programmes, projects, activities, and strategies (Brown, 2010).

Table 5.1: Classification of framework types[49]

Framework type	Description
Conceptual / Research / Theoretical	Recognises and maps the relationships which exist between factors that may impact the respective subject matter, and subsequent accomplishment of the objectives.
Results / Strategic	Recognises and maps the causal relationships which exist between all (intermediate) levels/stages of results relating to the desired goals, and how the results of each contribute to, and support, the achievement of the final objective. Aids the choice of activities to achieve strategic objectives.
Logical	A generic summary of the linear causal relationships between activities and objectives, and the logic behind them.
Logic models	Demonstrates the causal relationships between inputs, processes, outputs, outcomes, and impacts. Often represented by if-then relationships.

(Sources: Brown, 2010; Measure Evaluation, n.d.; UN Women, 2012)

[49] There was some disagreement in literature whether logical frameworks and logic models represent the same type of framework. Some sources contradicted themselves by listing them as different categories, yet covered them in detail as the same type of framework. Furthermore, there were several discrepancies in the stated differences between them. Thus, while presenting them here as separate categories, acknowledgement is made of this debate.

The decision was made to select a strategic framework as a conceptual model to increase the rate of commercialisation of MTRESs. The choice of such a framework acknowledges the many intermediary steps which exist in the technology commercialisation process, while providing sufficient support and flexibility in order to address the multiple elements and activities required. Lastly, given the importance of decision-making in the commercialisation process, made by individuals across a wide range of levels, the name ‘strategic management framework’ was deemed appropriate.

5.2 Design requirements

Given the wide scope of the research study, there was a need to formulate a specific list of design requirements for the conceptual model. The decision was made to use existing barriers to the commercialisation of MTRESs identified from literature (see Appendix B) in an attempt to address the many challenges that MTRESs currently face. The significant technical barriers are presented in Table 5.2, along with the financial and economic barriers in Table 5.3, and organisational, institutional and social barriers in Table 5.4.

Barriers which were identified as generic enough to be applicable to all categories are presented in Table 5.5. While each barrier is discussed separately, it is important to take note of the relationships which exist between many of the barriers. Overcoming one barrier may influence the impact of others on the commercialisation process, or give rise to entirely new barriers over time (Negro *et al.*, 2012).

Table 5.2: Technical barriers to the commercialisation of MTRESs

Barrier	Description
Consistency in energy supply; intermittent nature and low storage capacity	Many MTRESs lack a similar consistency in energy supply compared to fossil-fuel technologies, attributed to their intermittent nature and low level of storage capabilities. This inconsistency is often highlighted as a key issue limiting the uptake of such technologies.
Low (technical) quality standard of MTRESs	Much is still being learnt about the technical nature of MTRESs, their production processes, operation and maintenance (O&M), and overall system performance. As greater learning curves are realised, improved technological performance will be achieved resulting in greater energy output, and a lower overall cost.
Lack/shortage of skilled and specialised workforce	Lack of skills, knowledge, and expertise within the existing workforce provides the basis for the need to implement additional educational/skills training programmes.
Site location selection	Many MTRESs have specific criteria regarding the selection of sites for their construction, such as those areas with proven strength in the relevant renewable energy source, proximity to the grid, and water availability.
Lack of access to grid infrastructure	A general lack of infrastructure, such as the national electricity grid (transmission and distribution network), prevents IPPs from feeding electricity back into the grid, limiting broad deployment of MTRESs. This barrier is often used by established players to oppose MTRESs.
Lack of technical standards	Many new MTRESs lack a set of formally-certified technical and operating standards to guarantee levels of quality and promote confidence in the new technology.
Limited technical and O&M experience	Limited technical and O&M experience with MTRESs contributes to the relatively low level of knowledge of such technologies. However, this does present an opportunity for improved learning curves and greater cost reductions in the future.

Table 5.3: Financial and economic barriers to the commercialisation of MTRESs

Barrier	Description
Lack of funding & access to financial capital	Lack of sufficient funding, and access to financial capital, limits efforts to stimulate the industry through R&D, project development, workforce training, and so forth.
Large (initial) costs	MTRESs incur large costs due to the cost of finance and plant construction, resulting in a higher price being charged for electricity produced from MTRESs. The greatest percentage of these costs are incurred upfront due to plant development, with little operational costs due to the use of RE sources.
Existing market structure: dominance of fossil-fuel technologies and lack of competition	The existing market structure of the energy sector places MTRESs at a disadvantage considering the dominance of fossil fuel technologies. This dominance continues to be entrenched through high prices (poor economies of scale), low utility (poor performance, no networks/infrastructure, no free choice for consumers), and economic instability.
Economic and market instability	Such instability has a direct impact on all sectors and industries, limiting the desire to continue providing the investment needed to commercialise MTRESs in pursuit of more certain and short-term ROI's elsewhere.
Lack of a strong supportive manufacturing industry	A key facet in the commercialisation of any technology is the supply of components required for production, which can assist cost reduction efforts while providing additional benefits such as growing the existing workforce.
Long payback period	While a long payback period in itself is not necessarily a bad thing, investors and other stakeholders prefer a short-term ROI which has more certainty. The uncertainty in payment for RE-generated electricity from government, discourages the broad adoption of MTRESs.
Financial sustainability and bankability	Many MTRESs struggle to achieve financial close while providing an acceptable ROI, given the risks involved. This threatens the sustainability and bankability of such projects, while increasing the financial costs involved.
Economies of scale	MTRESs have yet to achieve significant economies of scale. Products/technologies are often cheaper if produced on a grand scale.

Table 5.4: Organisational, institutional and social barriers to the commercialisation of MTRESs

Barrier	Description
Ineffective implementation of commercialisation plans	Technology commercialisation is not a new phenomenon, with a history of technologies which have experienced success and failure in the attempt to reach a commercialised state. The implementation of commercialisation plans plays a key role in whether a technology is able to reach maturity successfully, and can be said to be of equal importance to the actual plan itself.
Policy ambiguity and uncertainty	Many policies are often ambiguous or misunderstood, resulting in confusion for a number of stakeholders. This contributes to great uncertainty in the RE industry, limiting the ability of governments to successfully meet the desired objectives.
Lack of sufficient supportive government policies and incentives	Greater support from government, in the form of policies and incentives, needs to be secured in order to support and foster efforts towards commercialising MTRESs.
Low public knowledge, education, and awareness (of MTRESs)	Lack of public knowledge, education, and awareness, together with misinformation about the benefits of MTRESs (environmental, financial, socio-economic and so on). This often leads to mistrust of such technologies.
Lack of knowledge and familiarity with green financing mechanisms	Many organisations and institutions, as well as individual consumers, are unaware of the various green financial mechanisms available to help offset the costs of MTRESs, and make such technologies more affordable. Overcoming this lack of knowledge and familiarity could help enhance the uptake of MTRESs globally.
Lack of robust planning of RE development at strategic and planning levels (for medium- to long-term)	A lack of medium- and long-term planning concerning the inclusion of MTRESs into energy mixes worldwide has hampered the commercialisation of such technologies. Poor planning contributes to the ongoing uncertainty surrounding the energy sector, and limits the uptake of such technologies.
Gap between (university) research projects and market needs	There is a disconnect between the research conducted by universities and other technical learning centres and the needs of the industry, with respect to the future technological and market development of MTRESs. By better synchronising these two areas, more effective progress can be made in addressing the most pressing problems currently faced by MTRESs.

Barrier	Description
Site location selection	Many MTRESs are often favoured by members of society, as long as they are not built close to their residence, a phenomenon termed not-in-my-back-yard (NIMBY). Moreover, opposition to such technologies often grows if they do not meet community expectations regarding energy supply, and other benefits.
Inadequate/ineffective engagement & coordination between stakeholders	Inadequate and ineffective engagement and coordination between stakeholders negatively impacts the harmonisation of efforts between different industry players needed to commercialise MTRESs.
Lack of start-up firm support through science and technology parks, incubators etc.	The commercialisation process involves the development of new and supportive industries to aid technological development. This is often achieved throughout start-up companies, which in turn grow to become dominant players in the new technology. The growth of such start-up firms can be assisted through science and technology parks, as well as technology incubators that offer protection against detrimental market forces.
Poor identification of potential adopters	Potential adopters are pivotal to a technology’s success, comprising first-buyers and champions that can generate the initial demand required for future investment, and lead commercialisation efforts. However, such individuals do not emerge independently, and sometimes need to be found or encouraged before they assume such a role.
Poor post-adoption support	Many MTRESs focus heavily on one-time demonstrations and first-time use, thereby neglecting post-adoption support, which has a key part to play in shaping a consumer’s overall perception of a technology, and willingness to purchase it again in the future.
Policy misalignment	National, provincial, and municipal policy often act against each other, partly as a result of competing interests and differences in opinion on best policy implementation practices. Misalignment between departments concerning policies, incentives, and initiatives contributes to a slow rate of commercialisation of MTRESs, as well as uncertainty surrounding the RE industry.
Lack of legitimacy	Lack of industrial, political, and social acceptance, and institutional support. Legitimacy is necessary to obtain resources, foster demand and achieve political strength to influence the institutional context. Non-acceptance can cause lock-in of existing traditional energy sources (coal, oil), and increase resistance to change to MTRESs. Also includes concerns about possible physical landscape changes that would be caused by the physical development of MTRESs.

Barrier	Description
Lack of (strong) networks, platforms, and associations for MTRES promotion & development	Strong networks, platforms, and associations are required to foster the cooperation needed between various stakeholders in order to ensure effective progress is made towards promoting and developing MTRESs, as part of commercialisation efforts.
Political instability (Stop-and-go policies)	Investors and entrepreneurs prefer a stable political environment where there is certainty and continuity regarding policy and regulatory frameworks, and clear mid- to long-term goals. Reluctance by investors to take risks and invest in MTRESs in an uncertain policy climate. National government seen as unreliable and lacking trust.
Dominance of government over private sector involvement	Government intervention is a primary driver behind the commercialisation of MTRESs. However, such efforts have not always been very effective.
Insufficient protection of IP rights	IP forms a key source of revenue for many firms. Without adequate protection of such rights, companies have little incentive to conduct the R&D necessary for technological development, limiting the rate of commercialisation realised.
Lack of enabling regulatory environment	Developing countries need assistance to develop enabling environments of regulations, policies, and institutions. Many claim that the role of government should be to create an enabling environment for technology development, and then let the private sector and market forces oversee the commercialisation process.
Attitude, strategy, and dominance of established players; lack of political will	Many established players may move to protect their business and personal interests, by mitigating the threat posed by MTRESs to traditional energy sources. This could have a large impact as established players have great influence on new energy policies. This includes the apparent lack of political will to enforce real change in the energy industry.
Administrative barriers	Administrative barriers represent a significant amount of 'red tape' to the development of MTRESs. Many processes, such as the Environmental Impact Assessment (EIA), tend to require numerous documents and permits just for consideration, dissuading many companies from even starting the application process. These barriers also lead to the inclusion of significant costs in the wider industry.

Table 5.5: Generic barriers to the commercialisation of MTRESs

Barrier	Description
Lack of (access to) information	Access to (sufficient) information is a universal barrier to the commercialisation of MTRESs. Without information, credible and rational decisions cannot be made, thus limiting possible progress in the commercialisation process. Measuring such progress is also made more difficult in the absence of information.
High risk profile	Risk is common to all aspects of the commercialisation process, with MTRESs possessing a high-risk profile due to their relative novelty, suitability, and reliability, and associated institutional and regulatory framework risks. Aversion to such risks forms a strong force in resisting adoption of MTRESs.
Lack of interest	The lack of interest in MTRESs can be attributed to factors such as the current high cost of such technologies, a lack of credibility, and poor knowledge and awareness of the technology. Without genuine interest in MTRESs and the benefits they offer, the rate of commercialisation will remain at a low level for the majority of these types of technologies.

5.3 Design methodology

The design methodology used during the development of the strategic management framework is illustrated in Figure 5.1. First, the framework was developed deductively from literature, using the relevant theory to inform the different components of the framework. No experts were involved in the initial design of the framework, as the researcher was unsure how many would be available for the validation stage of the framework, considering cost and time constraints, and the need to ensure the availability of a large number of individuals from a diverse range of backgrounds as prospective participants in the validation process. It also has to be noted that no expert involved in the design process would be eligible for the validation process, due to the possibility of bias and need for consistency in the validation process followed. The framework was subsequently verified against the design requirements set, following an iterative process until all the requirements were met.

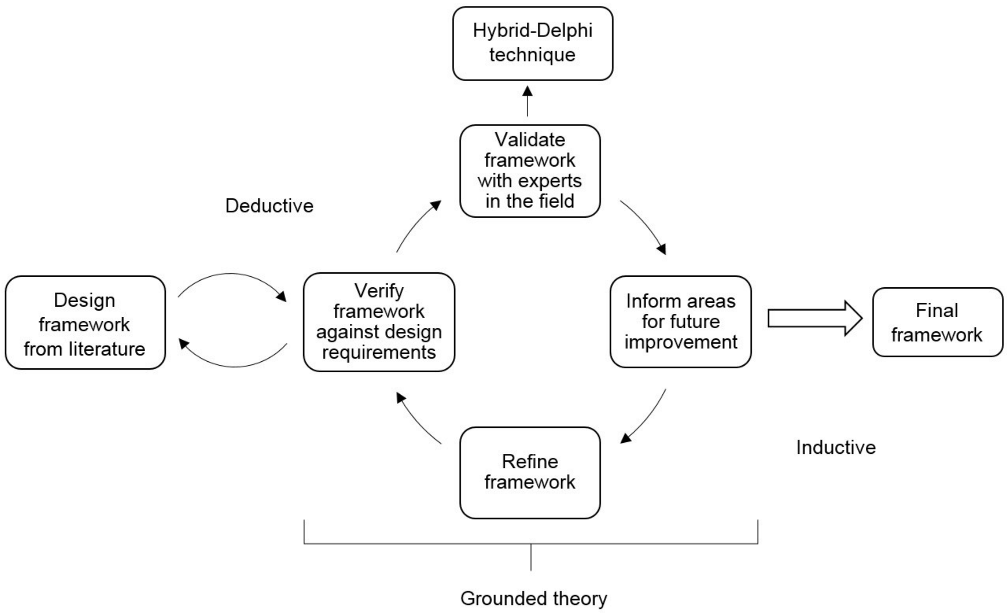


Figure 5.1: Framework design methodology

The verification step formed part of a grounded theory approach employed, comprising four iterative steps: (1) verification of the framework against the design requirements set, (2) validation of the framework with experts in the field through use of a hybrid-Delphi technique (see Chapter 7.1), (3) the supply of information regarding which areas of the framework needed improving, and (4) the ensuing refinement of the framework, and contribution to theory. Steps three and four represent the inductive part of the methodology.

Following the completion of the fourth step, the refined framework was once again verified against the design requirements before initiating a new round of validation interviews with experts. The number of iterations of the grounded theory approach conducted prior to generation of the final framework was subject to time and cost constraints. In addition, the consistency in feedback received on the framework also served as a guide regarding how many iterations to conduct with respect to the refinement of the framework. The rest of Chapter 5 focuses on the first stage of the design methodology: the initial design of the framework from literature.

5.4 Conceptualisation of the strategic management framework

Following the selection of a strategic management framework as an appropriate conceptual model to increase the rate of commercialisation of MTRESs, and in keeping with the methodology selected for the framework's design, a further review of literature was conducted. The following sources were used to assist the conceptual thinking behind the development of the framework and its components:

- Bhikha (2015)
- Fahey & Randall (2001)
- Pearce II & Robinson Jr (2009)
- Rasiel (1999)
- Stern & Deimler (2006)
- Ungerer, Ungerer & Herholdt (2015)

Several assumptions were held by the author both prior to, and during, the development of the strategic management framework. While the validity of these assumptions can be debated, they are listed here to provide additional context to the framework's development.

1. CSP technologies currently lie in an early-growth phase of the technology life cycle.
2. Single individuals and organisations are unlikely to be able to oversee the entire commercialisation process themselves, and conduct all activities in-house, given its complex nature.
3. Although national governments have a key role to play in the commercialisation process, the limited success achieved so far brings into question the wisdom of relying solely on government to drive the commercialisation of MTRESs (Aslani, 2015). Furthermore, many governments and state owned enterprises (SoEs) frequently contribute to uncertainty regarding their commitment to MTRESs. This is the case in South Africa, where Eskom (the state utility) has refused to sign the PPAs of many RE projects under the REI4P (Haynes, 2017). As such, there is a need for the private sector and national RE institutions to assume a greater role in the commercialisation of MTRESs.

4. In order to increase the rate of commercialisation of MTRESs, surety in the sector's development needs to be secured by establishing a significant market for such technologies. Alternative consumers need to be pursued in this regard, with a focus on energy-intensive industries in the private sector. As such, there may be a need to focus on export markets in addition to local markets.
5. Although many energy markets worldwide have experienced declining electricity sales, such as South Africa, it is believed that as coal power stations long past their end of life are decommissioned, the opportunity will exist for MTRESs to fill the capacity gap in electricity grids globally. It is acknowledged that this assumption may prove contentious, given the significant capacity size of coal power plants, with their operation as baseload sources of energy likely to provide a challenge for (certain) MTRESs to replace (le Grange, 2013). However, this does represent an opportunity for CSP technologies should they reach cost-parity with energy technologies operating in this time-of-day bracket, and grid infrastructure be extended into areas of high DNI.

Figure 5.2 illustrates the initial strategic management framework developed. The framework utilises a cube structure similar to that of the architecture framework investigated in Chapter 4.8 and Appendix A.8, while incorporating components deemed necessary for increasing the rate of commercialisation of MTRESs. The primary level component, or foundation, consists of people. People arguably form the most important component of any commercialisation approach, as they are responsible for all the decisions that are made. These decisions can either aid the commercialisation process, or ensure that MTRESs never reach a commercialised state. The three secondary level components, or pillars, of the framework are as follows:

1. Technology assessment (TA);
2. Market adoption, promotion and penetration strategies (MAPPSs); and
3. Organisational analysis (OA)

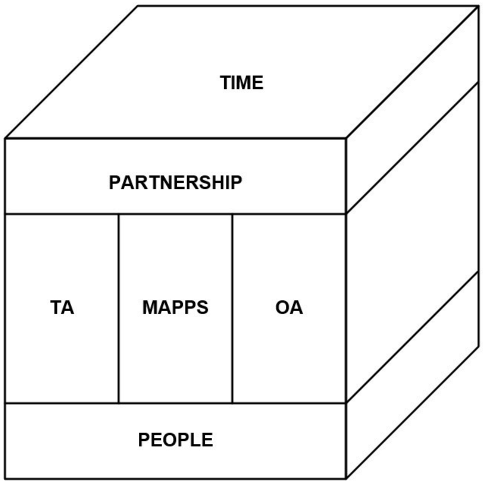


Figure 5.2: Strategic management framework

The first pillar, TA, is aimed at understanding the MTRES at hand. Without extensive knowledge of the multiple aspects of the technology in question, technological progress is limited. The TA component is holistic in nature, focusing on many different types of analyses to present a systematic view of the respective MTRES. The second pillar, MAPPS, comprises a selection of strategies designed to facilitate and increase the rate at which MTRESs are introduced, accepted, and adopted by the wider market, and society in general. These strategies seek to provide innovative solutions on how to successfully market MTRESs, and expand the market itself, through creating greater awareness, demand for, and use of such technologies.

The third pillar, OA, focuses on the organisational capabilities[50] required during the commercialisation of MTRESs. The term 'organisation' is used here to refer to any entity that holds an interest in increasing the rate of commercialisation of MTRESs. Many organisations may hold a financial interest in seeing certain MTRESs reach a commercialised state. Yet, these organisations may fail to give adequate consideration to the various capabilities needed to achieve such a goal, how these capabilities may change over time, or how to ensure that the relevant capabilities remain aligned to the needs of the respective MTRES. This component seeks to address these potential shortcomings by promoting awareness of the capabilities required to increase the rate of commercialisation of MTRESs.

The primary and secondary level components act to support the tertiary level component, which concerns the framework's implementation. It is proposed that a partnership be the

[50] Organisational capabilities are defined by Pearce II & Robinson Jr. (2009:171) as: "*the skills - the ability and ways of combining assets, people, and processes – that a company uses to transform inputs into outputs*".

primary means by which the framework is implemented, utilising the expertise and experience of various stakeholders to address the different tools, activities and capabilities required to drive the commercialisation process for the mutual benefit[51] of all involved. Consideration was also given to the interfaces between the three levels of the framework, ensuring that all components of the framework act together towards increasing the rate of commercialisation of MTRESs.

Lastly, the inclusion of a time dimension acknowledges that the process of commercialisation is one which takes time. Moreover, it recognises that the nature of the components is likely to change over time, both due to internal changes as MTRESs progress up the s-curve, and externalities such as black swan[52] events, whose impact may be felt in ways which are difficult to predict or plan for. Considering that it is impossible to fully predict the future, no attempt was made by the researcher to elaborate further on the time dimension, with the acknowledgement that it represents a 'black box' to a degree.

The rest of Chapter 5 presents an overview of the development of the framework's three secondary-level components (TA, MAPPS, OA), tertiary level component (partnership), and interfaces, as these components required more thought than the other components of the framework.

5.5 Technology assessment

Before proceeding with a discussion of the TA component of the strategic management framework, it is worth considering the connotations behind the term 'technology assessment'. Coates (2001) defines TA as: *"a policy study designed to better understand the consequences across society of the extension of the existing technology or the introduction of a new technology with emphasis on the effects that would normally be unplanned and unanticipated*". While TA is not limited to policy considerations, this definition describes the systematic view one needs to take in the assessment of a technology, not restricting the focus to the technology itself, but considering the broader implications. A particular implication includes the potential for unplanned and unanticipated effects that may limit the rate of commercialisation realised.

---

[51] If the rate of commercialisation of MTRESs is increased, the likely growth in the number of projects commissioned will present significant work opportunities and wealth creation for those associated with the RE industry. However, it is important to note that money and jobs may not be the only drivers behind the actions of some of the partnership's stakeholders.

[52] A black swan event is a rare event or set of circumstances which are often difficult to predict or imagine. They lie beyond any entity's ability to control, and possess the potential to significantly impact global operations across multiple organsiations, sectors, and geographic regions. (Flage & Aven, 2015)

The selection behind the various tools and methods for the TA component of the strategic management framework saw several TA sources consulted from literature, in addition to the list presented by Peach (2010) in Figure A.4. However, given the extensive range of tools and methods displayed in Figure A.4, the majority of the literature sources reviewed[53] were found to present categories and tools already covered by Peach (2010). As such, Figure A.4 was used as the dominant source for the TA tools and methods chosen for the framework.

Although each method and tool listed in Figure A.4 has merit, not all were considered necessary for use in the strategic management framework. Indeed, to incorporate all of them would burden the framework unnecessarily, making it more difficult and time-consuming to apply. Following careful evaluation of Figure A.4, six broad areas of TA (see Figure 5.3), together with a list of specific methods and tools (see Figure 5.4), were chosen as being most appropriate for use in the framework. A detailed explanation of each method and tool, and their relevance to the strategic management framework, can be found in Appendix C.

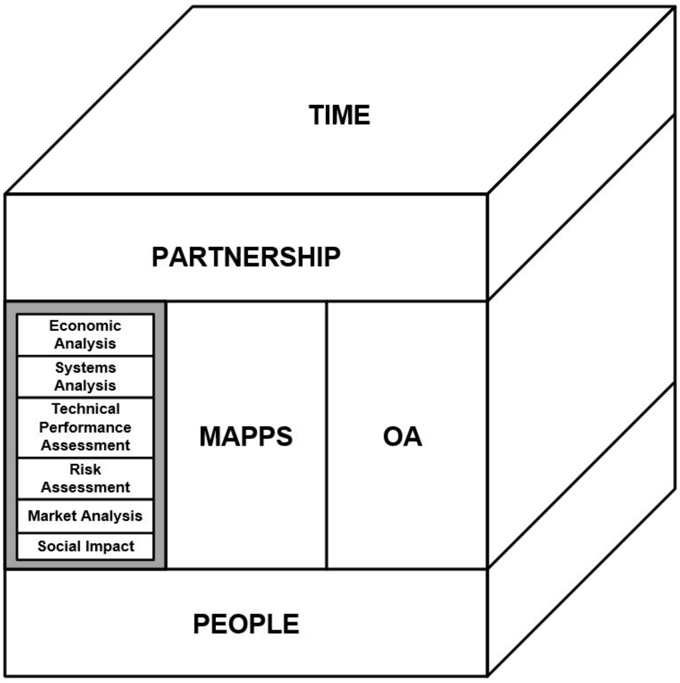


Figure 5.3: Strategic management framework - TA component

[53] The sources reviewed were: Musango & Brent (2011), Tran & Daim (2008), Coates (2001), Henriksen (1997), Evans, Strezov & Evans (2009), Maloney (1982), Troldborg *et al.* (2014), and Cetindamar *et al.* (2010:242).

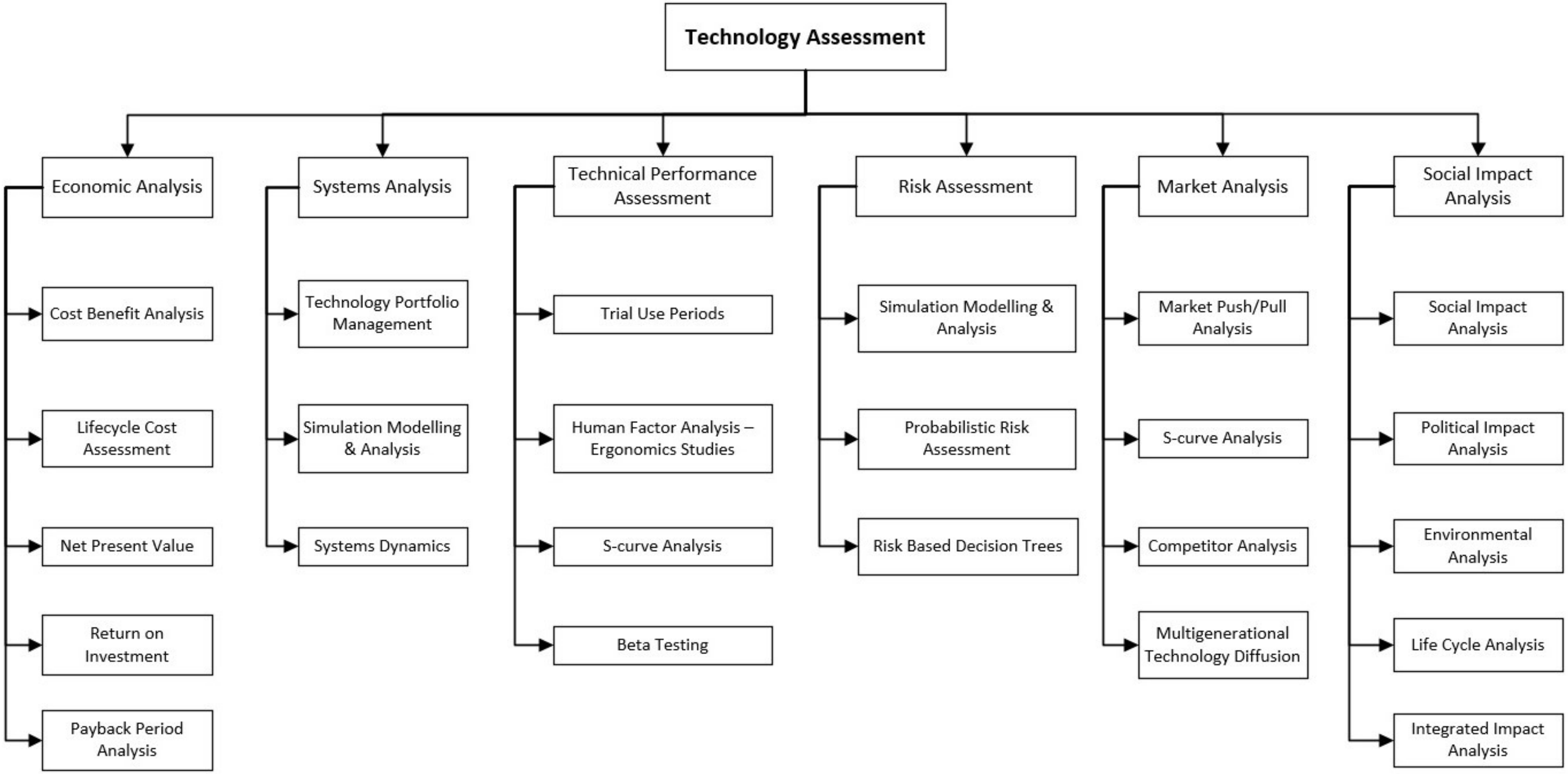


Figure 5.4: Technology assessment component breakdown

5.6 Market adoption, promotion and penetration strategies

A common obstacle in any commercialisation process is the lack of a significant market for the given technology, with the ability to stimulate an industry a key feature of any commercialisation approach (Al Natsheh, Gbadegeshin, Rimpiläinen, Imamovic-Tokalic & Zambrano, 2015). Haas, Eichhammer, Huber, Langniss, Lorenzoni, *et al.* (2004) advocate the use of an integrated and systematic approach, one that incorporates incentive-based measures, innovative regulations and institutions which encourage socio-economic structural reforms, together with the training and education of all agents involved.

While such an approach has its strengths, its components need to take on a more diverse nature, one better suited to the modern era[54]. Thus, four target areas were selected for building the market: government policy, the business sector, education initiatives, and social acceptance (see Figure 5.5). A strategy was developed for each area. Collectively, they present an integrated approach, or set of MAPPSs, to foster a market for MTRESs.

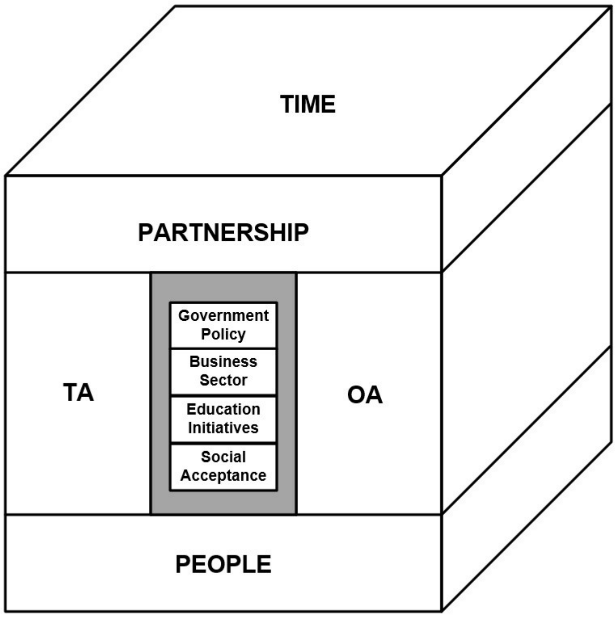


Figure 5.5: Strategic management framework - MAPPS Component

5.6.1 Government policy

Government policy plays an important role in the commercialisation process of MTRESs (Reddy & Painuly, 2004). Drawing on the discussion of existing government policies and

[54] The modern technological era has resulted in the development of new (digital) tools, such as cell phone applications and virtual reality (VR) headsets, used to increase consumer awareness of (new) technologies and products, aiding market expansion (Briggs, Foutty & Hodgetts, 2016; Organisation for Economic Co-operation and Development, 1998; Reede, 2016).

initiatives from Appendix A.6, a mix of policies was developed, focusing on technology-push, market-pull, and interface improvement policies[55] (see Figure 5.6). The use of a policy mix is supported by Taylor (2008) and Haas *et al.* (2004), who state that no one optimal policy exists, and that a mix of different mechanisms should be adopted based upon the respective MTRES and country. The policy mix will likely change over time, and should be reviewed at regular intervals, to ensure it is kept aligned with the present needs of the respective MTRES as progress is made through the different stages of the commercialisation process (Grubler, 2012).

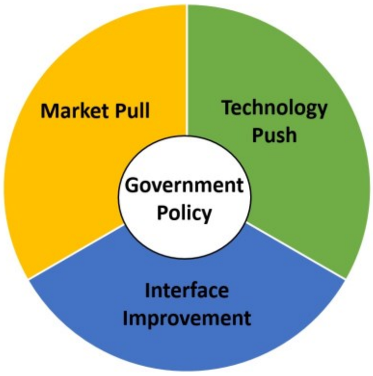


Figure 5.6: Government policy

Table 5.6 presents a breakdown of the policy mix for the strategic management framework. This policy mix was determined following a review of literature to identify existing market-pull, technology push, and interface improvement energy policies (see Appendix D.1), while consideration was also given to the design principles advocated by Grobbelaar *et al.* (2014) (see Appendix D.1.4). Although it is highly unlikely that all of these policies will be implemented together, the reason behind such a large range is to present policy-makers and management practitioners with various options. The actual choice is likely to be guided by the desired outcomes and objectives, and existing policy mechanisms deployed within a country, together with the country's policy-making environment[56] and governing legal framework, personal preference of the policy-makers, and evidence of success of other such policies globally.

[55] Although various classifications of policy exist, such as price vs quantity, investment vs generation, and regulatory vs voluntary (Haas, Panzer, *et al.*, 2011; Taylor, 2008), the three selected here were the categories encountered the most often in literature.

[56] For example: centralised policy-making on a national level versus decentralised policy-making on a local government level.

Table 5.6: Government policy mix

Market-pull[57]	Technology-push	Interface Improvement
FIT	RDI subsidies and grants	Certification and technical standards.
Tender bid programme	RDI loans	Regulations
Tax incentives	National RDI centre	Consultancy services
Carbon tax	Demonstration projects	Training and certification programmes
Carbon credits	Equity	Project assessment centre
Loans and bonds		
Tradeable green certificates (TGCs)		
Renewable portfolio standards / quotas		
Voluntary green pricing scheme		
Wheeling agreements		
(Installation) rebate		
Grid access legislation		

5.6.2 Business sector

The promotion of MTRESs has traditionally been the domain of government, with the role of the private sector typically limited to the development of power plants in response to governments' energy plans (Eberhard, Kolker & Leigland, 2014). However, given the poor record of governments worldwide in the commercialisation of MTRESs (Aslani, 2015), a change in mindset is required, one in which the business sector assumes a far greater role in the expansion of the RE industry, and commercialisation of MTRESs.

The change in focus of the business sector is vital not only from a commercialisation viewpoint, but also from the perspective of companies in the RE industry who wish to remain a going concern[58]. This shift in direction relating to the future RE industry forms an underlying trend of the MAPPS component of the framework, most notably through the drive to expand the customer base beyond government utility-scale into the commercial and industrial market segments, thus creating greater certainty and confidence in the industry. The new role for the business sector will consist of the following activities[59]:

[57] The number of market pull policies has increased substantially in recent years, supported through growth and development of new and innovative financial mechanisms. As a result, there is a tendency for these mechanisms to overlap to an extent in terms of meaning and implementation.

[58] A common financial term used to express the belief and expectation that a company will continue to operate in the short-term, that is: be able to cover all expenses incurred, and yield a profit.

[59] These activities were chosen based on the supply and value chains of the RE industry, and the technology

1. Increase demand for MTRESs
2. Finance and conduct R&D into MTRESs
3. Finance and develop MTRES power plants
4. Establish and strengthen skills training initiatives
5. Establish a local manufacturing hub(s) for the components of MTRESs
6. Exportation of (the components of) MTRESs
7. Assist the rollout of national grid (transmission and distribution) infrastructure.

5.6.2.1 Bridging the cost gap

Presently, a significant cost gap exists between MTRESs and other energy technologies (Department of Energy *et al.*, 2017). Despite the potential success efforts to improve awareness of, and demand for, MTRESs may achieve, organisations are reluctant to adopt technologies that are not deemed cost-effective (Herzlinger, 2006). Thus, it is assumed that once MTRESs achieve cost-parity with other energy technologies, they will be adopted on a larger scale, due to their environmental benefits, and security of energy supply.

While cost reduction is often attributed to R&D efforts, such activities take time (Gazzo *et al.*, 2010),. However, a significant percentage of the cost of developing MTRESs, such as CSP technologies, is due to financing costs (see Figure 5.7) that are partly as a result of the uncertainty regarding project bankability (Gauché *et al.*, 2017).

In order to bridge the existing cost gap as soon as possible, attention was placed on several (innovative) financial mechanisms, some of which have already been mentioned under the market-pull government policies of Chapter 5.6.1 and Appendix A.6. While these mechanisms may be more correctly termed as ‘revenue streams’, they nonetheless have the effect of improving the ability of MTRESs to compete on a cost-parity basis with established energy technologies. Table 5.7 outlines the financial mechanisms considered, along with their source of capital. Similar to the case of the government policies of Table 5.6, the list is merely designed to present different options based on the needs of the respective MTRES, and the preference of the framework’s user.

---

commercialisation process (see Figures 2.2 - 2.4). Appendix D.2 provides a more in-depth discussion of each activity and their relevance to the commercialisation process.

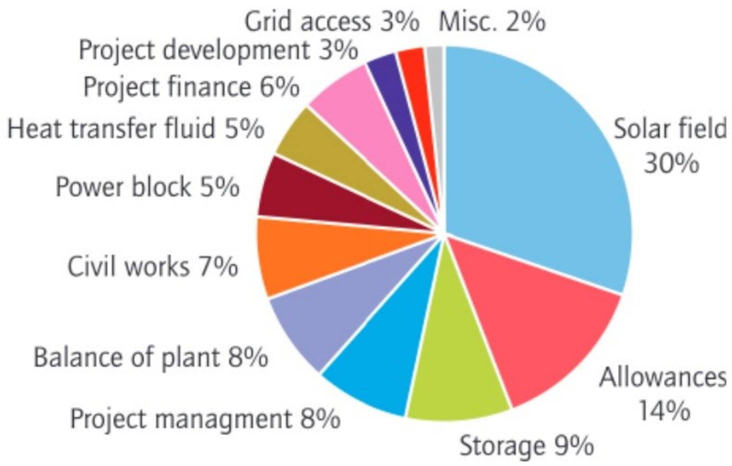


Figure 5.7: Capital cost breakdown for 50 MW CSP trough power plant with 7hrs storage

(Source: International Energy Agency, 2010)

Table 5.7: Financial mechanisms for bridging the cost gap

Financial mechanism	Source
Favourable loans (low interest rates, long payback periods)	Development banks, national government, investors (venture capital, private equity, institutions)
Crowdfunding[60]	General population
Leasing/renting	Business sector
Structural funds	Banks, venture capital, private equity
TGCs	General population, local government, business sector
FITs	Local government, business sector
CERs	Business sector
Wheeling agreements	PowerX, local government, business sector
Equity	Investors (venture capital, private equity, institutions)

5.6.3 Education initiatives

To assist the diffusion of knowledge concerning MTRESs, additional educational initiatives are required beyond those currently implemented. The view is held that the number of programmes offered on a tertiary level by technical institutions, learning centres and universities is sufficient. Educational programmes need to focus on broadening the pipeline of talented individuals who wish to pursue a career in the RE industry, as well as improving public knowledge and awareness of MTRESs. Therefore, the focus of this MAPPS is on creating awareness and knowledge of MTRESs through primary and secondary education, as well as public-based, initiatives.

[60] See Appendix D.2.2.1.

The educational initiatives proposed (see Table 5.8) are based on the researcher's schooling experience, as well as viable means of public education such as cell phones (the majority of global population has access to a mobile phone) (The World Bank, 2012), and educational tools of the future (such as virtual reality) (Reede, 2016). Ideally, these programmes will be driven and financed by government bodies, tertiary level learning institutions, and firms within the business sector wishing to equip individuals with skills and knowledge relating to MTRESs. The programmes presented are not presumed to be an exhaustive list, and education practitioners are welcomed and encouraged to devise their own initiatives to achieve the same end. A more detailed discussion of each initiative can be found in Appendix D.3.

Table 5.8: Educational initiatives

Primary	Secondary	Public
Basic MTRES operation	Integration of RE source material into school syllabus	Demonstration projects
Site visits (location dependent)	Site visits (location dependent)	Cell phone applications
		Virtual reality

It is anticipated that there may be reluctance on the part of educators to incorporate RE learning material into an already crowded school curriculum. To ease this transition, it is recommended that educators from national education departments are consulted extensively, regarding means of (further) incorporating RE material into the syllabus. Other, potentially more feasible, opportunities may also exist on an individual school basis, and within private school bodies[61].

Educators may raise the issue of cost relating to the relevant RE source material. It is acknowledged that teachers would need to be compensated for any additional time spent on the subject matter, although some may be convinced to assist on a voluntary basis. Regarding the cost of the material itself, institutions such as the Centre for Renewable and Sustainable Energy Studies (CRSES) have made source material freely available for download from their website. Free resources should be utilised wherever possible to minimise costs, and allow for any educator to access them.

[61] These bodies include school chains such as Reddam House, Curro, and Spark Schools that have begun to emerge as a result of the poor standard of (public) education in South Africa.

5.6.4 Social acceptance

Social acceptance of a new technology has the potential to form a strong driving force in the commercialisation process (de Jongh, Ghoorah & Makina, 2014). Prior to the formulation of a MAPPS to boost social acceptance of MTRESs, some of the underlying principles and factors that lead to such acceptance within the wider population were investigated[62]. Knowledge of the reasons and motivations behind such choices allowed for the selection of appropriate tools for a more effective social acceptance MAPPS.

Table 5.9 outlines several tools available to improve the social acceptance of MTRESs[63]. The tools listed here were identified based on the principles and factors of social acceptance investigated. The list is not presumed to be definite. Furthermore, individuals tasked with improving the social acceptance of MTRESs are welcomed, and encouraged, to explore additional avenues and tools. However, it needs to be said that the implementation of any (social acceptance) tool should be driven by a NGO, considered the most trustworthy type of organisation by the general public (Wustenhagen *et al.*, 2007).

Table 5.9: Tools for promoting social acceptance of MTRESs

Tool		Description
Cell phone applications		Cell phone applications can communicate large amounts of information to a large number of people in a short period of time. The more society learns about, and is able to access, information on MTRESs, the more receptive people will be to such technologies. Their importance as an avenue for accessing the broad population is highlighted by the fact that a large percentage of the global population has access to a cell phone (The World Bank, 2012). In addition, internet access through cell phones recently overtook that of desktop computers for the first time in history (Heisler, 2016).
Media	Mass	Use of mass media (TV, radio, newspapers, magazines, public demonstrations & exhibitions, community centre posters) in media campaigns can present information on the numerous benefits associated with MTRESs. The emphasis should be on providing trustworthy, accurate, and reliable information in an easy-to-interpret medium.
	Social	Use of social media platforms, such as Facebook, Twitter, and Instagram, together with public personality and celebrity endorsements, to inform and educate society about MTRESs.

[62] A discussion of the social acceptance of MTRESs, and underlying principles and factors, can be found in Appendix D.4.1.

[63] For the complete list of all tools considered, see Appendix D.4.2..

Tool	Description
Labelling and (technical) standards	Present the public with a reference point to promote trust in MTRESs through specific technical support and system reliability. This includes harnessing brand power that may begin to emerge due to competition between companies in the RE industry.
Decision-making process	While not a specific tool as such, all stakeholders, be they members of a local community, government officials, or external experts and investors, need to feel that they are able to participate in a fair, transparent, credible, and collaborative decision-making process. The process should involve significant sharing of all relevant information between stakeholders, and involve institutions perceived as trustworthy by society.

It is crucial that the social acceptance tools that are deployed create favourable and informed public awareness and opinion of MTRESs, thereby establishing credibility and legitimacy in the technologies. By carefully crafting the public image of such technologies, positive societal sentiment for the use and commercialisation of such technologies can be realised (Montalvo, 2008). Moreover, the measures deployed need to be aware of the broader energy debate that exists. To exert influence over this national discourse, management practitioners need to be selective of the issues they choose to address, ensuring that MTRESs are strategically positioned to become a major energy technology, one well supported by a nation's citizens.

5.7 Organisational analysis

The OA component of the strategic management framework (see Figure 5.8) highlights key organisational capabilities required for the commercialisation process. The capabilities selected for use in the strategic management framework, while by no means an exhaustive list, were chosen based on common supply and value chains of the RE sector, and the capabilities proposed by Pearce II & Robinson Jr. (2009). These capabilities are presented in Table 5.10. The decision of how to utilise each capability, and to what extent, is left to the discretion of those implementing the strategic management framework. Moreover, it is acknowledged that the capabilities will need to be reviewed as progress is made towards a commercialised state over time, and due to the effect of externalities[64] on the RE industry, and wider energy sector.

[64] Such as Brexit and the Trump presidency.

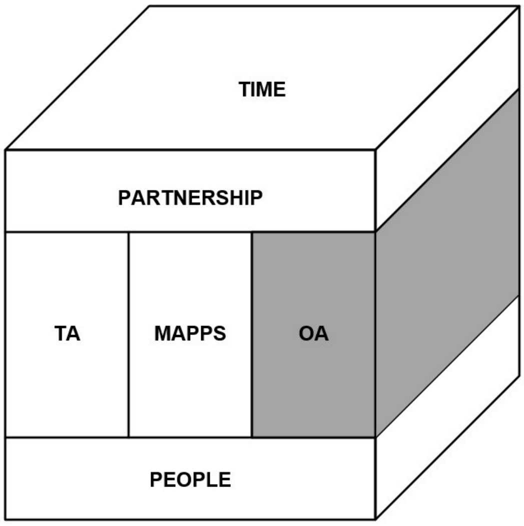


Figure 5.8: Strategic management framework - OA component

Table 5.10: Strategic management framework organisational capabilities

Organisational Capability	
Organisational structure	Leadership
Risk management	Communication
Asset management	Manufacturing
Strategic positioning	Data collection

5.8 Framework implementation

Given the wide range of tools and capabilities presented in the strategic management framework for the purposes of commercialising MTRESs, it is unlikely that a single entity, be it an organisation or individual, will be able to make use of the entire framework independently without assistance of some kind. Indeed, such a case could be considered highly unusual, given that commercialisation is an "*intricate, risky and expensive process*" (Sager *et al.*, 2015). Thus, in order to ensure that all the capabilities and tools contained within the framework for commercialisation are addressed, a partnership is proposed to be the entity that oversees the implementation of the framework (see Figure 5.9), and drive the commercialisation of MTRESs.

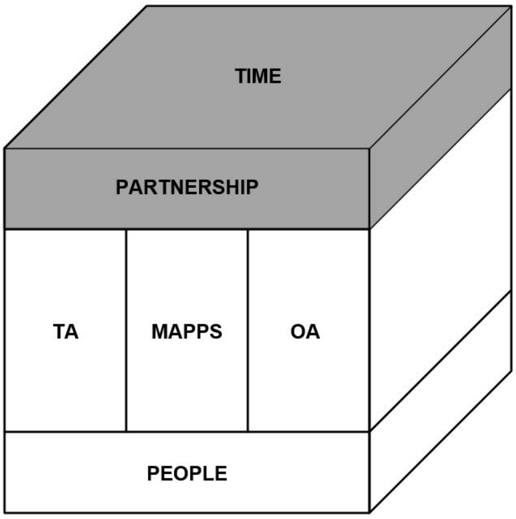


Figure 5.9: Strategic management framework – partnership component

Incorporating the ideas on partnership development of Glasbergen (2010) (see Appendix E), this section presents the following aspects relating to the partnership:

1. Objectives;
2. Key stakeholders as prospective partners;
3. Formal structure; and
4. Tools and metrics to monitor the partnership's progress.

The role played by the proposed partnership in the commercialisation process should not be underestimated. By creating and strengthening bonds between stakeholders in the supply chain, and broader society, numerous benefits can be realised. Apart from the obvious monetary benefits that commercialisation may bring through additional development of MTRESs, from a technology perspective these benefits may include: knowledge transfer, increased cost reduction, and greater confidence in the technology, thereby addressing investors' concerns, as well as supporting local manufacturing industries by providing a secure project pipeline. (SASTELA, Dti & GIZ, 2013)

5.8.1 Partnership objectives

Table 5.11 presents a template outlining some common energy-related objectives for the partnership, which should be reviewed on a regular basis to assess their continued relevance to the commercialisation process. An important aspect to keep in mind is the need for the partnership, and strategic management framework, to achieve success quickly. By targeting short-term success, initial scepticism can be overcome (Rasiel, 1999:36), and credibility established in the eyes of stakeholders and the wider public, thereby fuelling progress towards achieving medium- and long-term targets (Rasiel, 1999:133). The establishment of actual target values is expected to take place during application of the framework, based on short- (0-5 years), medium- (5-15[65] years), and long-term (15+ years) time frames.

Table 5.11: Partnership objectives

Objective	Short-term	Medium-term	Long-term
Additional installed capacity			
Annual electricity production			
% contribution to electricity supply			
% contribution to energy supply			
LCOE[66]			

5.8.2 Key stakeholders

The identification of key stakeholders is typically achieved through stakeholder mapping. Fortunately, sufficient literature already exists concerning this activity, such as the work of Balachandra *et al.* (2010) discussed in Chapter 2. Drawing on the stakeholders identified in Table 2.4 for the commercialisation of MTRESs, and their relationships as outlined in Figure 2.12, Table 5.12 presents a list of key stakeholders to be considered as partners in the partnership. The focus on the roles required for the commercialisation of MTRESs, instead of existing players in the RE industry, limits the possibility of bias on the part of the researcher. It is left to the (senior) individuals involved in the partnership to select which individuals and organisations would best suit the roles outlined.

Table 5.12: Key stakeholders

Stakeholder	Role in commercialisation process
(Wealthy) Municipalities	Medium- to high-income municipalities can implement certain supportive financial mechanisms (FITs, TGCs, wheeling agreements), establish a local carbon credit market, and institute policies aimed at greater business involvement on a local level.

[65] While 10 years is more commonly used as a boundary figure, it was deemed more prudent to allocate a longer time period for the mid-term to allow more time for the objectives to be met.

[66] While LCOE has enjoyed extensive use as a metric to compare different energy technologies, such comparisons are often made on incorrect assumptions, or fail to take into account all the relevant factors (Yelland, 2016). Furthermore, they are typically subject to data availability. The LCOE metric used here refers to the most commonly quoted figures regarding MTRESs in reports and other publications, that of new build power plants in the utility scale market.

Stakeholder	Role in commercialisation process
Business sector	Adopt the role as the primary driver of the commercialisation process of MTRESs, assuming leadership of all value and supply chain activities.
Solar institutions[67]	Possess the knowledge and expertise to advise and assist project developers, and conduct R&D into MTRESs.
SoEs	Includes important bodies such as state energy utilities and energy regulators, which have key roles to play in the (future) generation, transmission, and distribution of electricity globally.
Universities	Conduct R&D into MTRESs, resulting in greater cost reductions, increased energy output, and potential for technology export.
Technology & service providers	Assist project developers during development and operation of MTRESs.
NGOs	Lead efforts to increase social awareness and understanding of MTRESs, fostering greater societal acceptance.
Government departments	Set policy and legislation relating to future energy planning, and associated projects, thus driving demand.
Political allies	Provide institutional support to the development of the RE sector, which may be opposed by certain powerful political agents.
Donor funding agencies	Contribute to the financing of R&D and project finance.
Development banks	Contribute to the financing of R&D and project finance.
Institutional investors	The long-term nature of MTRESs is well suited to the long-term financial needs of institutional investors, such as green funds, insurance companies, and pension funds.

5.8.3 Partnership structure

The partnership, while intersectoral, is to be driven and run by the private sector, in part due to the poor record of governments globally in commercialising MTRESs (Aslani, 2015). To justify the time, effort, and capital invested in a technology during the commercialisation process, it needs to present an acceptable ROI to those involved, be it financial or socio-economic based (or some other metric) (Kraemer, 2015). The private sector is best positioned to realise such a goal, and therefore management of the partnership is ceded to this sector. Although the possibility of civil society overseeing the commercialisation process was considered, it lacks the required institutional strength and resources to manage such a partnership.

[67] Any institution whose role concerns the technological advancement and increase in use of solar energy by society.

5.8.3.1 Proposed partnership structure

To determine a suitable structure for the partnership, several common structures were investigated from literature[68], together with those found in partnerships to develop MTRES projects globally. Following an analysis of these structures, a structure based on South Africa's REI4P is proposed[69], with the inclusion of elements of a chaebol[70] structure. The partnership structure (as shown in Figure 5.10) incorporates multiple stakeholders, while being led by a professional manager chosen from the private sector. Such a position is termed a 'technology commercialisation officer' (TCO), with the principal role of coordinating and facilitating efforts (between partners) to advance the commercialisation of MTRESs.

Figure 5.10: Partnership structure

Once established, the partnership will come to form a significant entity in its own right. To ensure efficient and effective operation, it will require a number of assets to assist in its daily activities, such as its own premises, administrative staff, and financial capital. The decision of how to procure these assets and who finances them, is left up to the TCO and other partners. For additional information regarding the development of the partnership, and the activities to be conducted in support of the framework's three secondary components (TA, MAPPS, OA), please see Appendix E.

---

[68] Such as consortia, keiretsu, and chaebols (Pearce II & Robinson Jr., 2009:235).
[69] See Terblanche (2013).
[70] A chaebol structure is a large structure or conglomerate, often comprising multiple different members, and which is run by a central figure of power. This is reflected in the visual structure of the partnership in Figure 5.10.

5.8.4 Measures for monitoring progress

To measure the progress made by the partnership towards increasing the rate of commercialisation of MTRESs, there is a need for different metrics and monitoring devices within the framework to assess the progress made for any strategy developed and implemented. Such progress provides insight regarding whether present efforts are having a significant impact, or whether alternative activities should be implemented to produce better results.

The identification of metrics was guided in part by the triple bottom line approach, which analyses an organisation's social, financial, and environmental impact and performance (Crosno & Cui, 2014). In addition, there was a need for clear, concise and transparent indicators allowing for easy interpretation (Hales, Peersman, Rugg & Kiwango, 2010). Furthermore, these indicators needed to be easy to reproduce, comparable and complementary to regulatory programmes, involve cost-effective data collection, be stackable and scalable, hold value as a managerial tool, and protect organisations' information (Székely & Knirsch, 2005).

The mechanisms identified as holding the greatest value for monitoring the progress made in the commercialisation process are presented in Table 5.13. It is not assumed to be a complete list, and those involved in the partnership are welcomed and encouraged to include other mechanisms they deem appropriate, or suitable, for use in the strategic management framework. However, it needs to be said that it is often more effective to focus on a small group of key variables than try to achieve a wide range of objectives (Nevens, Summe & Uttal, 1990).

Table 5.13: Partnership monitoring mechanisms

Mechanism	Description
Economic efficiency	Measured as the change in LCOE of electricity-producing technologies over time. Typically represented as a range of values due to the many factors that influence the calculation of the metric.
Effectiveness	Measured as: 1. The new annual capacity (in kW) installed 2. The annual energy (in kWh) generated 3. The annual percentage change in contribution of the MTRES to a country's total energy supply The first two metrics can be expressed in absolute or percentage terms, as well as the change between years. To evaluate the values achieved, they need to be compared against figures realised by other energy-producing technologies over similar time periods, as well as the energy industry.
Economic growth	Measured as the percentage increase or decrease in sales, gross profit, and/or net profit. Alternatively, financial ratios such as gross profit and net profit margin can be used, or level of financial investment committed annually or cumulatively.
Number of existing power plants	The expansion of the industry can be tracked through the change in the number of projects that exist, whether in the development pipeline, under construction, or operational.
Milestone reviews	Establish a baseline based on the short-, medium-, and long-term goals of the partnership, with each activity or goal representing a milestone. The progress of the partnership can be tracked as it meets each milestone. At set time intervals, conduct an assessment of the current activities, after which the decision can be made whether to continue or refocus efforts based on the desired outcome(s), as well as allowing for potential resource (re)allocation.
Marketing success	Although it is nearly impossible to state with certainty the effect of marketing on an increase in sales of a product or technology, there are a number of tools that are able to provide some insight into the (relative) success of marketing operations. Some of these tools are outlined below: 1. Digital marketing: the number of views that websites and other social media sources receive can be recorded before and after a marketing campaign. However, one should take into account other factors that may have influenced any notable change in the number of views recorded. Other indicators such as action buttons (likes, subscribes) can also indicate changes in interest in a product or technology. 2. Green marketing: new search engine keywords, potential new customers. 3. Google analytics.
Information diffusion	▪ Surveys of different stakeholder groups can indicate the changes in social acceptance over time. ▪ Patent citations measure the growth in new (technical) knowledge, while also indicating the level of R&D investment, demand for the MTRES, and the MTRES industry's competitiveness.

(Sources: Edkins *et al.*, 2009; Haas, Panzer, *et al.*, 2011; Lee *et al.*, 2010; Pearce II & Robinson Jr., 2009)

5.9 Framework element interfaces

The last aspect of the strategic management framework to be explored is the interfaces (see Figure 5.11) which exist between its components, namely: the interactions and relationships between the primary (people), secondary (TA, MAPPS and OA), and tertiary (partnership) levels. These interfaces need to be aligned to support the core objective of the entire framework (increasing the rate of commercialisation of MTRESs), while mitigating any conflicting relationships which exist or may emerge in the future, and limiting any path variation which may occur in the process of achieving the identified objectives.

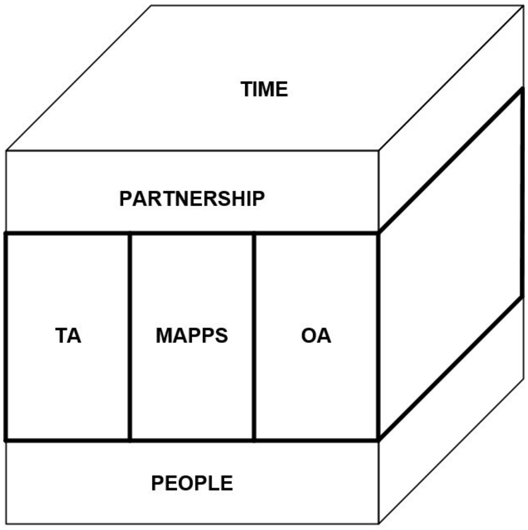


Figure 5.11: Strategic management framework interfaces

5.9.1 Primary and secondary level components

The interface between the primary and secondary level components of the strategic management framework entails the role that people play in the TA, MAPPS, and OA components. The TA component is one that consists of numerous analytical tools and methods. Although some of these tools focus on the impact of people on technology (development), the primary relationship is that these tools and methods utilised are deployed by people. While computers and other computational devices might be used to aid such analyses, people form the principal link between the two components. As such, the scope for human error exists. Furthermore, any actions taken on the basis of inaccurate and unreliable results may cause conflict within this interface. Therefore, care should be taken with the results of any analytical tools, with procedures implemented to verify the results produced.

The MAPPS component is arguably the secondary level component with the greatest involvement of people. Governments and businesses are run by people who bear responsibility for all decisions made. In addition, the initiatives aimed at promoting social acceptance and education of MTRESs are developed, targeted at, and implemented by different societal groups. The involvement of these numerous groups increases the potential for conflict, due to differing priorities and personal agendas. To ensure that this interface remains aligned with the framework's objectives, a willingness to engage with all stakeholders in a fair and transparent process is required, along with binding legal agreements between all parties regarding their conduct, support of the partnership and its goals, and commitment towards assisting the commercialisation of MTRESs.

The majority of the organisational capabilities outlined in the OA component involve people to varying degrees. The capability in which people play the most important role is arguably that of leadership, which has a significant influence on all other capabilities. Leadership has the responsibility to ensure that each capability, and the primary-secondary level interface, involves people in a harmonious manner, with a clear set of goals that support the commercialisation process.

5.9.2 Secondary level components

The interfaces that exist within the secondary level of the strategic management framework, consist of those between the TA and MAPPS, MAPPS and OA, and TA and OA components. A brief overview of each interface is presented below.

5.9.2.1 TA and MAPPS

TA tools and methods are aimed at ensuring an in-depth understanding of a technology, thereby clarifying the nature and activities required of the four MAPPS elements (government, business sector, education initiatives and social acceptance) to assist the market expansion of MTRESs. In this manner, the TA component has the potential to shape the MAPPS component as progress is achieved in the commercialisation process, with the results of the TA tools guiding the focus areas of the MAPPS, as new information is obtained. In addition, TA tools can be used to track progress in the different MAPPS elements, assessing the relative success achieved.

The TA and MAPPS' components share a mutual relationship. The selection of TA tools and methods from the existing literature was made with consideration of the four MAPPSs elements, and the information needed by each element. As progress in the commercialisation process is realised, the data needs of the different MAPPS' elements may change, shifting the emphasis placed on the different TA tools used, or requiring the introduction of new methods of TA entirely. This highlights an ongoing need for re-evaluation of both components.

5.9.2.2 MAPPS and OA

The interface between the MAPPS and OA components consists largely of the influence that different organisational capabilities have on the four MAPPS elements. Each MAPPS element requires a unique set of organisational capabilities to ensure successful implementation. The strength of each capability has a direct effect on the relative success realised by each MAPPS element in the commercialisation process.

As progress is achieved in the commercialisation process, the nature of the elements of the MAPPS components is likely to change, affecting which organisational capabilities are most important in the context of the commercialisation process. Thus, continual revision of both components, and their shared interface, is required throughout the commercialisation process.

5.9.2.3 TA and OA

The interface between the TA and OA components is focused on the role played by the different organisational capabilities within the various TA tools and methods. While the majority of the capabilities are involved to varying degrees, arguably the most important is data collection. The TA component is extremely data-intensive. To ensure that sufficient, accurate, and reliable data is available, strong data collection processes are needed. Communication is also prevalent here, as there needs to be a firm understanding not only of the quantity and quality of data needed, but the exact type of data required. Leadership is another noteworthy capability within this interface, using the results produced from the TA component to direct the necessary activities aimed at increasing the rate of commercialisation of MTRESs.

The results produced by the TA tools and methods provide insight into which aspects and activities should be focused on with respect to the commercialisation process, affecting the relative importance of the different organisational capabilities. Due to the dynamic nature of the commercialisation process, this interface will require continual revision and reassessment, in response to progress achieved, and the impact of any externalities.

5.9.3 Secondary and tertiary level components

The interface between the secondary and tertiary level components of the strategic management framework relates to how the TA, MAPPS, and OA components can be utilised by the partnership to support its objectives. Each component is of equal importance, addressing the different aspects of, and barriers to, the commercialisation of MTRESs. It is accepted that constraints placed on the partnership relating to time, funding, and other resources may prohibit it from implementing all the tools described in the strategic management framework. However, it is important that the partnership implement the three secondary components to the greatest degree possible, ensuring that the interface remains aligned with the framework's core objective.

The ability of the partnership to implement the three secondary level components depends to a large extent on the knowledge and expertise of its individual members. It is expected that its members will predominantly supply the resources that the partnership needs to meet its objectives. These include the assets needed by the partnership in the form of administrative staff, physical premises, and funding to coordinate its activities. For those elements of the secondary level components that the partnership is unable to conduct itself, it is recommended that third party organisations be used to assist with the respective tasks and activities.

5.10 Summary: Development of the framework

Chapter 4 documented the development of a strategic management framework to increase the rate of commercialisation of MTRESs. First, the design methodology to be followed was outlined and illustrated graphically. Next, a conceptual model for increasing the rate of commercialisation of MTRESs was selected, together with a set of design requirements based on existing barriers to the commercialisation of MTRESs sourced from literature.

In addition to the literature sources contained within Chapters 2 and 3, several other sources from literature were used to assist the conceptual thinking behind the development of the framework and its components. The framework's development was also based on certain assumptions held by the researcher concerning the commercialisation of MTRESs.

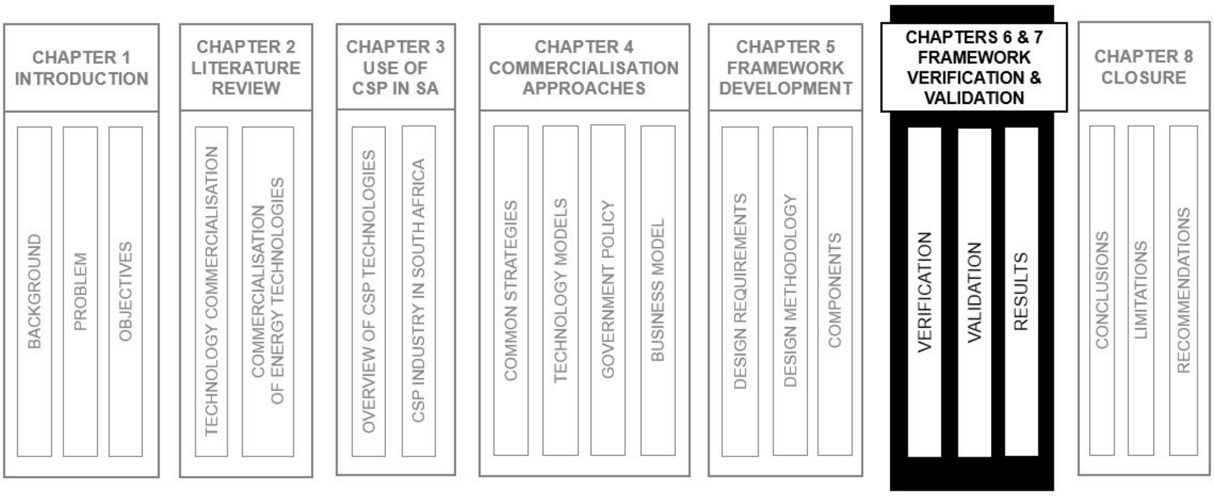
Subsequently, focus was placed on those components of the framework which required greater attention, namely: the three secondary level components (TA, MAPPS, and OA), and the various tools contained therein. Moreover, attention was given to the implementation of the framework through a partnership, with its objectives, key stakeholders, structure, and metrics to monitor the progress achieved. Finally, consideration was given to the strategy's interfaces and relationships, which may either contribute, or hinder, the rate of commercialisation achieved.

The next chapter, Chapter 6, discusses the verification of the strategic management framework.

Chapter 6

Verification of the Strategic Management Framework

Chapter 6 discusses the verification of the strategic management framework, namely: does the framework fulfil the purpose for which it was designed? The methodology followed in this section is to match the design requirements set in Chapter 5.2 with those sections of the framework developed in Chapter 4 designed to address them, and discuss how this may be achieved in practice. It is noted that the means and extent to which the framework addresses certain design requirements may be a matter of debate.



6.1 Technical barriers

Table 6.1 verifies the strategic management framework against the technical barriers of the commercialisation process.

Table 6.1: Verification of the framework's technical aspects

Barrier	Framework section	Discussion
Consistency in energy supply; intermittent nature and low storage capacity	5.5, 5.6.1, 5.6.2	Although certain MTRESs, such as CSP technologies, are able to ensure consistency in energy supply, greater and more consistent energy output from MTRESs in general can be achieved through (financing and conducting) R&D into different ESTs, and weather resource (wind, solar DNI and GHI etc.) forecasting tools, as well as the use of TA tools, to improve understanding of such technologies and their operation.
Low (technical) quality standard of MTRESs	5.5, 5.6.1, 5.6.2	Technological progress through practical deployment (O&M) and additional R&D will result in higher quality MTRESs. The use of TA tools can also highlight which areas should be prioritised for future improvement.
Lack/shortage of a skilled and specialised workforce	5.6.1, 5.6.2, 5.6.3, 5.6.4	Government training and certification programmes, as well as business sector skills training initiatives, can create a larger and more specialised workforce. The education initiatives and social acceptance tools of the framework also play a role in increasing the number of people interested in MTRESs, and who may decide to participate in such programmes.
Site location selection	5.5, 5.6.1, 5.6.2	The improvement in quality of MTRESs will allow for production of similar quantities of energy from lower RE resource areas. This will increase the number of sites available for plant construction, making selection of such sites an easier task. Furthermore, as greater and more accurate data is gathered over a longer period of time through the TA tools, the ability to ascertain the suitability of a site for a MTRES will also improve.
Lack of (access to) grid infrastructure	5.6.1, 5.6.2	Government policy can expand the national grid into those areas with high RE sources deemed favourable for MTRESs. The business sector can assist the government in the rollout by providing their expertise in this regard. In addition, the ability of the grid to be accessed through wheeling tariffs can assist the business sector in the rollout of MTRES projects, should costs fall sufficiently to make this a feasible option.

Barrier	Framework section	Discussion
Lack of technical standards	5.6.1, 5.6.4	Technical standards can be devised and implemented by the interface improvement policies of national government, or a credible and legitimate NGO/RE institution.
Limited technical and O&M experience	5.6.1, 5.6.2	Addressed through government training and certification programmes, and business sector skills training initiatives. The construction of new plants through government policy (such as tender-bid programmes), and business sector activities (such as technology export), will also improve technical and O&M experience with MTRESs.

6.2 Financial and economic barriers

Table 6.2 verifies the strategic management framework against the financial and economic barriers of the commercialisation process.

Table 6.2: Verification of the framework's financial and economic aspects

Barrier	Framework section	Discussion
Lack of funding & access to financial capital	5.6.1, 5.6.2	There are a number of innovative financial mechanisms presented, which can be driven by government policy and/or the business sector, in order to supply the financial capital needed for R&D, plant development, and other commercialisation activities.
Large (initial) costs	5.6	Through government- and business sector-driven R&D, the costs involved can be reduced. The use of different financial mechanisms may also assist in lowering the cost of project finance. Greater knowledge and familiarity with such technologies, achieved through the education and social acceptance initiatives proposed, will act to reduce the financial services' costs involved, reducing the overall technological cost.
Existing market structure; dominance of fossil-fuel	5.6	Changing the structure of a market, especially one as inert and large as the energy sector, is a slow and multi-faceted process. As such, it is difficult to state with any degree of certainty whether the framework is able to address this barrier. However, the existing market structure, dominated by fossil-fuel technologies, is targeted for change by the four MAPPSs proposed, through the different aspects required for a transition to a more sustainable energy sector.

Barrier	Framework section	Discussion
technologies and lack of competition		Nonetheless, it is likely that validation of the framework will provide greater insight into this requirement, and how the framework may be refined in order to better address it.
Economic and market instability	5.6, 5.8	General instability within the RE industry and wider energy sector is addressed by the four MAPPSs. The business sector assumes a greater role in the industry, while the level of knowledge and awareness of MTRESs in society is raised. In addition, the partnership will have a key role to play in encouraging dialogue and cooperation between different stakeholders, strengthening ties that may act to mitigate economic and market instability.
Lack of a strong supportive manufacturing industry	5.6.1, 5.6.2	Both government and the business sector have a responsibility to act towards developing a strong supportive manufacturing industry, one that is able to supply the components needed for MTRESs at a cost-effective price.
Long payback period	5.6.1, 5.6.2	The uncertainty and risk associated with a long-term payback period can be mitigated through innovative financing mechanisms and long-term institutional investors. A reduction in the costs involved can shorten the total payback period.
Financial sustainability and bankability	5.6.2	By assuming greater leadership over MTRESs and the RE industry, the business sector can greatly improve the financial sustainability and bankability of such projects, through sustainable demand and greater certainty of the industry’s future survival and growth.
Economies of scale	5.6.2	To generate the demand necessary to attain economies of scale and improve the profitability of MTRESs, it is necessary for the business sector to actively seek out global demand for different MTRESs. This demand may also exist for subcomponents of these systems, not only the entire MTRES itself, and may lie across markets not directly associated with the energy sector.

6.3 Social and institutional barriers

Table 6.3 verifies the strategic management framework against the social and institutional barriers of the commercialisation process.

Table 6.3: Verification of the framework's social and institutional aspects

Barrier	Framework section	Discussion
Ineffective implementation of commercialisation plans	5.1, 5.8	Careful consideration was given to the implementation of the commercialisation plan proposed in this research study (the framework). A partnership was analysed as it acted to ensure that the expertise and capabilities required for the commercialisation of MTRESs are addressed. In addition, the pivotal role played by people and stakeholders was given due focus. However, without actual implementation, it is not possible to state with certainty whether this design requirement will be met.
Policy ambiguity and uncertainty	5.1, 5.6.1, 5.6.3, 5.6.4	Policy ambiguity and uncertainty is addressed through the role of people as decision-makers. However, it is admittedly a rather challenging problem to overcome. The different policies required for commercialisation, as well as greater education and social acceptance of MTRESs, are two aspects which have the potential to improve the ability of policy-makers to set more clear and certain policies concerning MTRESs.
Lack of sufficient supportive policies and incentives	5.6.1, 5.6.2, 5.8	A range of government and business sector incentives is included in the framework, presenting management practitioners with a range of options with which to nurture industry growth. However, the partnership will need to play a prominent role to ensure such policies and incentives are implemented properly.
Low public knowledge, education, and awareness (of MTRESs)	5.6.3, 5.6.4	The education initiatives and social acceptance tools are geared towards improving knowledge and awareness of MTRESs across all age groups and demographics of society.
Lack of knowledge and familiarity with green financing mechanisms	5.6	Addressed by all four MAPPSs to varying degrees. Greater knowledge and familiarity with green financing mechanisms will require a coordinated approach to educate the population about such mechanisms in an easily-understandable form and manner.
Lack of robust planning of RE development at strategic and planning	5.6.1, 5.6.2, 5.7, 5.8	The lack of robust planning is addressed by both government and business sector activities, as well as the partnership in leading efforts towards commercialising MTRESs. This lack of planning can also be addressed by paying greater attention to the strength of organisational capabilities of those involved in the commercialisation process. In addition, the foundation of people acknowledges the human aspect involved.

Barrier	Framework section	Discussion
levels (for medium- to long-term)		
Gap between (university) research projects and market needs	5.6, 5.7, 5.8	To be addressed through the deployment of all four MAPPSs by the partnership. Aligning research projects with the needs of the market will lead to relevant problems being overcome faster, while also fostering stronger ties between different stakeholders. The role of certain organisational strengths, such as communication and leadership, also have a part to play in overcoming this gap.
Site location selection	5.6.3, 5.6.4	As a greater percentage of society learn about MTRESs and become more accepting of these technologies, less resistance may be encountered in the selection of different site locations. This will assist the development of future MTRES projects, and benefit the wider commercialisation process.
Inadequate/ ineffective engagement & coordination between stakeholders; lack of (strong) networks, platforms and associations for MTRES promotion & development	5.1, 5.7, 5.8	Addressed by the organisational capabilities of leadership and communication, as well as the guidance of the TCO given to the interactions and relationships that will come to exist between stakeholders involved in the partnership. The foundation of people, as decisionmakers with their own interests and agendas, also needs to be managed effectively for improved engagement and communication.
Lack of start-up firm support through science and technology parks, incubators etc.	5.6.1, 5.6.2, 5.8	Both government and the business sector need to provide support to start-up firms in the RE space, to allow them to flourish. The need for such support can also be addressed by the partnership.
Poor identification of potential adopters	5.8	Identification of potential adopters will be addressed by the partnership. In particular, it is important to identify those champions in government and business with the will and interest to actively promote and commercialise MTRESs.

Barrier	Framework section	Discussion
Poor post-adoption support	5.6.1, 5.6.2, 5.8	The provision of post-adoption support is typically the domain of the business sector, with the partnership having a key role to play in this regard. The need for such support can also be encouraged through government policy.
Policy misalignment	5.6.1, 5.8	Aligning and coordinating policy can only be done by policymakers. However, pressure can be brought to bear on them through lobbying from the TCO, and other influential partners in the partnership, in order to address the relevant problem areas.
Lack of legitimacy	5.8	The foundation of the social acceptance tools is aimed at promoting a favourable opinion of MTRESs, as well as the partnership. This will lead to legitimacy and credibility of the technology and respective agents involved in the commercialisation process.
Political instability (Stop-and-go policies)	5.6.1, 5.8	Consistency of policy can only be accomplished by policymakers. However, pressure can be brought to bear on them through lobbying from the TCO, and other influential partners in the partnership.
Dominance of government over private sector involvement	5.6.2	The business sector is to assume primary responsibility for the commercialisation process, as well as subsequent technological development, and the growth of the industry. Greater involvement of the business sector will act to mitigate some of the uncertainty and ineffectiveness of government action to date.
Insufficient protection of IP rights	5.6.1, 5.8	The allocation of IP is typically done by a government-affiliated body. Greater protection of IP rights can be achieved through engagement and lobbying of the government by the partnership, offering surety to businesses that investment in MTRESs will yield rewards.
Lack of enabling regulatory environment	5.6.1, 5.8	The regulatory environment is dependent on consistency and certainty created by government policy. This can be addressed through the lobbying of policy-makers by, and within, the partnership, and by other stakeholders in the commercialisation process.
Attitude, strategy, and dominance of established players; lack of political will	5.6.2, 5.6.3, 5.6.4	Greater lobbying on behalf of the RE business sector and the general public can have a significant influence on the stance of established players and policy makers. Moreover, by utilising education and social acceptance to provide the public with sound facts and knowledge, they can be empowered to make their own decisions,

Barrier	Framework section	Discussion
		leading to the emergence of future decision-makers who are more willing to promote MTRESs. Attitudes to MTRESs will also change once they become cost-competitive with traditional energy technologies and experience improved reliability.
Administrative barriers	5.6, 5.7, 5.8	The challenge of administrative barriers is addressed by many aspects of the framework. More streamlined government and business processes, greater knowledge of acceptance of the technology and associated processes, the ability to think critically, the organisational capabilities to handle all administrative tasks, and the implementation of the framework. All these processes seek to overcome the administrative barriers of the commercialisation process.

6.4 Generic barriers

Table 6.4 verifies the strategic management framework against the generic barriers of the commercialisation process.

Table 6.4: Verification of the framework's generic aspects

Barrier	Framework section	Discussion
Lack of (access to) information	5.6.3, 5.6.4	Addressed through the education initiatives and social acceptance tools of the framework, which raise knowledge and awareness of MTRESs by the general public across a range of mediums.
High risk profile	5.6.2, 5.6.3, 5.6.4	Addressed by the partnership working together for the good of technology and associated industry, to provide greater surety to all stakeholders. The risks involved can also be reduced through greater knowledge, awareness, and familiarity with such technologies from all members of the general public, especially investors.
Lack of interest	5.6.3, 5.6.4, 5.8	One of the key challenges facing the partnership will be how to foster widespread interest in MTRESs, given the diverse range of interests represented by the general population, many of which may be at odds with the commercialisation of

Barrier	Framework section	Discussion
		MTRESs. This may be achieved through the education and social acceptance initiatives proposed, and actions taken by the partnership.

6.5 Summary: Verification of the Strategic Management Framework

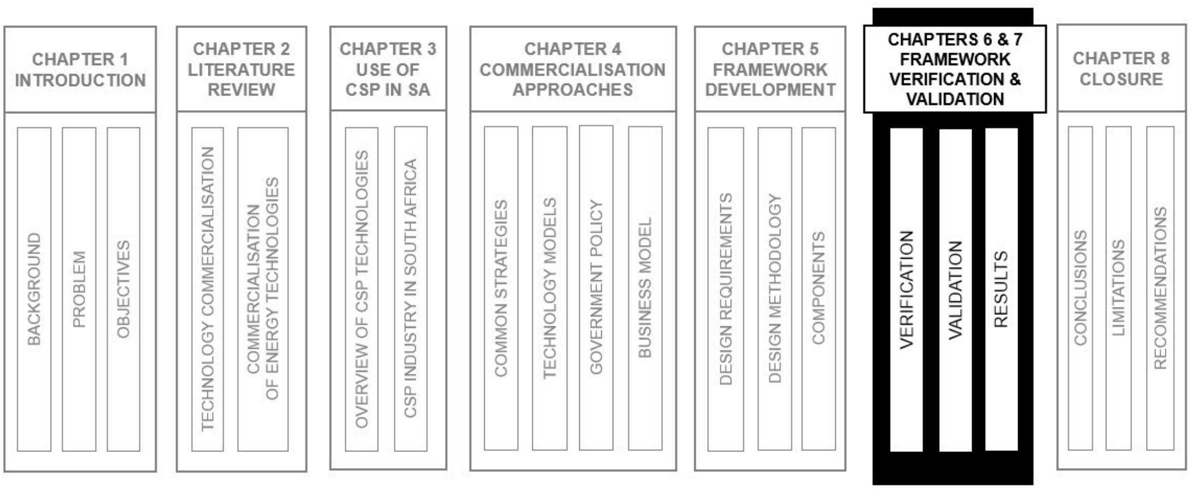
Having verified each of the design requirements against the strategic management framework developed, it is evident that the framework does indeed address each barrier. However, the verification process does not indicate the extent to which each barrier is addressed. Furthermore, the discussion of how each requirement is met only represents the researcher's views and perspective on the matter, which, given the researcher's relative lack of practical experience in the RE industry, may be subject to debate. It is likely that, through validation of the framework by experts in the field, the ability of the framework to overcome the barriers to the commercialisation process will be tested, strengthened, and refined. This will result in a potentially stronger tool to increase the rate of commercialisation of CSP technologies in South Africa. This brings us to the next chapter of this research study, Chapter 7, which discusses the validation of the strategic management framework.

Chapter 7

Validation of the Strategic Management Framework

Chapter 7 presents an overview of the validation process used to assess the extent to which the strategic management framework achieved the primary objective of the research study: An approach for increasing the rate of commercialisation of CSP technologies in South Africa. The chief question to be answered is whether consensus exists regarding the framework and its components, namely: Does the developed framework make sense to experts in the field, and not merely the researcher? Furthermore, how may the views of the participants be incorporated to refine the strategy, and thus better address the challenges and barriers faced by the commercialisation process?

The process used to validate the strategy is explained, together with an analysis of participants' opinions of the framework and its components, the subsequent amendments made and a general commentary on the validation process followed post-completion. Given the extensive list of design requirements for the framework (see Chapter 5.2), the validation of the framework focused on its structural components, and their ability to support the framework's objective.



7.1 Validation process

The purpose of a validation process is to assess the reliability and accuracy of any conclusions drawn from a body of research. Four main types of validity exist: measurement[71], internal[72], external[73] and ecological[74] (Bryman *et al.*, 2011:25). Knowledge of these validity types is key to a sound research process, thereby providing the researcher with a set of tools to evaluate the integrity of any conclusions and relationships ascertained from the given data set (Bryman *et al.*, 2011:25). The validation process followed in this research study contains elements of measurement, internal, and external validity, which are discussed later in this chapter.

Ideally, the validation of the strategic management framework would consist of a real-world application. However, the duration of the research study, together with other constraints such as the costs involved, and the number of people needed to implement the framework, marked such an approach infeasible. In response to these limitations, several alternative validation methods were considered, such as: workshops, questionnaires, and interviews. Of these, a Delphi technique[75] was judged most suitable, due to its ability to engage with a wide range of experts and professionals in academia, government, the private sector, and civil society. Thus, the technique allowed for the determination of whether the views and thoughts of the researcher were shared by experts in the field. These views were analysed with respect to the framework, and its ability to address the study's primary objective: increasing the rate of commercialisation of CSP technologies in South Africa.

The decision was made to proceed with a variation of the Delphi technique[76], termed a hybrid-Delphi technique for the purposes of this research study. The hybrid-Delphi technique meant involving as many individuals from different backgrounds as possible, until consensus on the subject matter was reached, rather than focusing on a smaller, core group. This decision was influenced by cost constraints, the limited availability of certain participants, and the desire to obtain feedback from as large a pool of diverse stakeholders as possible.

---

[71] Also known as construct validity, measurement validity assesses the reliability of a metric, determining whether it accurately conveys the idea it is meant to measure. Used primarily with measurement of social concepts and quantitative research (Bryman *et al.*, 2011:25).

[72] Internal validity is used to assess the substance of any causal relationships identified between the respective independent and dependent variables (Bryman *et al.*, 2011:26).

[73] External validity refers to the extent to which a research study's findings can be generalised beyond its boundaries, based on how representative the sample data pool is (Bryman *et al.*, 2011:26).

[74] Ecological validity describes the extent to which conclusions from (social) research can be applied to (social) circumstances encountered in everyday life (Bryman *et al.*, 2011:26).

[75] A Delphi technique is a tool used to predict the probability and results of a future event, topic, or trend. The tool involves the engagement with a group of experts in order to obtain their views, thoughts, and opinions relating to the subject in question. The information received is assessed by a facilitator, and often compiled into a report summarising any conclusions drawn. (Haughey, 2017)

[76] A standard Delphi technique is one in which the same group of experts is used repeatedly until consensus is reached regarding the source material.

In order to evaluate the measurement, internal, and external validity of the strategic management framework, the need was identified to discuss the framework at length with participants in order to attain as much constructive feedback as possible regarding the framework's strengths and weaknesses. To meet this need, and maximise the amount of time spent discussing the framework with participants, the decision was made to use a semi-structured interview method[77]. This method utilises a set of open-ended, opinion-based questions to guide the conversation on the different elements of the framework. This approach was favoured to allow participants the freedom to provide clarity on their answers, and express their views on the framework and wider research study. The approach also ensured that the conversation remained centred on the framework, and within the boundaries set for the research study.

It was predicted that there would be prospects for improvement of the framework from its initial version, given the complex nature of the commercialisation process, the researcher's relatively limited practical knowledge and experience of the field, and the development of the framework purely from a literature perspective[78]. As such, the choice of a semi-structured interview consisting of open-ended questions also allowed participants the opportunity to disclose the means by which they felt the framework could be strengthened to achieve its objectives.

Four different sample selection approaches were used to choose participants for the hybrid-Delphi technique: (1) purposive sampling, where participants were selected based on their relevance to the research topic; (2) convenience sampling, where participants were selected by their respective organisation; (3) snowball sampling, where participants suggested other viable candidates for participation; and (4) theoretical sampling, utilising the feedback received from participants as an indication of how many additional individuals were needed for the validation process (Bryman *et al.*, 2011:185). The choice of these four approaches was influenced by the nature of the research study, as well as constraints relating to participant availability, and the time duration of the study.

To ensure the inclusion of individuals who could make a worthwhile contribution to the validation process, certain criteria were used as part of the four sample selection approaches mentioned above to identify prospective participants. These criteria included: knowledge and

---

[77] Interviews are typically classified as structured, semi-structured, and unstructured or narrative (Stuckey, 2013).

[78] The lack of involvement of experts in the development phase of the framework (see Chapter 4) was based on the anticipated difficulty in scheduling appointments with desired individuals, and the need to ensure that sufficient individuals were available for the validation process who had not been exposed to the research study before, to limit the degree of bias they may have possessed.

experience of (1) technology management, (2) technology commercialisation, (3) renewable energy, and (4) CSP technologies, all preferably in the South African context. The physical location of participants was also a factor, with participants located close to the researcher preferred in order to limit travelling expenses. Individuals were chosen from as wide a range of backgrounds as possible, to ensure diversity of feedback received.

Participants were invited to partake in the validation process through a request for validation (see Appendix F.1). Once confirmation was received of their agreement to participate, meetings were scheduled on an individual basis. Each meeting consisted of a short presentation of the strategic management framework given by the researcher, followed immediately by an interview designed to receive feedback from the participant regarding the strengths and weaknesses of the framework, based on a set of pre-determined questions (see Appendix F.2). Although more time consuming in total than a focus group (due to multiple interviews), this method allowed for a personal and in-depth discussion with the individual participant, in accordance with the aim of maximising the feedback received from participants. Furthermore, scheduling individual appointments proved to be easier, thereby eliminating the need to establish a single meeting time that would work for multiple individuals.

Given the politicised nature of the energy sector (Krupa & Burch, 2011), and the sensitive nature of some of the ongoing projects involving prospective participants, there was a strong possibility that certain individuals may have been reluctant to take part in this study. In response to this issue, complete anonymity of participants was guaranteed on behalf of the researcher. To further put participants at ease, they were encouraged to treat the interview as more of a discussion of their perspectives on the strategic management framework and commercialisation of CSP technologies in South Africa, rather than focusing purely on the questions asked.

Three common methods of qualitative data analysis were considered for assessing participants' responses during the validation process: (1) analytic induction[79], (2) grounded theory[80], and (3) thematic analysis[81] (Bryman *et al.*, 2011:342). A grounded theory analysis was chosen to refine the framework in order to better address the research study's objectives. The theory was developed from the collection and analysis of data (in the form of the

---

[79] Analytic induction is described by Bryman *et al.* (2011:342) as seeking a complete explanation of a phenomenon through the pursuit of data until no divergent or negative cases are found, or cases differing from the proposed explanation.

[80] Grounded theory is an iterative process whereby theory is developed from data collected during a research study, with the stages of data collection and analysis taking place concurrently (Bryman *et al.*, 2011:345).

[81] Thematic analysis entails the identification, analysis, and description of themes and patterns that may exist in a data set (Bryman *et al.*, 2011:350).

participants' responses) concerning the commercialisation of CSP technologies in South Africa, and the strengths and weaknesses of the strategic management framework (and its components). The use of such an iterative methodology allowed the framework to be strengthened throughout the validation process, with feedback also received on any subsequent changes made to the framework. This resulted in a stronger tool than had any weaknesses in the framework only been addressed at the end of the validation process.

The hybrid-Delphi technique utilising a grounded theory approach was conducted by dividing participants into 'pods' of three, based on their location proximity to the researcher, availability, and professional background. The subject of the research study limited the total number of candidates available for consideration, with three individuals considered a suitable pod size. The first pod was presented with the initial version of the strategic management framework, following which their feedback on the framework's strengths and weaknesses was analysed, and incorporated into the framework to improve it. The updated framework was then used for the subsequent pod of three, ensuring an iterative process of refinement which incorporated the development of any new theory.

During each interview, a cell phone was used to record the participant's response, allowing the researcher to focus on the interview at hand, and obtain as much feedback on the strategic management framework as possible in the way of the participant's thoughts, views, and opinions. The interviews were subsequently transcribed to a text form using Atlas.ti[82] software. The choice of Atlas.ti over other software packages, such as Nvivo, was due to the researcher's prior experience with the program. The transcripts were summarised and tabulated (see Appendix F.3), based on the aggregation of responses received per iteration. Lastly, a set of conclusions were drawn from the results of the validation process (see Chapter 8), together with the limitations encountered by the research study and recommendations for future research.

7.2 Case study: CSP technologies in South Africa

As discussed in Chapter 1.3, the MTRES chosen as a case study for the strategic management framework was CSP technologies in South Africa. Given that commercialisation is a lengthy process, and considering the time constraints involved, the application of the strategic management framework was validated through engagement with experts as part of the hybrid-Delphi technique described in Chapter 7.1.

[82] Website: http://atlasti.com

Before the validation process began, some preliminary work was performed concerning the application of the strategic management framework to the respective case study. This was done to assist participants in the validation process in ascertaining the validity of the framework for its given purpose, with respect to CSP technologies in South Africa. Utilising the tools of the TA component, the use of CSP in South Africa was investigated through the different types of CSP technology which exist, and the state of the CSP industry in the country. This provided the researcher with a basic understanding of the current state of commercialisation of CSP technologies in South Africa, and how the framework may be applied to increase the rate of commercialisation achieved.

To guide the focus of the MAPPS' component, the market analysis tool of the TA component was used to conduct an analysis of the existing market and prospective future applications for CSP in South Africa. In addition, the policies contained within the strategic management framework (see Chapter 5.6.1) were assessed based on their potential for use in South Africa, as well as South Africa's own experience, or lack thereof, with said policy in order to determine whether (1) existing policies were sufficient, and should merely have their timeframes extended, (2) adjustments were required to existing policies, or (3) entirely new policies were needed altogether. The assessment also considered the manner and means by which they may be implemented practically in South Africa.

It is necessary to address one of the key talking points of late concerning the future commercialisation of CSP technologies in South Africa: The South African national government's position on CSP. Recent events, such as Eskom's refusal to sign off on the PPA of the 100 MW Redstone Project (Tsanova, 2016), and the exclusion of CSP from the updated 2016 IRP released for public comment (Creamer, 2016a), have made it apparent that the South African national government currently has little, if no, intention of incorporating CSP technologies into the country's energy mix on a large scale.

This lack of policy commitment is extremely problematic for efforts to increase the rate of commercialisation of CSP technologies in South Africa. As such, it often came up in the conversations held during the validation process that the current status of the CSP industry in South Africa, and wider energy sector, would prove a significant hindrance to the framework and any realistic prospects for practical implementation. Indeed, many of the changes made during the refinement of the framework were in response to this issue as it became more prevalent throughout the time period during which the research study was conducted. The point raised here is that while the government policies listed in the framework may not be strictly relevant at the moment, as CSP technologies appear to be out of favour in South Africa, their inclusion is more for strategic purposes. Thus, should the national government change its stance on CSP, guidance is already provided as to which policies should be implemented, and why.

Lastly, consideration was given to the implementation of the strategic management framework (through partnerships) in the context of the case study. This involved setting target values for the partnerships' objectives based on existing energy data sourced from literature. It is acknowledged that a degree of subjectivity exists here, and thus a range of values was presented wherever possible, although this did result in some disagreement from participants.

7.2.1 Case study participants

The number of participants to include in a validation process will always be a matter of debate. While ideally one would have as many participants as possible, time constraints often prevent such a case from being possible. The choice of the final number of participants in this research study was guided by convergence of feedback received on the framework, as well as the diversity in background of the different participants, with the researcher making the effort to engage with as many individuals from different backgrounds as possible. The participation of individuals from a wide range of different backgrounds was achieved to a certain extent. The only major stakeholders not consulted, and who met the four criteria established, were an environmental-based individual or organisation, and a government official. Successful contact was made with an energy expert from the media, but cost and time restrictions prevented this interview from taking place.

Eighteen individuals took part in the validation process, comprising five iteration rounds as per the design methodology followed (see Figure 5.1). An overview of the participants is presented in Table 7.1. In the interests of participant anonymity, each participant was named according to the iteration round that they participated in, and the order in which they were interviewed during each pod. For example, Participant 3-2 refers to the participant who took part in the third iteration round of validation process (and hence Pod 3), and was interviewed second amongst the three participants of the pod. In addition, the background of each participant is listed, along with the reason why they were identified as a feasible candidate for participation in the validation process.

Table 7.1: Overview of validation process participants

Participant name	Background	Reason for inclusion
Participant 1-1	Academia - University	CSP expert
Participant 1-2	Academia - University	CSP expert

Participant name	Background	Reason for inclusion
Participant 1-3	IPP, EPC, O&M / Solar thermal energy association	CSP industry expert
Participant 2-1	Academia – Business School	Innovation and strategy expert
Participant 2-2	Academia - University	Innovation and strategy expert
Participant 2-3	Academia - University	CSP expert
Participant 3-1	IPP, EPC, O&M	CSP expert
Participant 3-2	IPP, EPC, O&M	CSP expert
Participant 3-3	IPP, EPC, O&M	RE and commercialisation expert
Participant 4-1	Academia - University	Innovation, strategy, and commercialisation expert
Participant 4-2	Training and development institution	RE strategy expert
Participant 5-1	Consulting / service provider[83]	RE expert
Participant 5-2	Consulting / service provider	RE expert
Participant 5-3	Consulting / service provider	RE expert
Participant 5-4	Consulting / service provider	RE expert
Participant 5-5	Consulting / service provider	RE expert
Participant 5-6	Consulting / service provider	RE expert
Participant 5-7	Academia - University	RE expert

7.2.2 Case study results

This section discusses the results of the validation process. The feedback received from the participants on the different components of the strategic management framework was summarised, and analysed with reference to the framework and the commercialisation of CSP technologies in South Africa. For a detailed breakdown of the views and opinions of each participant, please see Appendix F.3.

7.2.2.1 The strategic management framework

There was a mixture of feedback received regarding the overall strategic management framework and choice of approach chosen for increasing the rate of commercialisation of CSP technologies in South Africa. Many participants commended the comprehensive nature of the framework, with Participant 5-2 declaring it a "*5th generation management model for technology and business developmen*t". However, there were some participants who felt that government policy should be the dominant approach towards increasing the rate of commercialisation of CSP technologies, with the need to focus on sustainable demand and cost reduction.

[83] Refers to engineering, consulting, technology, financial, and/or management consulting services.

A general comment received from participants was that some were unsure of what the framework and its components were trying to achieve, as well as what was meant by certain terms associated with the framework, and wider research study. While one reason for this uncertainty could have been the excessive amount of information contained within the presentation, with the researcher trying to convey a large amount of information in a limited period of time, a more likely factor responsible was the design requirements set for the original conceptual model (see Chapter 6), or more specifically, the lack of certain requirements.

While the design requirements covered a range of different fields, they were all functional in nature, with little consideration given to the user's experience of the framework. It can be said that the implementation of the framework was considered through the tertiary-level component, but this related to functional implementation rather than its ease of use. While this issue was remedied to a certain extent following Pod 5 of the validation process, whereby the framework was re-illustrated to make it easier to comprehend, it nonetheless remained a serious flaw in the design process followed, serving as an example of the benefit of hindsight.

The point was raised early in the validation process that the framework would not achieve its goal of increasing the rate of commercialisation of CSP technologies in South Africa, given its status as a tool, and the wide range of factors that influence the commercialisation process. This was elaborated on through discussion of the agendas and vested interests of powerful agents within the energy sector, particularly those in government, and the wide scope of the study's objective. Instead, the point was made, particularly by Participants 2-1 and 2-2, that the framework developed had more value as a tool to support the development of strategies for increasing the rate of commercialisation of MTRESs. Upon reflection, the researcher judged this view as a more accurate description of the framework developed, and narrowed the scope accordingly.

With respect to the choice of a strategic management framework as a conceptual model, the majority of participants highlighted government policy as a key approach for commercialising MTRESs. This is not surprising given the politicised nature of the energy sector. This was not viewed as a strong critique of the framework approach chosen, given that the framework contained government policy as one of the components necessary for market creation. However, it did suggest that government policy should be afforded a more prominent position in the framework, instead of being placed on an equal footing with other market generation initiatives.

Participants 5-1 to 5-6 mentioned the need to provide greater explanation of the (set of) activities required to implement the framework. While this feedback was implemented into subsequent iterations of the framework, the point raised appeared to indicate a preference for a TRM approach (see Chapter 4.6 and Appendix A.7), as opposed to the strategic management framework. If one considers the dominant role played by politics in the commercialisation of energy technologies, it is possible that a multi-organisation TRM designed to convince policy-makers of the benefits of a respective technology, might have been an appropriate choice of approach.

However, given that roadmaps are subject to redundancies considering how quickly things change in the modern era, the use of the framework was deemed more suitable due to its inherent flexibility. Furthermore, if one considers that TRMs represent a type of strategy, the ability of the framework to support strategy development allow for the creation and use of multiple TRMs, a viewpoint supported by Participant 4-2. Nonetheless, the question of activities was addressed through the explicit inclusion of the commercialisation activities in the framework after the 5th iteration (post-Pod 5 in the validation process). Another option regarding a choice of commercialisation approach may have been the use of transition management (TM), which focuses on socio-technical transitions and could be applied for the specific case of technology commercialisation, with an emphasis on decision-making on a national government level.

These contrasting viewpoints seem to indicate that there is no one single approach to technology commercialisation, or increasing the rate at which it takes place, and that the use of several different approaches may yield the best results. This finding is echoed by Haas *et al.* (2004), who state that there is "*no single, universally applicable 'best' support mechanism or policy for the bundle of different technologies known as renewable energy systems*". As a result, tools such as the strategic management framework developed here, despite how comprehensive they may appear, should not be used in isolation, providing commercialisation practitioners with a range of options in their toolkit depending on their specific needs.

7.2.2.2 Significant barriers to the commercialisation of CSP technologies in South Africa

Participants were asked to identify significant barriers to the commercialisation of CSP technologies in South Africa, as a means of determining whether those identified from literature (see Appendix B, Chapter 5.2, or Chapter 6) concerning MTRESs were also valid for the case study. The majority of participants highlighted political interference and poor policy implementation as the largest barriers to commercialisation. The actual policies themselves were well spoken of, with only the carbon tax highlighted as one policy that needed to be introduced soon to make CSP more competitive in South Africa's energy sector.

The refined framework addresses the issue of political interference and poor policy implementation to a certain extent through the use of education, social acceptance, and private sector lobbying of government in an attempt for CSP to find its way back into the future energy mix of the country. Yet, these are unlikely to be barriers which are ever fully overcome given the energy sector's politicised nature in South Africa (Krupa & Burch, 2011).

The second most cited barrier was the high costs associated with CSP. CSP has a perception of being an expensive technology, which while true, has to be balanced against the value proposition it offers. Unfortunately, this is not always the case for a number of reasons, such as a lack of information and awareness of the technology, as well as conflicting agendas and interests of different energy sector agents. Other prominent barriers that emerged during the research study included: project bankability, a lack of feasibility of local manufacturing operations for CSP-related components, the country's poor state of public education to promote not only knowledge of CSP but the fields of science and technology in general, and the state of South Africa's energy sector, with Eskom's monopoly over power generation, transmission and distribution.

7.2.2.3 Commercialisation process: market generation

The market generation/MAPPS component was generally well received, with many participants agreeing with the four target areas chosen. However, there were several improvements suggested (as listed in Chapter 6.3). The participants of Pod 2, in particular Participant 2-2, recommended that the framework should provide guidance as to when the government policies and business activities should be implemented, by mapping them to the s-curve of the TLC. In addition, Participant 5-7 stated the need to provide a clearer description of the policies selected for the policy mix in the South African context. This related predominantly to the inclusion of FITs into the mix, which, while illegal on a national level in South Africa, as they violate laws of procurement, have been implemented on a local government level by certain municipalities, most notably in the Western Cape.

It is intended that the policies contained within the framework will be implemented by policy-makers with sufficient knowledge and understanding regarding which policies are suitable to a country's specific context in terms of practicality, legality, and past record of success. Furthermore, the policy mix was designed to provide a choice regarding which policy to implement based on the needs of CSP technologies amidst the wider social, political, and economic environment. As such, the criticism and lack of specification given to policies, such as FITs, are unlikely to be prominent issues in the framework's practical application, and can be attributed to the researcher's inexperience with the legal intricacies of South Africa's national policies. However, the point raised by Participant 5-7, to draw attention to the policy-making environment on a country-basis in future presentations, was a useful one to consider.

Participants 2-2 and 2-3 added to the list of education initiatives proposed. These included nationwide science and technology challenges at primary and secondary schools, and the use of open days at universities, research councils, and other similar institutions. Such initiatives lessen the reliance on government-backed programmes. There was no change made to the list of social acceptance tools, although Participant 4-2 did advise that the role played by the tools in promoting trust in the respective MTRES, leading to legitimacy and credibility in the technology, be made clear.

The greatest issue raised by participants relating to the market generation/MAPPS component was the market analysis conducted of CSP technologies in South Africa, which formed part of the work done prior to the validation process. Given the researcher's lack of experience with the CSP industry in South Africa and market analyses, it was to be expected that there would be questions asked of the analysis completed for the case study. Participant 1-3 questioned the likelihood of large-scale CSP plants being deployed within the industrial and commercial market segments, to supply the demand needed to increase the rate of commercialisation of CSP technologies in South Africa. The argument was made that if such options were currently feasible, why have they not been done already? This argument was extended to the advocation of the use and hybridisation of CSP systems and their components in commercial and industrial market segments within South Africa to increase demand, based on the lack of interest shown in the country's utility scale market.

The recommendation was made by Participant 1-3 to consider where real and sufficient demand for CSP technologies would come in order to drive the commercialisation process. Furthermore, the point was made that, despite the attempt by the researcher to focus on markets outside the South African national government's influence, given their apparent lack of interest in CSP technologies, the significant influence and power of government on a technology's survival within the borders of South Africa could not be ignored.

In the pursuit of realistic and feasible markets for CSP technologies, attention was shifted to the potential for global export, due to the South African national government's stance on the technology. Export could be considered for the entire CSP systems or the hybridisation of their lower level components, with a focus on utility-scale markets in order to generate the demand necessary to entice the business sector to play a greater role within the commercialisation process. This was reflected in the objective and metrics set for the partnership, distinguishing between the local and export markets where possible. While the regional market within Southern Africa was also considered, Participant 1-3 drew attention to the limited demand available for such technologies, especially with persistent levels of poor economic growth.

This feedback received on the market analysis highlighted the need to truly understand the target market in which one hopes to commercialise a technology, while also ensuring that whichever market one operates in, is able to supply sufficient demand to support the sustainability of operations over an extended period of time.

7.2.2.4 Commercialisation process: TA

The inclusion of the TA component at the beginning of the commercialisation process was to ensure that a systematic understanding of the technology was achieved prior to market-related activities. The list of tools and methods presented were judged to be extensive and sufficient by most participants. With respect to the six broad areas selected (see Figure 5.3), Participant 5-2 mentioned the need to consider some form of technology forecasting or planning, linking the TA component to the framework's time dimension. The omission of this area from the initial framework was based on the fact that many forecasting tools, such as s-curve analysis and the analytic hierarchy process, were listed under the six areas included in the framework. However, it was acknowledged that the six broad areas and TA component as a whole, might benefit from some form of (long-term) planning. As such, a road mapping tool was added to each of the six broad areas.

The value offered by the wide range of tools of the TA component received a favourable response from Participant 3-3 and Participant 5-2 in particular. Participant 3-3, who had experience in a previous attempt to commercialise a novel MTRES locally, mentioned the importance of testing energy technologies to ensure compliance with existing energy regulation, and remarked that had they followed a similar list of tools they may have experienced a greater level of success with their technology, or ended the venture sooner. This point was expanded on by Participant 4-2 who discussed the importance of beta testing, one of the tools listed under the Technical Performance Assessment area, in determining whether a technology was ready for the market from a technical performance and reliability perspective. These responses affirmed the importance and strength of the TA component of the framework.

7.2.2.5 Commercialisation process: organisational capabilities

Following the first two rounds of the validation process, it became clear that there was a need to revisit the process used to identify and select the organisational capabilities required for the commercialisation process. A greater investigation of literature was conducted (see Appendix F.6), resulting in a more comprehensive set of organisational capabilities. This list remained largely unchanged during the rest of the validation process, apart from the inclusion of several policy and political related capabilities at the discretion of the researcher, as additional feedback on the framework was received.

7.2.2.6 Environment: people

Following the completion of the interviews comprising Pod 5, the decision was made to alter the structure of the framework, in an effort to make it easier to understand from the view of the participants as well as the user. This saw the removal of people as the base of a cube structure and rather positioned as one of the elements comprising the environment in which commercialisation takes place. However, given that people still play a critical role within the commercialisation process, the feedback received was still deemed relevant to the overall framework.

There was general consensus on the importance and suitability of people as being central to any commercialisation approach. Many participants raised the need to expand on this component, with greater explanation of the decision-making role and processes involving people within the framework and commercialisation process. Participant 3-3 stated that, in South Africa, the focus is typically on the community and what can be done to improve the socio-economic status of communities across the country. Yet, in Europe, the focus is on the citizen, and in the USA the attention is placed on the consumer. This need to be more specific was addressed in later iterations of the framework, with a focus on the impact of government, the business sector, and the end-user on the commercialisation process.

Participants 2-1 and 5-7 appeared to disagree with the choice of people as the foundation of the framework, arguing that cost reduction instead should prove the core focus of any approach aimed at commercialising CSP technologies. The critical importance of cost reduction is underlined by the fact that if one considers that in order to reach a commercialised state, there is a need for CSP technologies to experience significant cost reductions, given that they are currently more expensive that many other energy technologies. However, one needs to keep in mind that the decision to conduct the R&D necessary for cost reduction is made by people, and will typically act to serve some individual’s interest or agenda otherwise it would not be conducted in the first place. As such, the matter of cost reduction was addressed by other components of the framework.

7.2.2.7 Implementation: strategy development

One of the key elements in the development of strategies, aimed at increasing the rate of commercialisation of CSP technologies, is the use of partnerships. There was widespread agreement with the choice of a partnership as the dominant mechanism for implementing the framework. However, it was remarked upon that the initial presentation of the objectives, metrics, and target values was disjointed. Participants 2-1 and 2-2 suggested the use of a balanced scorecard approach to remedy this, and demonstrate the links that lie between the objectives, metrics, and target values. The incorporation of the objectives, metrics, and target values into the balanced scorecard also saw a more detailed process conducted regarding the identification of all possible options for inclusion into the scorecard (see Appendix F.7).

The objectives and metrics of the balanced scorecard adopted post pod-2 were subjected to the greatest scrutiny from Participants 3-1 and 3-2. This led to the introduction of several additional metrics, and a re-examination of the data and assumptions used to set the various target values. Participant 5-7 also had an issue with the lack of explanation behind certain objectives and metrics, such as those related to the LCOE. This necessitated revision of the metrics, and assignment of a more specific description to each. In addition, Participant 5-7 remarked on the need to give greater consideration to the existing national electricity grid, and the (potential) impact of CSP technologies, and other MTRESs, on the overall system cost. Although the net result was a very long list of metrics, the development of different strategies will require different means of measuring progress. The list merely provides options to consider, with constraints such as availability of data to be considered.

The original list of stakeholders proposed as prospective partners neglected to consider the role played by media or labour organisations, both of whom hold significant power in South Africa, as well as research councils such as the Council for Scientific and Industrial Research (CSIR). The fact that these stakeholders did not appear in the initial list of stakeholders suggests the stakeholder mapping results of the literature sources used were not as thorough as was originally presumed, or neglected consideration of stakeholders which may be relevant only on a country basis. While Participant 2-2 mentioned the value of the researcher conducting the activity of stakeholder mapping personally, no additional stakeholders were mentioned by participants during future iteration rounds, and thus the updated list was deemed complete.

The partnership structure proposed was criticised by Participant 1-2 as being vague, and not representing a true organisational structure. This led to a re-examination of how best to illustrate the various relationships that exist between the individual stakeholders. Participants 1-1 and Participant 1-2 stated that the management of the partnership will prove to be too large a task for a single person (the TCO), and that a group of people should oversee the partnership and commercialisation process instead. This led to the replacement of the TCO with a technology commercialisation board (TCB), comprising professional managers and high-level corporate executives from the business sector, to manage the partnerships and strategy development, and coordinate efforts towards increasing the rate of commercialisation of CSP technologies in South Africa. However, during future iterations of the framework, it was decided that the TCB should consist of the country’s solar thermal energy associations, who act as custodians of CSP within South Africa, representing the interests of the many actors associated with the country’s CSP industry, together with high level officials from government and the private sector.

One challenge faced by the partnerships is the means by which they will be developed. While this was covered during the framework’s development through use of a partnership formation ladder, discussions were also held with participants, most notably Participants 4-2 and 4-3, regarding how one can mobilise and achieve buy-in from large groups of people with diverse interests. The development of partnerships was not discussed in great detail during any of the validation interviews due to time constraints, favouring other aspects of the framework instead. However, the framework could be strengthened by building on the partnership development ladder, and incorporating practical and cost-effective means of fostering partnership development.

7.2.2.8 Case study validity

This section discusses the validity of the strategic management framework with respect to the case study, CSP technologies in South Africa, and the wider research field and associated objectives. The validation process was based on three types of validity: (1) measurement, assessing the different metrics used to measure progress achieved by the strategies developed and implemented through partnerships, and whether any additional metrics were required, (2) internal, the various relationships which exist between the different components of the framework, and the wider commercialisation process, and (3) external, referring to the potential for success of the framework’s practical application, and the extent to which the research’s findings can be applied to the commercialisation of other MTRESs, and different geographic locations. Table 7.2 presents a commentary on these three validity types.

Table 7.2: Commentary on the validity types of the validation process

Validity type	Commentary
Measurement	Certain objectives and metrics were included in the framework to measure the relative success achieved by strategies developed towards increasing the rate of commercialisation of CSP technologies in South Africa. While these were rearranged into a balanced scorecard format, there were other metrics identified during the validation process that were also relevant to the commercialisation process. However, not all of them are applicable to all MTRESs, but for sake of generality, they were included in the balanced scorecard regardless in order to provide a range of options. Following Pod 5, participants did not suggest the addition of any other metrics. Thus, while the list is not considered to be a universal collection of all metrics one may use to measure progress during the commercialisation of MTRESs, it is deemed sufficient in the context of this research study. For practical implementation, it is recommended that only a small group of metrics be selected and used to set target values in order to keep efforts focused. The metric subject to the greatest amount of debate during the validation process was the LCOE. This was due to the differing assumptions held by the participants about the metric, and the criticism that it does not typically take into account CSP's ability to provide thermal energy heat when compared to other energy technologies, which focus primarily on electricity. These concerns were noted, and a more explicit description given of the metric's use in the framework during later iteration rounds of the validation process.
Internal	Although certain relationships were universally agreed upon between the framework's components and their support of the wider objectives, with respect to the commercialisation process, such as the TA and OA components, there was some confusion regarding the contribution of certain components towards the greater goal of increasing the rate of commercialisation of CSP technologies in South Africa. Many participants attributed this confusion to an overload of information, and as an indication of the lack of user requirements considered during the framework's development. The relationships between the components was made more explicit following Pod 5 to make it easier for participants, and the framework user(s), to understand the different links which exist.
External	The diverse range of stakeholders engaged with in the validation process allowed for certain statements to be made concerning the potential success that such a framework may achieve if practically implemented, with reference to CSP technologies in South Africa. While the framework contains many of the components required for commercialisation, the existing structure of South

Validity type	Commentary
	Africa's energy sector limits the likely success that any strategies developed from the framework may achieve. In terms of other MTRESs, it is still too early to say whether such a framework could be applied to other technologies of a similar nature to CSP, and in different parts of the world. Certain MTRESs, such as biofuel technologies, contain complex supply chains, which the framework developed here may not be able to address in sufficient detail. However, the comprehensiveness of the framework means that it is likely to offer some value to all MTRESs as a strategy development tool, although some may gain more value than others. Finally, the growth in global supply chains raises questions over whether commercialisation can ever be said to take place in a single country, given that many systems rely on the import of cheaper components from abroad. As such, questions exist over the tool's applicability in a single country context.

7.3 Framework amendments

Tables 7.3 presents the amendments that were made to the strategic management framework per iteration round of the validation process, based on the participants' responses.

Table 7.3: CSP case study framework amendments

Iteration Round	Amendments
1	▪ Adoption of a grid expansion and integration plan (see Appendix F.4), as opposed to mere mention of it. ▪ Additional metrics: levelised profit of electricity (LPOE), job creation. ▪ Inclusion of entrepreneurship as an organisational capability. ▪ Greater emphasis on sustainable demand. ▪ Change in role of business sector with respect to commercialisation of CSP technologies. Need for greater government involvement → size, scope, and uncertainty involved with CSP presently too great for the private sector; business sector won't invest in a technology which has such uncertainty surrounding its future prospects & lack of demand. ▪ Greater clarity on commercialisation process boundaries, beneficiaries, drivers etc.
2	▪ Clarity needed on systems analysis vs technical performance assessment. ▪ Use of mapping with government policies and business activities → address the when and why of each policy & activity. ▪ Integration of policy mix: how policies are aligned with each other, and how departments behind them can coordinate efforts – need someone to ensure that policy is being implemented correctly.

Iteration Round	Amendments
	▪ Educational initiatives: nationwide science and technology/CSP challenges and competitions, school visits and small-scale practical demonstrations, open days (universities, research centres). ▪ Organisational capabilities: revise process used to identify relevant capabilities (see Appendix F.6), inclusion of production management. ▪ Link partnership objectives, metrics (quantitative & qualitative), and target values through balanced scorecard strategic tool. ▪ Revision of approach used to select objectives, metrics and target values (see Appendix F.7). ▪ Re-examination of target values used for partnership objectives; short-term figures slightly unrealistic / too optimistic. ▪ Inclusion of research councils and labour organisations (trade unions) as stakeholders/partners. ▪ More export-driven approach to framework given lack of opportunities within Southern African market.
3	▪ Revision of partnership's balanced scorecard objectives, metrics, and target values (see Appendix F.7): distinguish between local and export markets. ▪ Greater consideration of the role of people as decision-makers in the commercialisation process. ▪ Inclusion of media as partner in partnership: re-examination of partnership stakeholder selection process. ▪ Revision of framework component interfaces illustration to better reflect the relationships between the secondary level components. ▪ Revision of grid expansion and integration plan; consideration of technical aspects such as differing voltage levels of grid transmission and distribution lines.
4	▪ Inclusion of forecasting/planning into the six broad areas of TA. ▪ Differentiation of important decision-making groups (government, business, end-user) in commercialisation process, between their existing state and how they are expected to change over time, as CSP progresses towards commercial maturity. ▪ Mass mobilisation of people for the partnership: direct/force vs democratic approach.
5	▪ Inclusion of a (national) energy infrastructure analysis tool and yield analysis under the TA component. ▪ Specification of policy-making environment on a country-basis (centralised vs decentralised).

Iteration Round	Amendments
	▪ Re-illustration of the framework to make it easier for the audience to understand; focus on explicit contribution of each component to the commercialisation process. Greater focus on environment in which commercialisation process takes place as well as how partnerships can assist strategy development.

7.4 General commentary on validation process

Table 7.4 presents a general commentary on the validation process followed in order to better establish the credibility of the process used to collect results (which is the feedback from participants), and the reliability and accuracy of any conclusions drawn from the research study.

Table 7.4: Analysis of validation process

Point of Analysis	Commentary
Time length of presentation	The length of time afforded to the presentation of the framework was 15 – 20 min on average. Given the comprehensive nature of the framework, there was only time to discuss the major components of the framework. As a result, elements such as the partnership development and the framework interfaces, were not covered in great detail. This may have resulted in important feedback not given, feedback which may have altered the framework.
Time length of Q&A session	The limited time participants had to offer for the Q&A session that followed the presentation meant that many questions were not asked. In latter iteration rounds, the researcher attempted to focus on those questions which had not been answered in great detail, or pertained to new or refined parts of the framework. However, this was not always possible.
Hybrid-Delphi technique	The use of a face validation technique allowed for personal engagement with participants, allowing them to provide substantiated answers to any questions asked and meaningful feedback on the framework.
Open-ended questions	The use of open-ended questions allowed participants the freedom to express their thoughts on the framework and its components. Unfortunately, this led to many questions not being answered, in part due to the many elements inherent to the framework. In hindsight, it may have been more effective to give participants a short survey of close-ended questions to answer first, with those answers serving as a guide of which open-ended questions to ask.
Number of participants	The number of participants who agreed to participate in the validation process far exceeded the researcher's expectations. Some of the feedback received indicated that it may have been a better research decision to

Point of Analysis	Commentary
	consult one or two experts in the design process of the original framework, as opposed to developing the framework purely from literature and the design requirements. This may have resulted in a stronger design methodology. However, one needs to consider that of the seventy-eight participants or organisations contacted for participation in the validation process, only twenty-six replied, and only fourteen[84] indicated their willingness to participate - a success rate of 18%. Thus, there is evidence that supports the original decision made.

7.5 Summary: Validation of the Strategic Management Framework

Chapter 7 presented an overview of the validation process conducted as part of the research study. A hybrid-Delphi Technique was developed, whereby experts in the field were interviewed in pods of three to obtain their views and perspectives on the strategic management framework. This formed part of a process of iterative refinement, incorporating feedback from a diverse range of stakeholders of different backgrounds. The results of the validation process were discussed, highlighting some of the more interesting points and findings relating to the strategic management framework's strengths and weaknesses.

It is acknowledged that debate may exist over the use of open-ended questions during the validation process, rather than a combination of open- and closed-ended questions. Both approaches have merits and flaws with respect to the amount of feedback gained versus time constraints. By recognising these differences, it is possible to better understand the process that lead to the results mentioned. Regarding the feedback received, the initial questions asked always sought to obtain broad feedback on the framework, which was deemed beneficial in allowing the participant to state any serious issues or misunderstandings they had either with the framework, or the presentation in general.

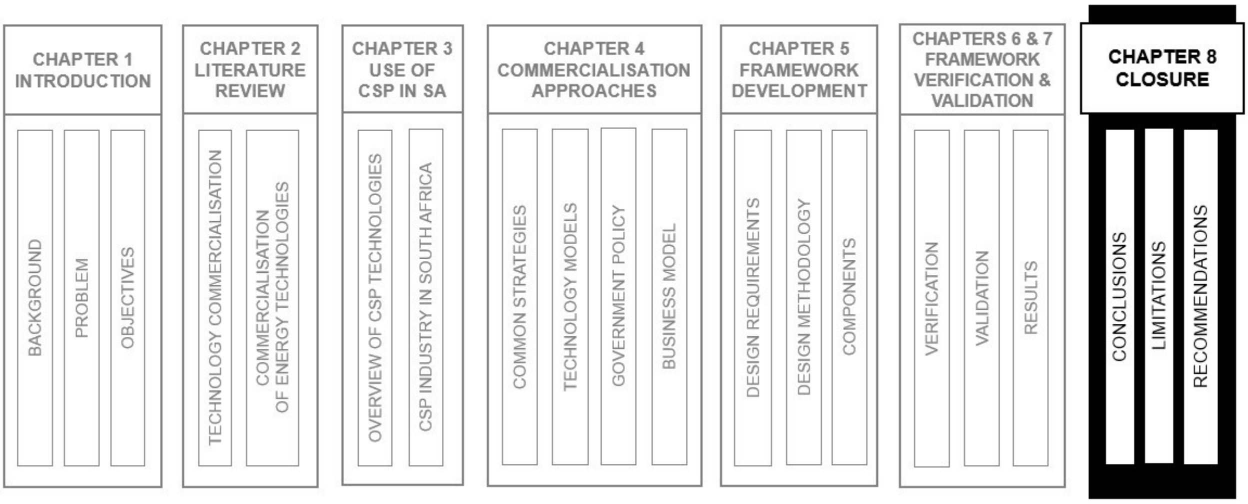
The following chapter, Chapter 8, concludes the research study.

[84] Of these fourteen, some were not interviewed due to time and cost constraints. However, through snowball sampling certain participants were able to involve other members of their respective organisation in the validation process.

Chapter 8

Closure

Chapter 8 provides closure to the research study. A discussion of the conclusions drawn from the results of the study is presented, followed by the relevant contribution to theory. Finally, identification of the study's limitations and recommendations for future research are disclosed.



8.1 Conclusions

This section discusses the prominent conclusions drawn from the research study. These relate to the political ecology of CSP technologies in South Africa, the role played by global production networks (GPNs) in the commercialisation process, and the importance of innovation networks. While these all represent entire fields of discussion in their own right, the focus here is limited to their relevance to the commercialisation process of CSP technologies in South Africa.

8.1.1 The political ecology of CSP technologies in South Africa

At the beginning of this research study in early 2016, CSP technologies in South Africa were facing an uncertain future. Despite a number of projects having been successfully commissioned under the country's REI4P, confidence in the country's ability or desire to maintain a growing CSP build programme was waning. One example was the 100 MW Redstone project, which, despite winning one of two bids allocated to CSP in Bid Window 3.5 of the REI4P in 2014, had yet to reach financial close with Eskom (Ndebele, 2017).

Prospects for CSP technologies in South Africa did not improve during the course of 2016. Rather, they got worse. Eskom continued to refuse to sign the PPA associated with the Redstone project on several occasions throughout the year (Tsanova, 2016), while the draft version of the long overdue update[85] to the IRP-2010, published towards the end of 2016, excluded new CSP from the country's future energy mix (Creamer, 2016). In a response to the IRP-2016 published by the CSIR, CSP did not fare much better, only receiving a significant percentage of the energy mix in the decarbonised scenario projected for 2050 (Wright *et al.*, 2017).

In February 2017, the President of South Africa, Mr Jacob Zuma, stated that the latest rounds of projects under the REI4P would be signed (Creamer, 2017). However, Eskom continued to refuse to do so, citing cost concerns, and the lack of need for the additional capacity. Then, in September 2017, the announcement was made by the country's energy minster that outstanding projects which had been awarded winning bids under recent rounds of the REI4P would be signed, but only at a maximum tariff price of 77c/kWh, despite there being no legal basis to do so (Van Rensburg, 2017a). This is not a tariff price that CSP technologies may ever reach, nor does it make concessions for the unique value proposition of the technology.

---

[85] The IRP-2010 remains the only promulgated version of the document, and therefore continues to form the official basis for South Africa's future energy plans.

These set of events, in a clear demonstration of the *political ecology*[86] of the energy sector, have put a significant brake on the prospects for the commercialisation of CSP technologies in South Africa, let alone any attempt at increasing the rate at which the process takes place. Aware of the challenges faced by the CSP industry in South Africa, the focus of the strategic management framework was initially placed on the industrial and commercial market segments from a market opportunity perspective.

However, despite recent literature identifying several opportunities in these segments in South Africa which could make use of CSP's solar thermal energy properties, it became evident that significant barriers exist to such an approach. These barriers include: the current high cost of the technology, and the unwillingness of businesses, in pursuit of short-term profit and the need to remain a going concern, to enter into long-term PPAs at a higher energy price, when cheaper energy could be sourced from the national grid. In the face of continued opposition from the national government, attention was also placed on the potential for the global export of CSP technologies. However, as stated by Participant 3-3 during the validation process, it is extremely difficult to commercialise a technology for a market you are not situated in geographically.

In order for MTRESs to reach commercial status, there needs to be sufficient demand to ensure that the commercialisation of the technology is financially viable for those involved in the process. In the case of South Africa, the researcher foresees two options as being feasible in the short-term with respect to market opportunities. One, is to convince the national government to incorporate CSP back into the country's energy mix. Yet, the question of how to successfully secure the political will necessary to make such a decision is a challenging one, and is unlikely to have a single or simple answer. The framework prescribes different methods of engaging policy-makers through education, social acceptance, and lobbying from CSP-associated organisations in the private sector, as well as the use of sound business cases, such as that put forward by Sager *et al.* (2015).

The second option is the exploration of international markets for CSP opportunities, despite the obvious difficulties involved. It is important to be aware of the export potential not only for entire CSP systems, but also of subsystem components, in part through the hybridisation of CSP with other forms of energy, such as solar PV and coal technologies. In addition, other markets could also be leveraged, as identified by SASTELA *et al.* (2013). Furthermore, as per

---

[86] The study of the relationships which exist between political, economic, and social factors, in the wider context of environmental issues and challenges. Often examines such relationships through a political economy lens. (Escobar, 1996)

the technology commercialisation process (see Chapter 2), there is potential for the export of licenses and other IP rights concerning knowledge associated with CSP systems. This represents another avenue of commercialisation for CSP technologies in South Africa. However, the impact of the political ecology is prevalent once again, as it is likely that international opportunities, and the accompanying strategic alliances that need to be formed, will be subject to the political agenda of international governments, among other factors.

Hence, the argument can be made that now, more than ever, there is a need to focus on various measures, such as the framework developed in this study, which contribute to efforts aimed at increasing the rate of commercialisation of CSP technologies in South Africa. On the other hand, given the influence of the political ecology on CSP technologies, and the wider energy sector, in South Africa, one could say that such a research study is futile in its purpose. Moreover, apart from the strong government support needed, the commercialisation of CSP technologies, or any energy technology for that matter, is subject to too wide a range of uncontrollable factors for any tool to be able to speed up the rate at which the commercialisation process is able to take place.

However, the final validated framework presented here does not pretend to guarantee the commercialisation of CSP technologies in South Africa, nor that it will increase the rate at which the process occurs. It's value, apart from inspiring further dialogue on the subject, is to assist strategy development towards such a goal. However, the existing structure of South Africa's energy sector, and recent political events, make it unlikely that the framework will presently be able to achieve such a goal. Thus, the benefit of this framework, and the wider research study, is to focus attention on what needs to be done to realise such a goal, as well as provide guidance concerning how one may develop strategies in order to achieve such an objective. In this regard, it should be considered as a proof-of-concept regarding such an approach, that should conditions change in South Africa's CSP industry, and energy sector, it may be possible for it to achieve its purpose as a tool for strategy development.

It is also worth mentioning the debate concerning whether CSP as an energy technology is even needed in the South African context, or globally for that matter. In order to meet periods of peak demand on a daily basis within national energy systems, there is undoubtedly a need for dispatchable MTRESs. Currently, it has been proven that a fleet of CSP technologies offers a cheaper means of meeting the daily peak demand than open cycle gas turbines (OCGTs), the incumbent technology currently used in South Africa for this purpose (Silinga & Gauché, 2013)

A second option to meet this peak demand requirement, besides CSP, is the use of solar PV systems combined with battery technology (Deign, 2014). However, this option is only likely to become viable should the price of battery technologies fall sufficiently. Yet, there is no guarantee that such a scenario will be realised in the future. As such, it would be prudent for policy makers to continue with a carefully planned rollout of CSP technology into the national grid. This choice would not bind policy makers and the state utility to use of a single MTRES, should better alternatives emerge in the future. Furthermore, this option would allow them to hedge their bets should the anticipated decrease in the price of battery technologies fail to materialise.

Lastly, one also needs to consider CSP's potential for job localisation and reduced water consumption (through dry cooling) when compared to other energy technologies. These two factors are especially prevalent in the South African context, given the country's high levels of unemployment (SASTELA *et al.*, 2013), and water scarcity (Meyer & van Niekerk, 2011). Therefore, there is certainly a place for CSP technologies in a future sustainable energy mix of South Africa.

8.1.2 Global production networks

With the advent of globalisation, the supply chains of many industries have become globalised, leading to the development of GPNs. GPNs are able to leverage cheap sources of labour and production for the purposes of sustainable competitive advantage, as well as securing new markets for technologies. The CSP industry in South Africa has been no different, with many international firms establishing a presence to supply the necessary skills and equipment. Given the localisation requirements of the bids awarded under the REI4P, there has been progress made in establishing a local CSP industry. Furthermore, given that CSP systems comprise many standardized components, there is potential to harness South Africa's expertise in alternative sectors, such as mining and defence manufacturing, to support commercialisation efforts. (SASTELA *et al.*, 2013)

However, in order to be truly competitive on a global scale, there is a need to focus on which parts of the CSP GPN South Africa should specialise in. This focus should be based on the country's existing capabilities, as well as the strategies undertaken by other key players worldwide. Sufficient literature already exists on the subject[87]; what is needed is the political will to implement the required measures in order for South Africa to secure a place in the GPN of CSP technologies.

---

[87] See Grobbelaar *et al.* (2014), SASTELA *et al.* (2013), and Sager *et al.* (2015).

The role played by GPNs also highlights the fact that technology commercialisation typically does not happen in isolation in a single country. As such, when one speaks about the commercialisation of CSP in a country context, such as South Africa, it is important to clarify that this refers to the environment in which the process takes place. As included in the final iteration of the strategic management framework, the environment consists of factors such as the regulatory and legal framework governing a nation's energy sector and commercialisation mechanisms, while also being subject to the actions of powerful role players within the respective energy sector.

8.1.3 Innovation networks

In order to mobilise different stakeholders in support of efforts to increase the rate of commercialisation of CSP technologies, there is a need to consider the role played by innovation networks[88]. These networks are crucial for forming partnerships to complement the skills, expertise, and resources of different organisations. These partnerships should also have the ability to leverage different opportunities, as well as the necessary finance, to increase the rate at which commercialisation takes place.

However, it is important to make clear the benefit of forming such networks to potential stakeholders, while being aware that money is not always the sole driver behind such decisions. Following completion of the validation process, several potential drivers were identified towards achieving buy-in into the commercialisation process of CSP technologies in South Africa through addressing the different interests of various stakeholder groups. While not a definitive list, these prospective drivers are summarised in Table 8.1.

Table 8.1: Achieving buy-in from stakeholders

Potential sources to achieve stakeholder buy-in	
Money (value for money)	Jobs
Technical demonstrations	News (adverts → money)
Environmental benefits (reduced CO_2 emissions, lower water consumption)	Public image
Technology perception (technology of the future)	Votes (re-election)
Research projects & funding	

[88] Innovation networks are "*people, institutions, and companies that are outside the firm … they are intellectual assets that companies can link up with to solve problems and find ideas, while beginning to think about those assets as an extended part of their organisation*" (Huston, 2007); "*those networks that involve the interplay of people, ideas and organizations to create new, technologically feasible, commercially-realizable products, processes and organizational structures*" (Huston, 2007)

8.2 Theoretical contribution

The completion of the research study is considered to have made a contribution to several fields of research. The first is the body of knowledge concerning technology commercialisation, specifically that of CSP technologies in South Africa, with wider implications for the country's energy sector. Given that commercialisation takes place in response to a market need, want, or problem that needs solving, the commercialisation process is always likely to be one driven predominantly by government policy and political will. Although this is beginning to change through liberalised energy markets, such systems are still subject to strict government regulation, even in so-called free energy markets. Thus, any strategy or framework developed and implemented in the energy space has to address the politics of the sector in order to have a chance of achieving a significant degree of success. The framework recognises this fact through the role played by the political ecology of CSP technologies in South Africa, examining different means by which demand for these technologies can be fostered through the current dominant commercialisation mechanism for CSP technologies, the REI4P.

The second body of knowledge is technology management, holding implications for managerial decision-making. The decision-making behind any commercialisation process is of vital importance to its success, as just one incorrect decision could result in the technology valley of death never being overcome (see Figure 2.10). Indeed, one could argue that any efforts to increase the rate of commercialisation of any technology should focus entirely on the decision-making behind the process. The contribution of the study to this body of knowledge is with respect to the strategies developed in order to manage CSP technologies through the commercialisation process, providing guidance as to what needs to be considered in the development of such strategies, and how the strategies may be developed, to ensure their effectiveness and efficiency of implementation.

It should be noted that despite the considerable attention given to the capacity of the framework to support the development of strategies to increase the rate of commercialisation of CSP technologies, the actual development of effective and efficient strategies rests on the ability of the respective entity making use of the framework. In addition, the ability of management practitioners to foster new relationships with prospective partners will also be tested. While assistance is provided by the framework through the ladder of partnership development, such activities need to be handled carefully in the early stages, and be built on trust. As many can attest, trust in relationships is something that takes a long time to build, yet can be easily broken, often unintentionally.

The last mention is the body of knowledge concerning socio-technical transitions in the global energy sector, namely: the transition to a global sustainable energy supply in support of sustainable development. Recently, literature regarding such transitions[89] has begun to change from a focus on understanding such transitions, to debate over the potential for rapid large-scale energy transitions, and how the process may be sped up, if at all. While it cannot be stated with certainty the effect, if any, that the framework may have on such transitions, it still serves as a useful starting point to encourage further dialogue on the subject. The framework also investigates additional means of how the rate of commercialisation may be increased in order to support efforts to address sustainable development challenges.

8.3 Research study limitations

A number of limitations were encountered during the course of the research study. Knowledge of these limitations is important to assist the reader's understanding of the framework developed, the subsequent results and conclusions distilled, and the wider context in which the research study took place. The limitations are presented as follows:

- The belief that there is a future for CSP technologies in South Africa. Recent events in South Africa's energy sector have brought into question whether there is a future for CSP in South Africa, given the apparent disinterest shown by national government to incorporate CSP into the country's energy mix on a large scale. Demand is a core requirement for any commercialisation process to reach completion, without which it is unlikely that the necessary investment in a technology will be made. Without demand, the commercialisation process is unable to reach completion, thus limiting the success of any efforts to speed up the rate at which the process takes place.

  Many of the experts involved in the validation process questioned the usefulness of the framework developed, given the stance taken by the South African national government. Were many of the current actors in South Africa's CSP industry to leave the country to pursue opportunities elsewhere, believing that no further projects are likely to emerge in the short- to medium-term, it would represent a significant loss in terms of technology champions and institutional capacity. This loss would arguably be felt the most in institutions such as country's two solar thermal energy associations[90], comprising individuals who are most likely to make use of such a framework. Therefore, this stance does place a limitation on the research study with respect to the potential for practical

[89] See Kern & Rogge (2016), Sovacool (2016), and Grubler *et al.* (2016).

[90] Southern Africa Solar Thermal and Electricity Association (SASTELA) and Solar Thermal Association of Southern Africa (STASA).

implementation of the framework, and its likelihood of increasing the rate of commercialisation CSP technologies in South Africa.

The position taken by the national government could also result in a reduction in the amount of funding allocated to institutions concerned with CSP research in South Africa, such as the Solar Thermal Energy Research Group (STERG) at the University of Stellenbosch. Such research is crucial towards gaining a greater understanding of the value proposition presented by CSP technologies to South Africa's energy sector, while also playing a key role in measures aimed at cost reduction of the technology.

- The validation process made use of face validation through a hybrid-Delphi technique due to time and cost constraints and the scope of the study. Although such a technique represents a sound validation tool, the views, opinions, and conjecture of experts in the field cannot be said to be a definitive substitute for any potential lessons that may be learnt through practical application of the framework, and subsequent assessment of its relative success. Furthermore, with respect to the diversity of background of the participants, while certain individuals contacted did express their availability to assist with the research study, it was not always possible due to scheduling clashes. It is possible that certain individuals, particularly from the public sector, may have been able to offer valuable insight into the framework, potentially resulting in a different final deliverable (see Appendix F.8).

- The scope of the research study. During the validation process, there were several participants who were unsure of what the framework was trying to accomplish, or the context behind the study. A lack of clarity regarding certain terms was also exposed. Although this could be attributed to the researcher's relative lack of experience with conducting a validation process, or poor communication of the framework, it was found that the short time period allocated for presentation of the framework and the entire interview, was inadequate to cover all aspects of the framework in order for participants to truly understand it. Indeed, participants frequently remarked on the enormity of the task selected for the research study, with the large amount of detail inherent to the framework contributing to the uncertainty regarding the framework and its components, and how they related to the commercialisation process. Despite being addressed to a certain extent, through the change in visual conceptualisation of the framework following Pod 5 of the validation process (see Appendix F.8), many participants felt that a smaller scope would have been more beneficial to the research study. However, there is a strong possibility that a smaller scope may have resulted in a less comprehensive approach, one that would not have been able to address all of the design requirements identified in Tables 5.2 to 5.5.

- Bias. During the interviews conducted, many participants, being working professionals, had limited time to offer to the validation process. This led to a greater focus placed on those components of the framework deemed more important in the researcher's eyes, or on refinements that were made during the iterative procedure of the validation process. As a result, some of the questions were dealt with only briefly, or skipped entirely, such as those relating to the strategic management framework interfaces. While the inclusion of a short set of quantitative questions utilising a 5-point scale may have served as a better indicator of which of the open-ended questions to ask, the time taken to complete this set of questions would have reduced the time available for the participant to supply other constructive feedback on the framework. This case represents several forms of bias: (1) researcher bias, the choice of which questions were asked was decided by the researcher, (2) non-response bias, the answering of other questions may have revealed different insights into the research study, (3) response bias, where the participant may have provided answers based on what they believe the researcher wanted to hear, and (4) interviewer bias, where the researcher may have unintentionally led respondents to make responses which they would not normally have given, influencing the final feedback obtained.

8.4 Recommendations for future research

Several areas were identified for future research during the research study, partly as a result of the limitations placed on the study, as well as the respective results and conclusions reached. The following recommendations are made:

- The validation of the strategic management framework was conducted through use of a hybrid-Delphi technique. As such, it was difficult for experts to state definitively whether the framework would indeed be able to support the development of strategies aimed at increasing the rate of commercialisation of CSP technologies in South Africa. Hence, the recommendation is made that the framework be implemented practically, either with CSP technologies, or a different kind of MTRES. It is possible that a small-scale MTRES may prove an easier case study to assess the practical application of the framework.
- While the framework was developed and applied for the case of CSP technologies in South Africa, it would be interesting to assess its potential applicability to other MTRESs in need of such efforts. Consulting the different life cycle positions of Figure 1.6, it is clear that solar PV might offer the most promising opportunity. Wind energy technologies are

very close to commercial maturity, while 2nd generation biofuels are yet to reach a point where commercialisation efforts are required.

- One of the challenges highlighted during the intended implementation of the framework through strategy development was how to obtain the buy-in required of partners to commit to any venture in the CSP space. While this question is partly addressed in Table 8.1, there is a need to investigate this issue in greater depth. The research opportunity exists for a framework to be developed that examines how one is able to achieve buy-in from multiple stakeholders in the South African context, with its complex socio-political history, such as the stakeholders identified in this study, as well as the processes that lead to such support in the way of decision-making and behavioural traits. Following a brief search of the literature, this line of research may be assisted by considering studies such as those conducted by Manoukian (2013), and Shakeel, Takala & Zhu (2017).
- If, in the near future, CSP technologies receive a greater share of South Africa's energy mix, and begin to experience an increased rate of commercialisation, such development might be aided by a supportive framework governing the technologies' industrialisation[91]. Some work has already been accomplished on the matter by Grobbelaar *et al.* (2014) in the form of an industry roadmap.

[91] While technology commercialisation and industrialisation share many common elements, industrialisation is seen as the process that seeks to expand the existing number of industry-related operations and entities. However, it is likely that many of the elements inherent to the framework presented here would also appear in a framework aimed at the industrialisation of CSP technologies.

List of References

Abdmouleh, Z., Alammari, R.A.M. & Gastli, A. 2015. Review of policies encouraging renewable energy integration & best practices. *Renewable and Sustainable Energy Reviews*. 45(2015):249–262.

Ahuja, D. & Marika, T. 2009. Sustainable Energy for Developing Countries. *S.A.P.I.EN.S*. 2(1):1–16.

Akella, A.K., Saini, R.P. & Sharma, M.P. 2009. Social, economical and environmental impacts of renewable energy systems. *Renewable Energy*. 34(2):390–396.

Amarender Reddy, A. 2013. *Training Manual on Value Chain Analysis of Dryland Agricultural Commodities*.

Amer, M. & Daim, T.U. 2010. Application of technology roadmaps for renewable energy sector. *Technological Forecasting and Social Change*. 77(8):1355–1370.

Amui, L.B.L., Jabbour, C.J.C., de Sousa Jabbour, A.B.L. & Kannan, D. 2017. Sustainability as a dynamic organizational capability: a systematic review and a future agenda toward a sustainable transition. *Journal of Cleaner Production*. 142(2017):308–322.

Anderson, B., Lin, S., Newing, A., Bahaj, A.B. & James, P. 2017. Electricity consumption and household characteristics: Implications for census-taking in a smart metered future. *Computers, Environment and Urban Systems*. 63(2017):58–67.

Apax Partners. 2005. *Understanding Technology Transfer*. [Online]. Available: http://www.wipo.int/export/sites/www/sme/en/newsletter/2011/attachments/apax_tech_transfer.pdf.

Archibugi, D. & Coco, A. 2005. Measuring technological capabilities at the country level: A survey and a menu for choice. *Research Policy*. 34(2):175–194.

Aslani, A. 2015. Strategic variables of commercialization of renewable energy technologies. *Journal of Renewable and Sustainable Energy*. 7(2):23105.

Aslani, A. & Mohaghar, A. 2013. Business structure in renewable energy industry: Key areas. *Renewable and Sustainable Energy Reviews*. 27(2013):569–575.

Aslani, A., Naaranoja, M. & Wong, K.-F. V. 2013. Strategic analysis of diffusion of renewable energy in the Nordic countries. *Renewable and Sustainable Energy Reviews*. 22(2013):497–505.

Assefa, G. & Frostell, B. 2007. Social sustainability and social acceptance in technology assessment: A case study of energy technologies. *Technology in Society*. 29(1):63–78.

Baharoon, D.A., Rahman, H.A., Omar, W.Z.W. & Fadhl, S.O. 2015. Historical development of concentrating solar power technologies to generate clean electricity efficiently – A review. *Renewable and Sustainable Energy Reviews*. 41(2015):996–1027.

Baker, L. 2015. Renewable energy in South Africa's minerals-energy complex: a "low carbon" transition? *Review of African Political Economy*. 42(144):245–261.

Baker, L. & Wlokas, H.L. 2015. *South Africa' s renewable energy procurement: A new frontier?* Cape Town.

Balachandra, P., Kristle Nathan, H.S. & Reddy, B.S. 2010. Commercialization of sustainable energy technologies. *Renewable Energy*. 35(8):1842–1851.

Banks, D. & Schäffler, J. 2006. *The potential contribution of renewable energy in South Africa*. [Online]. Available: http://www.earthlife.org.za/wp-content/uploads/2009/04/potential-of-re-in-sa-feb06.pdf.

Battisti, G. 2008. Innovations and the economics of new technology spreading within and across users: gaps and way forward. *Journal of Cleaner Production*. 16(2008):22–31.

Behrangrad, M. 2015. A review of demand side management business models in the electricity market. *Renewable and Sustainable Energy Reviews*. 47:270–283.

Bhattacharyya, S.C. 2013. Financing energy access and off-grid electrification: A review of status, options and challenges. *Renewable and Sustainable Energy Reviews*. 20(2013):462–472.

Bhikha, S. 2015. *A blue ocean strategy for a salad bar concept*. MBA thesis. Stellenbosch: Stellenbosch University.

Bittman, M. 2013. *Is Natural Gas "Clean"?* [Online]. Available: https://opinionator.blogs.nytimes.com/2013/09/24/is-natural-gas-clean/ [2017, September 02].

Blazejczak, J., Braun, F.G., Edler, D. & Schill, W.P. 2014. Economic effects of renewable energy expansion: A model-based analysis for Germany. *Renewable and Sustainable Energy Reviews*. 40(2014):1070–1080.

Blenkinsopp, T., Coles, S.R. & Kirwan, K. 2013. Renewable energy for rural communities in Maharashtra, India. *Energy Policy*. 60:192–199.

Borrás, S. & Lundvall, B.-Å. 2005. Science, Technology and Innovation. In J. Fagerberg, D.C. Mowery, & R.R. Nelson (eds.). Oxford: Oxford University Press. *Innovation Handbook*. 599–631.

Botes, A. 2012. *Purchasing Carbon Credits in South Africa*. [Online]. Available: http://www.urbanearth.co.za/articles/purchasing-carbon-credits-south-africa [2016, December 15].

Botes, A. 2013. *Amatola Green Power - South Africa's only existing private renewable energy trader*. [Online]. Available: http://www.urbanearth.co.za/articles/amatola-green-power-south-africa%25E2%2580%2599s-only-existing-private-renewable-energy-trader [2016, August 17].

Brand South Africa. 2011. *Northern Cape province, South Africa*. [Online]. Available: https://www.brandsouthafrica.com/tourism-south-africa/geography/northern-cape [2017, March 30].

Brent, A.C. 2015. Solar Energy RDI Roadmap for South Africa. (May):48–53.

Brent, A.C. & Pretorius, M. 2011. Industrial and commercial opportunities to utilise concentrating solar thermal systems in South Africa. *Journal of Energy in Southern Africa*. 22(4):15–30.

Brick, K. & Visser, M. 2009. *Green Certificate Trading*.

Briggs, B., Foutty, J. & Hodgetts, C. 2016. *Tech Trends 2016: Innovating in the digital era*. [Online]. Available: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Technology/gx-tech-trends-2016-innovating-digital-era.pdf.

Brown, L. 2010. Logic Models: An Integral Part of Designing and Evaluating Your Program. In Louisiana Public Health Institute *Childhood Obesity and Public Health Conference*. [Online]. Available: http://www.pbrc.edu/childhood_obesity_conference/presentations/brown.pdf.

Bryman, A., Bell, E., Hirschsohn, P., Dos Santos, A., Du Toit, J., Masenge, A., Van Aardt, I. & Wagner, C. 2011. *Research Methodology: Business and Management Contexts*. 3rd ed. Oxford: Oxford University Press.

Brzustowski, T.A. 2008. *The Way Ahead: Meeting Canada's Productivity Challenge*. Ottawa: University of Ottawa Press.

BSR. 2011. *Stakeholder Mapping*. [Online]. Available: http://gsvc.org/wp-content/uploads/2016/10/Stakeholders-Identification-and-Mapping.pdf.

Bullis, K. 2006. *How To Build a Solar Generator*. [Online]. Available: https://www.technologyreview.com/s/406114/how-to-build-a-solar-generator/ [2017, May 27].

Burkman, E. 1987. Factors affecting utilisation. In Hillsdale, New Jersey: Lawrence Erlbaum Associates, Publishers *Instructional Technology: Foundations*.

Business Set Free Ltd. 2013. *4 Stages of the Small Business Product Life Cycle*. [Online]. Available: http://www.businesssetfree.com/small-business-product-life-cycle/ [2017, November 17].

Cetindamar, D., Phaal, R. & Probert, D. 2010. *Technology Management Activities and Tools*. New York: Palgrave Macmillan.

Chen, C.-J. 2009. Technology commercialization, incubator and venture capital, and new venture performance. *Journal of Business Research*. 62(1):93–103.

City Energy. 2015. *Municipal Wheeling Agreement for Green Power Development: Nelson Mandela Bay Metropolitan Municipality - Renewable Energy Wheeling Agreement for Green Power Trading*.

Coates, J.F. 2001. A 21st century agenda for technology assessment. *Technological*

Forecasting and Social Change. 67(2001):303–308.

Coombs, J.E. & Bierly III, P.E. 2006. Measuring technological capability and performance. *R&D Management*. 36(4):421–438.

Craig, O.O., Brent, A.C. & Dinter, F. 2017. Concentrated Solar Power (CSP) Innovation Analysis in South Africa. *South African Journal of Industrial Engineering*. 28(August):14–27.

Creamer, T. 2016a. *Wind and solar PV bodies cautiously welcome IRP, CSP body to contest exclusion*. [Online]. Available: http://www.engineeringnews.co.za/article/wind-and-solar-pv-bodies-cautiously-welcome-draft-irp-csp-body-to-contest-exclusion-2016-11-23 [2017, March 30].

Creamer, T. 2016b. *Carbon tax will help lower South Africa's emissions, study shows*. [Online]. Available: http://www.engineeringnews.co.za/article/carbon-tax-will-help-lower-south-africas-emissions-study-shows-2016-11-10/rep_id:4136.

Creamer, T. 2017. *Zuma says Eskom will sign renewables contracts amid disrupted, economy-focused Sona*. [Online]. Available: http://www.engineeringnews.co.za/article/zuma-says-eskom-will-sign-renewables-contracts-amid-disrupted-economy-focused-sona-2017-02-09 [2017, September 15].

Credible Carbon. 2016. *Credible Carbon - Making Carbon Work for the Poor*. [Online]. Available: http://www.crediblecarbon.com/ [2016, December 15].

Creswell, J.W. 2009. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. 3rd ed. Nebraska: Sage Publications.

Creswell, J.W. 2015. *Educational Research: Planning, Conducting, and Evaluation Quantitative and Qualitative Research*. 5th ed. Nebraska: Pearson Education Inc.

Crosno, J.L. & Cui, A.P. 2014. A Multilevel Analysis of the Adoption of Sustainable Technology. *The Journal of Marketing Theory and Practice*. 22(2):209–224.

CSIR Energy Centre. 2017. *Least Cost Electricity Mix for South Africa - Optimisation of the South African power sector until 2050*. [Online]. Available: http://www.crses.sun.ac.za/files/news/CSIR_BischofNiemz_pp.pdf [2018, February 02].

CSP Today. 2015. CSP in South Africa: Industry Development Guide CSP Today South Africa 2015. 2015. [Online]. Available: www.csptoday.com/southafrica.

Daidj, N. 2015. *Developing Strategic Business Models and Competitive Advantage in the Digital Sector*. Business Science Reference.

Daim, T.U. & Oliver, T. 2008. Implementing technology roadmap process in the energy services sector: A case study of a government agency. *Technological Forecasting and Social Change*. 75(5):687–720.

Dale, V.H., Efroymson, R.A., Kline, K.L., Langholtz, M.H., Leiby, P.N., Oladosu, G.A., Davis, M.R., Downing, M.E., et al. 2013. Indicators for assessing socioeconomic sustainability of bioenergy systems: A short list of practical measures. *Ecological Indicators*.

26(2013):87–102.

Davis, K., Mazzuchi, T. & Sarkani, S. 2012. Architecting Technology Transitions : A Sustainability-Oriented Sociotechnical Approach. *Systems Engineering*. 16(2):193–212.

Deign, J. 2014. *PV with batteries: a threat to CSP?* [Online]. Available: http://www.csptoday.com/csp/pdf/TESvsBatteriesENG.pdf.

Department of Energy. 2003. *White Paper on Renewable Energy*. [Online]. Available: http://unfccc.int/files/meetings/seminar/application/pdf/sem_sup1_south_africa.pdf.

Department of Energy. 2015a. *State of Renewable Energy in South Africa*. [Online]. Available: http://www.gov.za/sites/www.gov.za/files/State of Renewable Energy in South Africa_s.pdf.

Department of Energy. 2015b. State of Renewable Energy in South Africa.

Department of Energy. 2016. *Integrated Resource Plan Update: Assumptions, Base Case Results and Observations - Revision 1*.

Department of Energy, Department of National Treasury & Development Bank of Southern Africa. 2016. Independent Power Producers Procurement Programme (IPPPP): An Overview As at 31 March 2016.

Department of Energy, Department of National Treasury & Development Bank of Southern Africa. 2017. *Independent Power Producers Procurement Programme (REIPPP): An Overview - June 2017*. [Online]. Available: https://www.ipp-projects.co.za/Publications.

Department of Energy SA. 2015. *Renewable energy finance and subsidy office*. [Online]. Available: http://www.energy.gov.za/files/esources/renewables/r_refso.html [2017, February 22].

Department of Environmental Affairs SA. 2015. *Green Fund*. [Online]. Available: https://www.environment.gov.za/projectsprogrammes/greenfund [2017, February 22].

Department of Minerals and Energy. 2006. *Digest of South African energy statistics*. [Online]. Available: www.energy.gov.za/files/media/ explained/2006 Digest PDF version.pdf.

Diesendorf, M. 2016. *Dispelling the nuclear baseload myth: nothing renewables can't do better*. [Online]. Available: http://energypost.eu/dispelling-nuclear-baseload-myth-nothing-renewables-cant-better/ [2017, August 30].

Dincer, F. 2011. The analysis on wind energy electricity generation status, potential and policies in the world. *Renewable and Sustainable Energy Reviews*. 15(9):5135–5142.

Dincer, I. 2000. Renewable energy and sustainable development: a crucial review. *Renewable and Sustainable Energy Reviews*. 4(2):157–175.

DST & DoE. 2010. *Solar technology Roadmap of South Africa*. [Online]. Available: http://www.energy.gov.za/files/SETR/SOLAR ENERGY TECHNOLOGY ROADMAPNew Folder/setr_overview.html.

Earle, M.D. & Earle, R.L. 2001. *A systematic approach to managing the development of commercial food products*. Chadwick House Group Ltd.

Eberhard, A. 2014. Feed-in tariffs or auctions? Procuring renewable energy supply in South Africa. *Energize RE: Renewable Energy Supplement*. (June):36–38.

Eberhard, A., Kolker, J. & Leigland, J. 2014. *South Africa's Renewable Energy IPP Procurement Program: Success Factors and Lessons*. [Online]. Available: http://www.ee.co.za/article/south-africas-reippp-programme-success-factors-lessons.html.

Economic Development Board of South Australia. 2015. *Using value chain mapping to build competitive advantage*.

Edkins, M., Winkler, H. & Marquard, A. 2009. *Large-scale rollout of concentrating solar power in South Africa*. Cape Town. [Online]. Available: http://www.erc.uct.ac.za/Research/publications/09Edkins-etal-Rollout_of_CSP.pdf%5Cnpapers2://publication/uuid/5251BA1C-E355-474B-BD16-090EBC2D079E%5Cnpapers2://publication/uuid/D3DF4E82-098D-496A-95C4-9A35DBE275CB.

Edkins, M.A.X., Marquard, A. & Winkler, H. 2010. *South Africa's renewable energy policy roadmaps*. [Online]. Available: https://open.uct.ac.za/bitstream/item/19473/Edkins_South_Africa_039_s_renewable_2010.pdf?sequence=1.

Ehrnberg, E. 1995. On the definition and measurement of technological discontinuities. *Technovation*. 15(7):437–452.

Eichhammer, W. & Morin, G. 2010.

Eleftheriadis, I.M. & Anagnostopoulou, E.G. 2015. Identifying barriers in the diffusion of renewable energy sources. *Energy Policy*. 80(2015):153–164.

Ensor, L. 2017. *Budget in a nutshell: tax hikes hit South Africans' pockets hard*. [Online]. Available: https://www.businesslive.co.za/bd/economy/2017-02-22-budget-in-a-nutshell-tax-hikes-hit-south-africans-pockets-hard/ [2017, April 14].

EPRI. 2015. *Power Generation Technology Data for Integrated Resource Plan of South Africa: Technical Update, August 2015*. [Online]. Available: http://www.energy.gov.za/IRP/irp files/Tech_Data_for_Integ_Plan_of_South_Africa_July_08_2010_Final.pdf.

Escobar, A. 1996. Construction Nature: Elements for a post-structuralist ecology. *Futures*. 28(4):325–343.

ESI Africa. 2015. *Helio100 pilot project well under way in South Africa*. [Online]. Available: https://www.esi-africa.com/news/helio100-pilot-project-well-under-way-in-south-africa/ [2017, May 21].

Eskom. 2013. [Online]. Available: http://www.eskom.co.za/AboutElectricity/FactsFigures/Documents/The_Solar_Water_Heating_SWH_Programme.pdf.

Eskom. 2016. *Transmission development plan 2016-2025*. [Online]. Available: http://www.eskom.co.za/Whatweredoing/TransmissionDevelopmentPlan/Documents/TransDevPlan2016-2025Brochure.pdf.

European Commission, Idea Consult & Danish Technological Institute. 2014. *Study on the relationship between the localisation of production, R&D and innovation activities*. [Online]. Available: http://ec.europa.eu/DocsRoom/documents/6958/attachments/1/translations/en/renditions/native.

Evans, A., Strezov, V. & Evans, T.J. 2009. Assessment of sustainability indicators for renewable energy technologies. *Renewable and Sustainable Energy Reviews*. 13(5):1082–1088.

Eyre, N. 1998. A golden age or a false dawn? Energy efficiency in UK competitive energy markets. *Energy Policy*. 26(12):963–972.

Fahey, L. & Randall, R.M. 2001. *The Portable MBA in Strategy*. 2nd ed. New York: John Wiley & Sons, Inc.

Fang, S.-C., Wang, M.-Y., Wu, F.-S. & Chen, W.-Y. 2014. Effects of Organisation's Dynamic Capabilities on the Duration of Patent Commercialisation: The Case of Taiwan Biotechnological Industry. In Kanazawa, Japan. *PICMET '14: Infrastructure and Service Integration*. 1189–1200.

Fay, J. & Kumar, U. 2013. An index-based model for determining the investment benchmark of renewable energy projects in South Africa. *South African Journal of Economics*. 81(3):416–426.

Ferdows, K. 1997. Making the Most of Foreign Factories. *Harvard Business Review*. (March):73–88. [Online]. Available: https://hbr.org/1997/03/making-the-most-of-foreign-factories.

Ferroukhi, R., Lopez-Peña, A., Kieffer, G., Nagpal, D., Hawila, D., Khalid, A., El-Katiri, L., Vinci, S., et al. 2016. *Renewable Energy Benefits: Measuring the Economics*. [Online]. Available: http://www.irena.org/publications/2016/Jan/Renewable-Energy-Benefits-Measuring-the-Economics.

Flage, R. & Aven, T. 2015. Emerging risk - Conceptual definition and a relation to black swan type of events. *Reliability Engineering and System Safety*. 144(2015):61–67.

Fluri, T. 2009.

Frederick, S. 2009. CNS-UCSB Traveling Technologies Research Template Introduction to the Value Chain Approach for Nanotechnology in Society. 1–14.

Gallego Carrera, D. & Mack, A. 2010. Sustainability assessment of energy technologies via social indicators: Results of a survey among European energy experts. *Energy Policy*. 38(2):1030–1039.

Gauché, P., Backström, T.W. Von & Brent, A.C. 2013. A concentrating solar power value proposition for South Africa. *Journal of Energy in Southern Africa*. 24(1):67–76.

Gauché, P., Brent, A.C. & von Backström, T.W. 2014. Concentrating solar power: Improving electricity cost and security of supply, and other economic benefits. *Development Southern Africa*. 31(5):692–710.

Gauché, P., Rudman, J., Mabaso, M., Landman, W.A., von Backström, T.W. & Brent, A.C. 2017. System value and progress of CSP. *Solar Energy*. 152(2017):106–139.

Gazzo, A., Kost, C.P., Ragwitz, M., Govindarajalu, C., Roos, P. & Hassan, F. 2010. Review of CSP Technologies. *MENA Assessment of the local manufacturing potential for Concentrated Solar Power projects*. 9–68. [Online]. Available: http://arabworld.worldbank.org/content/awi/en/home/research/mena_solar.html.

Gereffi, G., Dubay, K., Robinson, J. & Romero, Y. 2010. *Concentrating Solar Power: Clean Energy for the Electric Grid*. [Online]. Available: http://www.cggc.duke.edu/environment/climatesolutions/greeneconomy_Ch4_ConcentratingSolarPower.pdf.

Geroski, P.. 2000. Models of technology diffusion. *Research Policy*. 29(2000):603–625.

Giddings, B., Hopwood, B. & O'Brien, G. 2002. Environment, economy and society: Fitting them together into sustainable development. *Sustainable Development*. 10(4):187–196.

Glasbergen, P. 2010. Understanding partnerships for sustainable development analytically: The ladder of partnership activity as a methodological tool. *Environmental Policy and Governance*. 21(2011):1–13.

Goldberg, P.K. & Pavcnik, N. 2006. *Distributional Effects of Globalization in Developing Countries*. [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/15003161%5Cnhttp://cid.oxfordjournals.org/lookup/doi/10.1093/cid/cir991%5Cnhttp://www.scielo.cl/pdf/udecada/v15n26/art06.pdf%5Cnhttp://www.scopus.com/inward/record.url?eid=2-s2.0-84861150233&partnerID=tZOtx3y1.

le Grange, E. 2013. *The case for midmerit power generation*. [Online]. Available: http://www.engineeringnews.co.za/article/the-case-for-mid-merit-power-generation-2013-08-09 [2017, September 15].

Green Business Guide. 2013. *Environmental financial incentives in South Africa 2013*. [Online]. Available: http://www.greenbusinessguide.co.za/environmental-financial-incentives-in-south-africa-2013/ [2017, February 22].

Green Power. 2017. *Government Incentives*. [Online]. Available: http://green-power.co.za/incentives/.

GreenCape. 2016. *Utility-scale Renewable Energy Sector: Market Intelligence Report 2016*.

Griffith, S.J. 2016. *Measuring Compliance*. [Online]. Available: https://wp.nyu.edu/compliance_enforcement/2016/05/05/measuring-compliance/ [2017, June 09].

Grobbelaar, S. 2016. *Technology Management 873 Class Notes: STI Policy and supporting policy-making*. Stellenbosch: Department of Industrial Engineering, Stellenbosch University.

Grobbelaar, S. 2017.

Grobbelaar, S., Gauche, P. & Brent, A. 2014. Developing a competitive concentrating solar power industry in South Africa : Current gaps and recommended next steps. *Development Southern Africa*. 31(3):475–493.

Grubler, A. 2012. Energy transitions research: Insights and cautionary tales. *Energy Policy*. 50(2012):8–16.

Grubler, A., Wilson, C. & Nemet, G. 2016. Apples, oranges, and consistent comparisons of the temporal dynamics of energy transitions. *Energy Research and Social Science*. 22(2016):18–25.

Haas, R., Eichhammer, W., Huber, C., Langniss, O., Lorenzoni, A., Madlener, R., Menanteau, P., Morthorst, P.E., et al. 2004. How to promote renewable energy systems successfully and effectively. *Energy Policy*. 32(6):833–839.

Haas, R., Panzer, C., Resch, G., Ragwitz, M., Reece, G. & Held, A. 2011. A historical review of promotion strategies for electricity from renewable energy sources in EU countries. *Renewable and Sustainable Energy Reviews*. 15(2):1003–1034.

Haas, R., Resch, G., Panzer, C., Busch, S., Ragwitz, M. & Held, A. 2011. Efficiency and effectiveness of promotion systems for electricity generation from renewable energy sources - Lessons from EU countries. *Energy*. 36(4):2186–2193.

Hajiyeva, N. 2016. *The triadic nexus: Energy factor, national security and foreign policy*. [Online]. Available: http://thepoliticon.net/2016/07/27/the-triadic-nexus-energy-factor-national-security-and-foreign-policy.html [2017, August 29].

Hales, D., Peersman, G., Rugg, D. & Kiwango, E. 2010. *An Introduction to Indicators*. [Online]. Available: http://www.unaids.org/sites/default/files/sub_landing/files/8_2-Intro-to-IndicatorsFMEF.pdf.

Hall, N., Lacey, J., Carr-Cornish, S. & Dowd, A.M. 2015. Social licence to operate: Understanding how a concept has been translated into practice in energy industries. *Journal of Cleaner Production*. 86(2015):301–310.

Hannon, M.J., Foxon, T.J. & Gale, W.F. 2015. "Demand pull" government policies to support Product-Service System activity: The case of Energy Service Companies (ESCos) in the UK. *Journal of Cleaner Production*. 108(2015):1–16.

Harmelink, M., Voogt, M. & Cremer, C. 2004. Analysing the effectiveness of renewable energy supporting policies in the European Union. *Energy Policy*. 34(3):343–351.

Harryson, S.J. 2008. Entrepreneurship through relationships – navigating from creativity to commercialisation. *R&D Management*. 38(3):290–310.

Hartmann, A. & Huhn, W. 2009. *Energy: A key to competitive advantage - New sources of growth and productivity*. [Online]. Available: http://www.mckinsey.com/search.aspx?q=energy:+a+key.

Harvey, F. 2015. *Paris climate change agreement: the world's greatest diplomatic success*.

[Online]. Available: https://www.theguardian.com/environment/2015/dec/13/paris-climate-deal-cop-diplomacy-developing-united-nations [2017, March 27].

Haughey, D. 2017. *Delphi Technique: A step-by-step guide*. [Online]. Available: https://www.projectsmart.co.uk/delphi-technique-a-step-by-step-guide.php [2017, January 30].

Haynes, R. 2017. *Independent power producers hit hurdles*. [Online]. Available: https://mg.co.za/article/2017-03-10-00-independent-power-producers-hit-hurdles [2017, March 22].

He, P. 2014. *The determinants of renewable energy technology adoption: empirical evidence from China*. PhD thesis. Zürich: ETH Zürich.

Heisler, Y. 2016. *Mobile internet usage surpasses desktop usage for the first time in history*. [Online]. Available: http://bgr.com/2016/11/02/internet-usage-desktop-vs-mobile/ [2017, July 09].

Helio100. 2017. *Helio100*. [Online]. Available: http://helio100.sun.ac.za/ [2017, February 02].

Henriksen, A.D. 1997. A technology assessment primer for management of technology. *International Journal of Technology Management*. 13(Nos 5/6):615–638.

Herzlinger, R.E. 2006. *Why Innovation in Health Care Is So Hard*. [Online]. Available: https://hbr.org/2006/05/why-innovation-in-health-care-is-so-hard [2017, April 14].

Hillman, K., Nilsson, M., Rickne, A. & Magnusson, T. 2011. Fostering sustainable technologies: a framework for analysing the governance of innovation systems. *Science and Public Policy*. 38(5):403–415.

Hinkley, J., Curtin, B., Hayward, J., Wonhas, A., Boyd, R., Grima, C., Tadros, A., Hall, R., et al. 2011. Concentrating solar power – drivers and opportunities for cost-competitive electricity. (March):1–32. [Online]. Available: www.csiro.au.

Hofman, D.M. & Huisman, R. 2012. Did the financial crisis lead to changes in private equity investor preferences regarding renewable energy and climate policies? *Energy Policy*. 47(2012):111–116.

Hopwood, B. 2005. Sustainable Development: Mapping Different Approaches. *Sustainable Development*. 13(2005):38–52.

Huijts, N.M.A., Molin, E.J.E. & Steg, L. 2012. Psychological factors influencing sustainable energy technology acceptance: A review-based comprehensive framework. *Renewable and Sustainable Energy Reviews*. 16(1):525–531.

Huston, L. 2007. *Innovation Networks: Looking for Ideas Outside the Company*. [Online]. Available: http://knowledge.wharton.upenn.edu/article/innovation-networks-looking-for-ideas-outside-the-company/ [2018, January 21].

Hyv, J. 2007. Strategy, performance measurement techniques and information technology of the firm and their links to organizational performance. *Management Accounting Research*. 18(2007):343–366.

IEA. 2010. *Energy Technology Roadmaps: a guide to development and implementation*. [Online]. Available: https://www.iea.org/publications/freepublications/publication/technology-roadmap--a-guide-to-development-and-implementation-.html.

IEA. 2011. *Modelling the capacity credit of renewable energy sources*. [Online]. Available: https://www.iea.org/media/weowebsite/energymodel/Methodology_CapacityCredit.pdf.

IEA. 2016. *World Energy Outlook 2016 (Executive Summary)*. [Online]. Available: https://www.iea.org/publications/freepublications/publication/WorldEnergyOutlook2016ExecutiveSummaryEnglish.pdf.

IEA. 2017. *Energy access database*. [Online]. Available: http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/ [2017, September 02].

IEA & OCED. 2005. *Lessons from liberalised electricity markets*. [Online]. Available: http://www.iea.org/publications/freepublications/publication/lessonsnet.pdf.

International Energy Agency. 2010. *Technology Roadmap: Concentrating Solar Power*. [Online]. Available: https://www.iea.org/publications/freepublications/publication/csp_roadmap.pdf.

International Energy Agency. 2016. *Key World Energy Statistics 2016*. [Online]. Available: https://www.iea.org/publications/freepublications/publication/KeyWorld2016.pdf.

International Energy Agency. 2017. *Key World Energy Statistics 2017*.

IRENA. 2012. *Renewable Energy Technologies: Cost Analysis Series -Concentrating Solar Power*. [Online]. Available: http://www.ingenia.org.uk/ingenia/articles.aspx?Index=244.

IRENA. 2015. *Solar Heating and Cooling for Residential Applications*. [Online]. Available: http://www.irena.org/documentdownloads/publications/irena_etsap_tech_brief_r12_solar_thermal_residential_2015.pdf.

IRENA. 2016. *The Power To Change: Solar and wind cost reduction potential to 2025*. [Online]. Available: http://www.irena.org/DocumentDownloads/Publications/IRENA_Power_to_Change_2016.pdf.

Isabella, G., Yu, A.S.O., Silva, A.M. da & Pegetti, A.L. 2017. Another driver of the Brazilian fuel ethanol supply chain: the consumers' preferences. *Revista de Administração*. 52(2017):1–13.

Jackson, F. 2016a. *Wind Energy 744 Class Notes Section 7 - Power Quality and Grid Integration*. Stellenbosch: Sustainability Institute.

Jackson, F. 2016b. *Wind Energy 744 Class Notes Section 8 - Managing Variability*. Stellenbosch: Sustainability Institute.

Jackson, F. 2016c. *Wind Energy 744 Class Notes Section 6 - Project Development*. Stellenbosch: Sustainability Institute.

Jacobsson, S. & Johnson, A. 2000. The diffusion of renewable energy technology: An analytical framework and key issues for research. *Energy Policy*. 28(9):625–640.

Jeffrey, H., Sedgwick, J. & Robinson, C. 2013. Technology roadmaps: An evaluation of their success in the renewable energy sector. *Technological Forecasting and Social Change*. 80(5):1015–1027.

Joffe, H. 2017. *Fitch downgrades South Africa to junk status*. [Online]. Available: https://www.businesslive.co.za/bd/economy/2017-04-07-fitch-downgrades-south-africa/ [2017, April 13].

de Jongh, D., Ghoorah, D. & Makina, A. 2014. South African renewable energy investment barriers: An investor perspective. *Journal of Energy in Southern Africa*. 25(2):15–27.

Karekezi, S. 2002. Renewables in Africa - Meeting the energy needs of the poor. *Energy Policy*. 30(11–12):1059–1069.

Kemp, R. & Volpi, M. 2008. The diffusion of clean technologies: a review with suggestions for future diffusion analysis. *Journal of Cleaner Production*. 16(2008):14–21.

Kern, F. & Howlett, M. 2009. Implementing transition management as policy reforms: A case study of the Dutch energy sector. *Policy Sciences*. 42(4):391–408.

Kern, F. & Rogge, K.S. 2016. The pace of governed energy transitions: Agency, international dynamics and the global Paris agreement accelerating decarbonisation processes? *Energy Research and Social Science*. 22(2016):13–17.

Khalil, T.M. 2000. *Management of Technology - The key to competitiveness and wealth creation*. McGraw-Hill.

Kim, B. 2003. Managing the transition of technology life cycle. *Technovation*. 23(5):371–381.

King, D.L., Boyson, W.E. & Kratochvil, J.A. 2002. Analysis of Factors Influencing the Annual Energy Production of Photovoltaic Systems. In Albuquerque: IEEE *Photovoltaic Specialists Conference*.

Klein, S.J.W. & Rubin, E.S. 2013. Life cycle assessment of greenhouse gas emissions, water and land use for concentrated solar power plants with different energy backup systems. *Energy Policy*. 63(2013):935–950.

Klepper, S. 1997. Industry life cycles. *Industrial and Corporate Change*. 6(1):145–181.

Kolk, A. & van den Buuse, D. 2013. *Business Models for Sustainable Energy Development*. [Online]. Available: http://www.europeanfinancialreview.com/?p=976 [2017, August 29].

Kosmadakis, G., Karellas, S. & Kakaras, E. 2013. Renewable and Conventional Electricity Electricity Generation Systems: Technologies and Diversity of Energy Systems. In Vol. 23. E. Michalena & J.. Hills (eds.). Springer *Renewable Energy Governance: Complexities and Challenges*. 9–29.

Kraemer, H. 2015. *How Ford CEO Alan Mullaly turned a broken company into the industry's comeback kid*. [Online]. Available: https://qz.com/431078/how-ford-ceo-alan-mullaly-turned-a-broken-company-into-the-industrys-comeback-kid/ [2017, April 18].

Krupa, J. & Burch, S. 2011. A new energy future for South Africa: The political ecology of South African renewable energy. *Energy Policy*. 39(10):6254–6261.

Kumbaroğlu, G., Madlener, R. & Demirel, M. 2008. A real options evaluation model for the diffusion prospects of new renewable power generation technologies. *Energy Economics*. 30(4):1882–1908.

Larsen, N. 2010. Market Segmentation - A Framework for Determining the Right Target Customers. [Online]. Available: http://pure.au.dk/portal/files/11462/ba.pdf.

Lee, M., Kim, K. & Cho, Y. 2010. A study on the relationship between technology diffusion and new product diffusion. *Technological Forecasting and Social Change*. 77(5):796–802.

Li, B. 2015. The Effects of New Technology Flexibility on Innovation Performance in the Post-Implementation Age Department of Management. *International Journal of Business and Social Science*. 6(5):22–27.

Lichtenthaler, U. 2008. External technology commercialisation projects: objectives, processes and a typology. *Technology Analysis & Strategic Management*. 20(4):483–501.

Löfstedt, R.E. & Renn, O. 1997. The Brent Spar controversy: An example of risk communication gone wrong. *Risk Analysis*. 17(2):131–136.

Löfsten, H. 2016. Organisational capabilities and the long-term survival of new technology-based firms. *European Business Review*. 28(3):312–332.

Lohmann, L. 2009. Climate as Investment. *Development and Change*. 40(6):1063–1083.

Lomborg, B. 2014. *Cost of gathering data on new development goals could be crippling*. [Online]. Available: https://www.theguardian.com/global-development/poverty-matters/2014/sep/24/gathering-data-sustainable-development-crippling [2017, April 19].

Loock, M. 2012. Going beyond best technology and lowest price: On renewable energy investors' preference for service-driven business models. *Energy Policy*. 40(1):21–27.

Lopes, J.A.P., Hatziargyriou, N., Mutale, J., Djapic, P. & Jenkins, N. 2007. Integrating distributed generation into electric power systems: A review of drivers, challenges and opportunities. *Electric Power Systems Research*. 77(2007):1189–1203.

Lund, H. 2007. Renewable energy strategies for sustainable development. *Energy*. 32(2007):912–919.

Lund, P.D. 2006. Analysis of energy technology changes and associated costs. *International Journal of Energy Research*. 30(December 2005):967–984.

Lund, P.D. 2009. Effects of energy policies on industry expansion in renewable energy. *Renewable Energy*. 34(1):53–64.

MacDonald, J. 2016. *Clean energy defies fossil fuel price crash to attract record $329bn global investment in 2015*. [Online]. Available: http://about.bnef.com/press-releases/clean-energy-defies-fossil-fuel-price-crash-to-attract-record-329bn-global-investment-in-2015/?utm_medium=microsite&utm_campaign=BNEF2015&utm_source=PRlink&utm_content=link&utm_term= [2016, March 30].

Mahbuba, D. & Rousseau, R. 2011. The Matthew effect and a relation with concept symbols and defaults. *Annals of Library and Information Studies*. 58(4):335–345.

Maloney, J.D. 1982. How companies assess technology. *Technological Forecasting and Social Change*. 22(1982):321–329.

Manoukian, A. 2013. *Stakeholders' Partnership Synergy and its Impact on Commercialization of New Technologies: Renewable Energy Industry Study*. PhD thesis. Toledo: University of Toledo.

Maphelele, T., Stanford, R. & Kooverji, B. 2013. South African PV Industry – Overview. (Draft 2):1–14.

Markard, J., Raven, R. & Truffer, B. 2012. Sustainability transitions: An emerging field of research and its prospects. *Research Policy*. 41(2012):955–967.

Masini, A. & Menichetti, E. 2013. Investment decisions in the renewable energy sector: An analysis of non-financial drivers. *Technological Forecasting and Social Change*. 80(3):510–524.

Matek, B. & Gawell, K. 2015. The Benefits of Baseload Renewables: A Misunderstood Energy Technology. *The Electricity Journal*. 28(2):101–112.

Mbadlanyana, T. 2013. The Political Economy of Carbon Tax in South Africa. *Africa Insight*. 43(1).

McDowall, W. 2012. Technology roadmaps for transition management: The case of hydrogen energy. *Technological Forecasting and Social Change*. 79(3):530–542.

Mckenzie, M. 2012. *26 GWHS of Green Electricity for Sale from City of Cape Town*. [Online]. Available: http://www.urbanearth.co.za/articles/26-gwhs-green-electricity-sale-city-cape-town [2017, April 14].

Meadowcroft, J. 2009. What about the politics? Sustainable development, transition management, and long term energy transitions. *Policy Sciences*. 42(4):323–340.

Measure Evaluation. n.d. *Monitoring And Evaluation: Frameworks*. [Online]. Available: https://www.measureevaluation.org/resources/training/capacity-building-resources/m-e-of-malaria-programs-1/m-e-of-malaria-programs.

Mendelsohn, M., Lowder, T. & Canavan, B. 2012. Utility-Scale Concentrating Solar Power and Photovoltaics Projects: A Technology and Market Overview. *National Renewable Energy Laboratory*. 303(April):275–3000.

Merten, M. 2017. *In numbers: Budget 2017*. [Online]. Available: https://www.dailymaverick.co.za/article/2017-02-22-in-numbers-budget-2017/#.WO_fOfl97IU [2017, April 13].

Meyer, A.J. & van Niekerk, J.L. 2011. Roadmap for the Deployment of Concentrating Solar Power in South Africa. *Proceedings of Solar Power and Chemical Energy Systems conference (SolarPACES 2011)*.

Minoja, M. 2012. Stakeholder Management Theory, Firm Strategy, and Ambidexterity. *Journal of Business Ethics*. 109(1):67–82.

Mohammed, Y.S., Mustafa, M.W. & Bashir, N. 2014. Hybrid renewable energy systems for off-grid electric power: Review of substantial issues. *Renewable and Sustainable Energy Reviews*. 35(2014):527–539.

Monstadt, J. 2007. Urban governance and the transition of energy systems: Institutional change and shifting energy and climate policies in Berlin. *International Journal of Urban and Regional Research*. 31(2):326–343.

Montalvo, C. 2008. General wisdom concerning the factors affecting the adoption of cleaner technologies: a survey 1990-2007. *Journal of Cleaner Production*. 16(2008):S7–S13.

Mouton, J. 2001. *How to succeed in your Master's & Doctoral studies: A South African guide and resource book*. Pretoria: Van Schaik Publishers.

Mpakama, Z.T. 2016. An investigation of construction risk in renewable energy Public-Private-Partnerships : The case of South Africa's Renewable Energy Independent Power Producer Programme. Stellenbosch University.

Msimanga, B. & Sebitosi, A.B. 2014. South Africa's non-policy driven options for renewable energy development. *Renewable Energy*. 69(2014):420–427.

Murmann, J.P. & Frenken, K. 2006. Toward a systematic framework for research on dominant designs, technological innovations, and industrial change. *Research Policy*. 35(7):925–952.

Murphy, B., Jennings, T., Hughes, M., Ashcroft, M., Burke, O., Lehmann, N., Hope-Morley, A. & Besseling, J. 2014. *Accelerating the commercialisation of emerging renewable energy technologies*. [Online]. Available: http://iea-retd.org.

Musango, J.K. & Brent, A.C. 2011. Assessing the sustainability of energy technological systems in Southern Africa: A review and way forward. *Technology in Society*. 33(2011):145–155.

Nahman, A., Wise, R. & Lange, W. 2009. Environmental and resource economics in South Africa: Status quo and lessons for developing countries. *South African Journal of Science*. 105(October):350–356.

National Academy of Sciences, National Academy of Engineering & National Research Council. 2010. Renewable Electricity Generation Technologies. In Washington, DC *Electricity from Renewable Resources: Status, Prospects, and Impediments*.

Al Natsheh, A., Gbadegeshin, S.A., Rimpiläinen, A., Imamovic-Tokalic, I. & Zambrano, A. 2015. Identifying the Challenges in Commercializing High Technology: A Case Study of Quantum Key Distribution Technology. *Technology Innovation Management Review*. 5(1):26–36.

Ndebele, P. 2017. *Comments on the Draft IRP 2016*. Kimberley: SASTELA.

Negro, S.O., Alkemade, F. & Hekkert, M.P. 2012. Why does renewable energy diffuse so slowly? A review of innovation system problems. *Renewable and Sustainable Energy Reviews*. 16(6):3836–3846.

Nepelski, D. & De Prato, G. 2015. International technology sourcing between a developing country and the rest of the world. A case study of China. *Technovation*. 35(2015):12–21.

Nevens, T.M., Summe, G.L. & Uttal, B. 1990. Commercializing Technology: What the Best Companies Do. *Harvard Business Review*. (May):154–163.

Nhamo, G. & Mukonza, C. 2016. Policy, Institutional and Programme Readiness for Solar Energy Uptake in South Africa. *AFRICA INSIGHT*. 45(4).

Nkabinde, S. 2016. *Could the carbon tax be good for SA economy?* [Online]. Available: http://today.moneyweb.co.za/article?id=591880&acid=ftxLrFdpqcceZeuwhd4cWQ%3D%3D&adid=u1uRXTUkXMiZgIjL7JoXSA%3D%3D&date=2016-05-25#.WCDYRC197IW [2016, August 18].

Nogee, A., Clemmer, S., Paulos, B. & Haddad, B. 1999. *Powerful Solutions: 7 Ways to Switch America to Renewable Electricity*. [Online]. Available: http://www.ucsusa.org/sites/default/files/legacy/assets/documents/clean_energy/ps-all.pdf%5Cnhttp://www.ucsusa.org/clean_energy/smart-energy-solutions/increase-renewables/barriers-to-renewable-energy.html#.WCZtxYWcGUk.

Odendaal, N. 2017. *Eskom's refusal to sign new renewables PPAs costing jobs, investments – DCD*. [Online]. Available: http://www.engineeringnews.co.za/article/eskoms-refusal-to-sign-new-renewables-ppas-costing-jobs-investments-dcd-2017-02-03 [2017, April 14].

OECD. 2014. *Research Co-operation between Developed and Developing Countries in the Area of Climate Change Adaptation and Biodiversity*. Paris. [Online]. Available: http://www.oecd.org/environment/Research_Cooperation.pdf.

Ordanini, A., Miceli, L., Pizzetti, M. & Parasuraman, A. 2011. Crowd-funding: transforming customers into investors through innovative service platforms. *Journal of Service Management*. 22(4):443–470.

Organisation for Economic Co-operation and Development. 1998. *21st Century Technologies: Promises and Perils of a Dynamic Future*. [Online]. Available: https://www.oecd.org/futures/35391210.pdf.

Oxford, A. 2017. *The Cape Town scheme that lets you sell electricity to the grid – just don't call it a feed-in tariff…*. [Online]. Available: http://www.htxt.co.za/2015/01/27/the-cape-town-scheme-that-lets-you-sell-electricity-to-the-grid-just-dont-call-it-a-feed-in-tariff/ [2017, February 22].

Oxman, J.A. 1992. The global service quality measurement program at American Express Bank. *National Productivity Review*. 11(3):381–392.

Painuly, J.P. 2001. Barriers to renewable energy penetration: A framework for analysis. *Renewable Energy*. 24(1):73–89.

Papapetrou, P. 2014. *Enabling Renewable Energy in South Africa: Assessing the Renewable Energy Independent Power Producer Programme*. [Online]. Available: http://awsassets.wwf.org.za/downloads/enabling_re_in_sa.pdf.

Park, H.W., Sung, T.E. & Kim, S.G. 2015. Strategic implications of technology life cycle on technology commercialization. *IAMOT 2015 - 24th International Association for Management of Technology Conference: Technology, Innovation and Management for Sustainable Growth, Proceedings*. 2736–2748. [Online]. Available: http://www.scopus.com/inward/record.url?eid=2-s2.0-84959307592&partnerID=tZOtx3y1.

Passeya, R., Spooner, T., MacGill, I., Watt, M. & Syngellakis, K. 2011. The potential impacts of grid-connected distributed generation and how to address them: A review of technical and non-technical factors. *Energy Policy*. 39(10):6280–6290.

Peach, W.D. 2010. *The development of the Sustainable Technology Balance Sheet: a generic technology assessment tool to assess the sustainability of renewable energy technologies.* M. Eng thesis. Pretoria: University of Pretoria.

Pearce II, J.A. & Robinson Jr., R.B. 2009. *Strategic Management: Formulation, Implementation, and Control*. 11th ed. McGraw-Hill.

Pearson, T. & Wegener, R. 2013. *Big data: The organizational challenge*. [Online]. Available: http://www.bain.com/Images/BAIN_BRIEF_Big_Data_The_organizational_challenge.pdf.

Peter, R., Ramaseshan, B. & Nayar, C. V. 2002. Conceptual model for marketing solar based technology to developing countries. *Renewable Energy*. 25(4):511–524.

Peters, I.., Lotz, M. & Brent, A.. 2014. Investigating the Financial Close of Projects Within the South African Renewable Energy Independent Power Producer Procurement Programme. *South African Journal of Industrial Engineering*. 25(3):57–68.

Petticrew, M. & Roberts, H. 2006. *Systematic Reviews in the Social Sciences: A Practical Guide*. Blackwell Publishing Ltd.

Pfeiffer, B. & Mulder, P. 2013. Explaining the diffusion of renewable energy technology in developing countries. *Energy Economics*. 40(2013):285–296.

Pfenninger, S. & Keirstead, J. 2015. Comparing concentrating solar and nuclear power as baseload providers using the example of South Africa. *Energy*. 87(2015):303–314.

Phaal, R. 2004. Technology roadmapping - A planning framework for evolution and revolution. *Technological Forecasting and Social Change*. 71(2004):5–26.

Pierce, W., Gauché, P., Von Backström, T., Brent, A.C. & Tadros, A. 2013. A comparison of solar aided power generation (SAPG) and stand-alone concentrating solar power (CSP): A South African case study. *Applied Thermal Engineering*. 61(2):657–662.

Pieterse, E. 2005. *The Development of an Internal Technology Strategy Assessment Framework within the Services Sector Utilising Total Quality Management Principles*. M. Eng thesis. Pretoria: University of Pretoria.

Platzer, W.J. 2016. Combined solar thermal and photovoltaic power plants - An approach to 24h solar electricity? *AIP Conference Proceedings*. 1734.

PMG. 2014. *Higher education challenges: presented by Higher Education South Africa (HESA)*. [Online]. Available: https://pmg.org.za/committee-meeting/17037/ [2017, April 13].

Popp, D., Newell, R.G. & Jaffe, A.B. 2010. Energy, the Environment, and Technological Change. In Vol. 2. B.H. Hall & N. Rosenberg (eds.). Elsevier. *Handbook of the Economics of Innovation*. 873–937.

Power, M., Newell, P., Baker, L., Bulkeley, H., Kirshner, J. & Smith, A. 2016. The political economy of energy transitions in Mozambique and South Africa: The role of the Rising Powers. *Energy Research and Social Science*. 17(2016):10–19.

Pyke, T. 2017. *The energy debate: Renewable energy cannot replace fossil fuels*. [Online]. Available: http://developmenteducation.ie/feature/the-energy-debate-renewable-energy-cannot-replace-fossil-fuels/ [2017, September 03].

Rademaekers, K., Yearwood, J., Ferreira, A., Pye, S., Hamilton, I., Agnolucci, P., Grover, D., Karásek, J., et al. 2016. *Selecting Indicators to Measure Energy Poverty*. Rotterdam. [Online]. Available: https://ec.europa.eu/energy/sites/ener/files/documents/Selecting Indicators to Measure Energy Poverty.pdf.

Rao, K.U. & Kishore, V.V.N. 2010. A review of technology diffusion models with special reference to renewable energy technologies. *Renewable and Sustainable Energy Reviews*. 14(3):1070–1078.

Rasiel, E.M. 1999. *The McKinsey Way*. New York: McGraw-Hill.

Reddy, S. & Painuly, J.P. 2004. Diffusion of renewable energy technologies - barriers and stakeholders' perspectives. *Renewable Energy*. 29(9):1431–1447.

Redman, T.C. 1998. The Impact of Poor Data Quality on the Typical Enterprise. *Communications of the ACM*. 41(2):79–82.

Reede, E. 2016. *When Virtual Reality Meets Education*. [Online]. Available: https://techcrunch.com/2016/01/23/when-virtual-reality-meets-education/ [2017, April 12].

Relancio, J., Cuellar, A., Walker, G. & Ettmayr, C. 2016. South African CSP projects under the REIPPP programme - Requirements, Challenges and Opportunities. *AIP Conference Proceedings*. 1734(1):11002.

REN21. 2016. *Renewables 2016 Global Status Report*. [Online]. Available: http://www.ren21.net/resources/publications/.

REN21. 2017a. *Renewables Global Futures Report: Great debates towards 100% renewable energy*. [Online]. Available: http://www.ren21.net/wp-content/uploads/2017/03/GFR-Full-Report-2017.pdf.

REN21. 2017b. *Renewables 2017 Global Status Report*. [Online]. Available:

http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf.

Van Rensburg, D. 2017a. *Price talks could kill green projects*. [Online]. Available: http://www.fin24.com/Economy/Eskom/price-talks-could-kill-green-projects-20170901 [2017, October 23].

Van Rensburg, D. 2017b. *Fight or flight as Eskom "squashes" renewable IPP programme*. [Online]. Available: http://www.fin24.com/Economy/Eskom/fight-or-flight-as-eskom-squashes-renewable-ipp-programme-20170910-3 [2017, September 13].

RESET. 2015. *Renewable Energy - Environmentally Friendly and Low Cost Energy from Inexhaustible Sources*. [Online]. Available: https://en.reset.org/knowledge/renewable-energy-environmentally-friendly-and-low-cost-energy-inexhaustible-sources [2018, January 29].

Retief, F. & Chabalala, B. 2009. The Cost of Environmental Impact Assessment in South Africa. *Journal of Environmental Assessment Policy and Management*. 11(1):51–68.

Reuters. 2016. *Five Pacific islands lost to rising seas as climate change hits*. [Online]. Available: https://www.theguardian.com/environment/2016/may/10/five-pacific-islands-lost-rising-seas-climate-change [2017, March 27].

Richardson, L. 2016. *Tesla's solar panel roof: solar glass tiles are the new solar shingles*. [Online]. Available: http://news.energysage.com/tesla-solar-panel-roof-the-next-solar-shingles/ [2017, March 30].

Richter, M. 2012. Utilities' business models for renewable energy: A review. *Renewable and Sustainable Energy Reviews*. 16(5):2483–2493.

Rinne, M. 2004. Technology roadmaps: Infrastructure for innovation. *Technological Forecasting and Social Change*. 71(2004):67–80.

Rollauer, T. 2013. *Are Companies Using the Right Metrics to Measure Compliance Risk?* [Online]. Available: http://deloitte.wsj.com/riskandcompliance/2013/09/04/are-companies-using-the-right-metrics-to-measure-compliance-risk/ [2017, June 09].

Romero, M. & González-Aguilar, J. 2014. Solar thermal CSP technology. *Wiley Interdisciplinary Reviews: Energy and Environment*. 3(1):42–59.

Rotmans, J., Kemp, R. & Van Asselt, M. 2001. More evolution than revolution: transition management in public policy. *Journal of Future Studies, Strategic Thinking and Policy*. 3(1):15–31.

Sager, M. 2014. *Renewable Energy Vision 2030 – South Africa*. [Online]. Available: http://awsassets.wwf.org.za/downloads/a16369_wwf_reip_report_online.pdf.

Sager, M., Ellen, D., Ritchken, E. & Osborne, S. 2015. *Concentrated solar power: A strategic industrial development opportunity for South Africa*. [Online]. Available: http://awsassets.wwf.org.za/downloads/concentrated_solar_power_report_final.pdf.

Samuel, M. 2009. *Visualising sustainability*. [Online]. Available:

https://computingforsustainability.com/2009/03/15/visualising-sustainability/ [2017, September 07].

Santos, L., Soares, I., Mendes, C. & Ferreira, P. 2014. Real Options versus Traditional Methods to assess Renewable Energy Projects. *Renewable Energy*. 68(2014):588–594.

SAPVIA. 2017. *SARS Renewable Energy, R&D and Energy Efficiency Incentives*. [Online]. Available: http://www.sapvia.co.za/sars-renewable-energy-rd-and-energy-efficiency-incentives/ [2017, February 22].

SARS. 2014. [Online]. Available: http://www.sars.gov.za/AllDocs/OpsDocs/Policies/SE-EL-04 - Environmental Levy on Electricity Generated in South Africa - External Standard.pdf.

SASTELA, Dti & GIZ. 2013. *Assessment of the localisation, industrialisation and job creation potential of CSP infrastructure projects in South Africa – A 2030 vision for CSP*. [Online]. Available: http://sastela.org/wp-content/uploads/2015/09/giz_csp_study_-_final_report_june_2013.pdf.

Schilling, M.A. & Esmundo, M. 2009. Technology S-curves in renewable energy alternatives: Analysis and implications for industry and government. *Energy Policy*. 37(5):1767–1781.

Scott, E. 2012. *Technology Commercialization*. Krakow: ES Technology Limited. [Online]. Available: www.uprp.gov.pl/uprp/redir.jsp?place=GalleryStats&id=47375.

Selko, A. 2012. *Steps Industry Can Take to Reduce Energy Consumption*. [Online]. Available: http://www.industryweek.com/articles/steps_industry_can_take_to_reduce_energy_con sumption_26819.aspx [2017, August 30].

Shahmarichatghieh, M. & Haapasalo, H. 2015. Product Life Cycle, Technology Life Cycle and Market Life Cycle; Similarities , Differences and Applications. In *Managing Intellectual Capital and Innovation for Sustainable and Inclusive Society*. 1143–1151.

Shakeel, S.R., Takala, J. & Zhu, L.D. 2017. Commercialization of renewable energy technologies: A ladder building approach. *Renewable and Sustainable Energy Reviews*. 78(2017):855–867.

Silinga, C. & Gauché, P. 2013. Scenarios for a South African CSP peaking system in the short term. *Energy Procedia*. 49:1543–1552.

Silinga, C., Gauché, P., Rudman, J. & Cebecauer, T. 2015. The South African REIPPP Two-tier CSP Tariff: Implications for a Proposed Hybrid CSP Peaking System. *Energy Procedia*. 69(2015):1431–1440.

Sklar-Chik, M.D., Brent, A.C. & De Kock, I.H. 2016. Critical Review of the Levelised Cost of Energy Metric. *South African Journal of Industrial Engineering*. 27(4):124–133.

Smith, V. 2011. Enabling environments or enablin discord: Intellectual property rights, public-private partnerships, and the quest for green technology transfer. *Georgetown Journal of International Law*. 42(2011):817–854.

Solangi, K.H., Islam, M.R., Saidur, R., Rahim, N.A. & Fayaz, H. 2011. A review on global solar energy policy. *Renewable and Sustainable Energy Reviews*. 15(4):2149–2163.

Solargis. 2016. *Direct Normal Irradiation*. [Online]. Available: http://solargis.com/assets/graphic/free-map/DNI/Solargis-World-DNI-solar-resource-map-en.png [2016, July 04].

Solomon, B.D. & Krishna, K. 2011. The coming sustainable energy transition: History, strategies, and outlook. *Energy Policy*. 39(2011):7422–7431.

SOLTRAIN. 2016. *About SOLTRAIN*. [Online]. Available: http://www.soltrain.co.za/about-soltrain [2016, November 09].

Sood, A. & Tellis, G.J. 2005. Technological Evolution and Radical Innovation. *Journal of Marketing*. 69(3):152–168.

Soon Heng, L. 2017. *Why Singapore needs to make nuclear power work*. [Online]. Available: http://www.straitstimes.com/opinion/why-singapore-needs-to-make-nuclear-power-work [2018, January 29].

South African Institute of International Affairs. 2012. *Green Economy Incentives: South Africa*. Johannesburg. [Online]. Available: http://www.saiia.org.za/feature/global-think-tank-survey-2012-released.html.

Sovacool, B.K. 2016. How long will it take? Conceptualizing the temporal dynamics of energy transitions. *Energy Research and Social Science*. 13(2016):202–215.

SQWenergy. 2010. *Renewable and Low-carbon Energy Capacity Methodology Methodology*. [Online]. Available: http://www.sqw.co.uk/files/5313/8712/1026/41.pdf.

Srinivasan, R., Lilien, G.L. & Rangaswamy, A. 2006. The Emergence of Dominant Designs. *Journal of Marketing*. 70(2006):1–17.

Stapleton, G.J. 2009. Successful implementation of renewable energy technologies in developing countries. *Desalination*. 248(2009):595–602.

Steinfeld, A. 2005. Solar thermochemical production of hydrogen: A review. *Solar Energy*. 78(5):603–615.

Stern, C.W. & Deimler, M.S. 2006. *The Boston Consulting Group on Strategy*. 2nd ed. Hoboken, New Jersey: John Wiley & Sons, Inc.

Stigka, E.K., Paravantis, J.A. & Mihalakakou, G.K. 2014. Social acceptance of renewable energy sources: A review of contingent valuation applications. *Renewable and Sustainable Energy Reviews*. 32(2014):100–106.

Stuckey, H.L. 2013. Three types of interviews: Qualitative research methods in social health. *Journal of Social Health and Diabetes*. 1(2):56–59.

Suarez, F.F. 2004. Battles for technological dominance: an integrative framework. *Research Policy*. 33(2004):271–286.

Surbhi, S. 2015. *Difference Between the Supply Chain and Value Chain*. [Online]. Available: http://keydifferences.com/difference-between-supply-chain-and-value-chain.html [2017, January 20].

Suzuki, M. 2013. Addressing key issues in technology innovation and transfer of clean energy technologies: a focus on enhancing the enabling environment in the developing countries. *Environmental Economics and Policy Studies*. 16(2014):1–13.

Swart, P.D. 2015. *An Asset Investment Decision Framework to Prioritise Shutdown Maintenance Tasks*. M. Eng thesis. Stellenbosch: Stellenbosch University.

Székely, F. & Knirsch, M. 2005. Responsible leadership and corporate social responsibility: Metrics for sustainable performance. *European Management Journal*. 23(6):628–647.

Tagotra, N. 2017. The Political Economy of Renewable Energy : Prospects and Challenges for the Renewable Energy Sector in India Post-Paris Negotiations. *India Quarterly*. 73(1):99–113.

Taylor, M. 2008. Beyond technology-push and demand-pull: Lessons from California's solar policy. *Energy Economics*. 30(6):2829–2854.

Taylor, M. & Taylor, A. 2012. The technology life cycle: Conceptualization and managerial implications. *International Journal of Production Economics*. 140(1):541–553.

Terblanche, V. 2013. *CSP Projects : Ownership / Structure, Financing and Contracting Strategies*. [Online]. Available: http://www.eskom.co.za/AboutElectricity/RenewableEnergy/Documents/C1CSPProject OwnershipStructFinancingContractingStrategies.pdf.

The Department of Trade and Industry of South Africa. 2016. *The path to technology commercialisation*. [Online]. Available: https://www.thedti.gov.za/financial_assistance/Commercialisation.pdf.

The National Archives. 2013. *Effective Communications: Raising the profile of your archive service*. [Online]. Available: www.nationalarchives.gov.uk.

The World Bank. 2012. *Mobile Phone Access Reaches Three Quarters of Planet's Population*. [Online]. Available: http://www.worldbank.org/en/news/press-release/2012/07/17/mobile-phone-access-reaches-three-quarters-planets-population [2017, April 14].

Thiam, D.R. 2011. An energy pricing scheme for the diffusion of decentralized renewable technology investment in developing countries. *Energy Policy*. 39(7):4284–4297.

Thompson-Smeddle, L. 2012. *A South African renewable energy guide for local government*. Juta.

Thosago, M.P. 2011. *Determinants that drive commercialisation of potential university innovation outputs through technology transfer offices*. MBA thesis. Pretoria: University of Pretoria.

Tran, T.A. & Daim, T. 2008. A taxonomic review of methods and tools applied in technology assessment. *Technological Forecasting and Social Change*. 75(2008):1396–1405.

Troldborg, M., Heslop, S. & Hough, R.L. 2014. Assessing the sustainability of renewable energy technologies using multi-criteria analysis: Suitability of approach for national-scale assessments and associated uncertainties. *Renewable and Sustainable Energy Reviews*. 39(2014):1173–1184.

Tsanova, T. 2016. *Eskom again avoids signing PPA for 100MW CSP park*. [Online]. Available: https://renewablesnow.com/news/eskom-again-avoids-signing-ppa-for-100-mw-csp-park-report-538099/ [2017, March 30].

Tse, L. & Oluwatola, O. 2015. Evaluating Renewable Energy Technology Transfer In Developing Countries : Enabling Factors & Barriers. 6(1).

Tushman, M.L. & Anderson, P. 1986. Technological Discontinuities and Organizational Environments. *Administrative Science Quarterly*. 31(3):439–465. [Online]. Available: http://www.jstor.org/stable/2392832.

UN Women. 2012. *Monitoring and Evaluation Frameworks (3 parts)*. [Online]. Available: http://www.endvawnow.org/en/articles/335-monitoring-and-evaluation-frameworks-3-parts.html [2017, March 03].

UNEP. 2015. *The Three Dimensions of Sustainable Development: Is an Integrated Approach beyond our Reach?* [Online]. Available: http://web.unep.org/ourplanet/march-2015/unep-work/three-dimensions-sustainable-development [2018, January 29].

Ungerer, M., Ungerer, G. & Herholdt, J. 2015. *Crystallising the strategic business landscape*. Randburg, South Africa: KR Publishing.

United Nations. 2017. *The Sustainable Development Agenda*. [Online]. Available: http://www.un.org/sustainabledevelopment/development-agenda/ [2017, September 02].

United States Energy Information Administration. 2017. *Electricity Explained - Factors Affecting Electricity Prices*. [Online]. Available: https://www.eia.gov/energyexplained/index.cfm?page=electricity_factors_affecting_prices [2017, August 29].

United States Enviromental Protection Agency. 2017. *International Climate Impacts*. [Online]. Available: https://www.epa.gov/climate-impacts/international-climate-impacts [2017, March 27].

Varun, Bhat, I.K. & Prakash, R. 2009. LCA of renewable energy for electricity generation systems-A review. *Renewable and Sustainable Energy Reviews*. 13(5):1067–1073.

Vasileiadou, E., Huijben, J.C.C.M. & Raven, R.P.J.M. 2015. Three is a crowd? Exploring the potential of crowdfunding for renewable energy in the Netherlands. 128(2016):142–155.

Votteler, R.G. & Brent, A.C. 2016. A literature review on the potential of renewable electricity sources for mining operations in South Africa. *Journal of Energy in Southern Africa*. 27(2):1–21.

Wangler, L.U. 2012. The political economy of the green technology sector: A study about institutions, diffusion and efficiency. *European Journal of Law and Economics*. 33(1):51–81.

Wee, R.Y. 2017. *Countries With The Lowest Access To Electricity*. [Online]. Available:

http://www.worldatlas.com/articles/countries-with-the-lowest-access-to-electricity.html [2017, August 30].

Wheels 24. 2017. *#Budget2017: SA fuel levy hike - here's how it will affect you*. [Online]. Available: http://www.wheels24.co.za/News/Guides_and_Lists/budget2017-sa-fuel-levy-hike-heres-how-it-will-affect-you-20170223 [2017, February 24].

World Economic Forum. 2016. *Energy as a Competitive Advantage*. [Online]. Available: http://reports.weforum.org/manufacturing-growth/energy-as-a-competitive-advantage/ [2017, March 27].

World Nuclear Association. 2013. *Sustainable Energy*. [Online]. Available: http://www.world-nuclear.org/information-library/energy-and-the-environment/sustainable-energy.aspx#References [2018, January 29].

World Nuclear Association. 2016. *Radioactive Wastes - Myths and Realities*. [Online]. Available: http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-wastes-myths-and-realities.aspx [2017, May 31].

World Nuclear Association. 2017. *Radioactive Waste - Myths and Realities*. [Online]. Available: http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-wastes-myths-and-realities.aspx [2017, October 10].

Wright, J.G., Bishof-Niemz, T., Calitz, J., Mushwana, C., Heerden, R. van & Senatla, M. 2017. *Formal comments on the Integrated Resource Plan (IRP) Update Assumptions, Base Case and Observations 2016*. [Online]. Available: https://www.csir.co.za/sites/default/files/Documents/20170331CSIR_EC_DOE.pdf.

Wustenhagen, R., Wolsink, M. & Burer, M.J. 2007. Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy*. 35(5):2683–2691.

Van Wyk, R.J. 1988. Management of technology: new frameworks. *Technovation*. 7(4):341–351.

Yekini Suberu, M., Wazir Mustafa, M. & Bashir, N. 2014. Energy storage systems for renewable energy power sector integration and mitigation of intermittency. *Renewable and Sustainable Energy Reviews*. 35(2014):499–514.

Yelland, C. 2016. *The true cost of electricity in South Africa*. [Online]. Available: https://mybroadband.co.za/news/energy/172890-the-true-cost-of-electricity-in-south-africa.html [2014, September 15].

Yelland, C. 2017. *SA needs to ditch "baseloadism" for flexible power generation*. [Online]. Available: https://www.fin24.com/Companies/Industrial/the-end-for-baseloadism-in-sa-and-the-need-for-flexible-power-generation-20170802 [2018, January 29].

Yumkella, K. & Vinanchiarachi, J. 2003. Leading Issues on Africa's Path to Industrialisation: The Role of Support Systems and Instruments. *Journal of African Economies*. 12(1):30–40.

Yun, S. & Lee, J. 2015. Advancing societal readiness toward renewable energy system adoption with a socio-technical perspective. *Technological Forecasting and Social*

Change. 95(2015):170–181.

Zacks. 2017. *What Factors Influence the Rates of Return on an Investment?* [Online]. Available: http://finance.zacks.com/factors-influence-rates-return-investment-1420.html [2017, April 13].

zaRECS. 2010. *About RECs*. [Online]. Available: http://www.zarecs.co.za/about-recs.

de Zúñiga, H.G., Jung, N. & Valenzuela, S. 2012. Social Media Use for News and Individuals' Social Capital, Civic Engagement and Political Participation. *Journal of Computer-Mediated Communication*. 17(2012):319–336.

Appendices

Appendix A

Strategies, approaches, and techniques for the commercialisation of MTRESs

Appendix A presents an evaluation of the strategies, approaches, and techniques identified from literature for the commercialisation of MTRESs. Each approach is described in full, together with an analysis of its strengths and weaknesses, and applicability to MTRESs. The section concludes with a brief discussion of the applicability of each strategy to the case of CSP technologies in South Africa.

Appendix A.1 In-house development

In-house development is a commercialisation strategy whereby an organisation commercialises a technology internally through use of its own production and distribution processes, and other related (core) competencies (Cetindamar *et al.*, 2010:58). This strategy may also involve the development of entirely new capabilities in order to commercialise a specific technology, or even result in the formation of new business units entirely (The Department of Trade and Industry of South Africa, 2016). This form of commercialisation is heavily influenced by R&D activities, and new technology, product, and process development (Cetindamar *et al.*, 2010:34).

While the commercialisation of MTRESs may occur in-house for some of these types of technologies, unless an organisation is a government-related entity it is unlikely to be able to generate the size of market needed to support the continual commercialisation of a given MTRES. The advent of liberalised energy markets and embedded generation have seen market opportunities begin to grow outside the government sphere. However, utility-scale projects still dominate energy sectors globally, due to their ability to offer greater market opportunities than other market segments, such as residential, industrial, or commercial. Thus, this strategy is unlikely to be appropriate for the large-scale commercialisation of MTRESs, given the growing reliance on multiple stakeholders in the commercialisation process. However, it does hold value for the commercialisation of MTRESs used for specific applications, as well as certain components of MTRESs on an elementary level, or in an early phase of the TLC (Cetindamar *et al.*, 2010:60). This is due to the low levels of support required for these specific types of technology (Cetindamar *et al.*, 2010:60). This case specific nature concerning which commercialisation strategy to employ is not surprising, given that organisations typically lack the financial capital to develop all technologies in-house, yet are equally unlikely to outsource everything using a technology transfer commercialisation strategy (see Appendix A.3) (Cetindamar *et al.*, 2010:42).

Appendix A.2 Joint commercialisation

Joint commercialisation refers to the strategy employed whereby an organisation enters into a strategic alliance with one or more partners in order to harness the collective expertise and knowledge with respect to production, distribution, and other processes. Given the different activities required during the commercialisation process, this is an attractive option for many organisations in pursuit of a cost-effective approach to technology commercialisation. In the case of MTRESs, the need to engage with governments to ensure continued large-scale demand for the future commercialisation of such technologies marks this as a more suitable approach than in-house development. This is especially true with respect to large-scale commercialisation efforts. However, the nature of the technology being commercialised is still likely to dictate the choice of joint commercialisation as a suitable commercialisation strategy. (Cetindamar *et al.*, 2010:42)

Appendix A.3 Technology transfer

Technology transfer introduces a selling approach to the commercialisation process, through the licensing and/or transfer of IP rights. These IP rights may relate to ideas, initial designs, and/or other forms of technology. This strategy may be employed at any point during the commercialisation process, but is often favoured when an organisation develops technology not deemed essential to its core business principles. In addition, certain organisations may wish to purchase technology instead of developing it themselves, before introducing it into the market as part of their strategic operations. Such a strategy is guided by factors such as scarce resources, time constraints, shortage of supportive assets, diversification, and the protection of its own technologies. Similar to the joint commercialisation strategy, technology transfer also demands the use of alliances or acquisition channels to allow for the transfer of the desired technology. (Cetindamar *et al.*, 2010:42)

The process of technology transfer is more complicated than the previous two strategies evaluated, given that the technology itself is often changed during the transfer from creator to user. Hence, the process requires a greater level of managerial skill to ensure successful commercialisation, comprising activities such as determination of the transfer method, role players, timing of market entry, completion of any necessary pre-transfer tasks, the transfer activities themselves, as well as any evaluations and improvements of the respective technology. However, it offers greater flexibility than the previous two strategies evaluated. Given that the choice of strategy is often decided on a case-by-case basis based on the given technology and respective organisation, it may be prudent to utilise an approach which allows for the freedom of choice regarding which strategy to use. However, the role of government in establishing energy markets, and setting the rules and regulations which govern energy sectors, cannot be ignored. (Cetindamar *et al.*, 2010:66)

Appendix A.4 Technology life cycle analysis

It is important to note that commercialisation efforts may differ based on the current life cycle stage of a given MTRES, affecting the choice of activities implemented to reach a commercial state (Park, Sung & Kim, 2015). Thus, it may be worthwhile to investigate the potential use of a TLC analysis for the commercialisation of MTRESs. A TLC is a tool which analyses the factors responsible for the progress of a technology up the s-curve, together with a technology's (potential) impact on its environment (Varun, Bhat & Prakash, 2009). The tool's usefulness is underlined by Taylor & Taylor (2012), who claim that, for effective technology management, organisations need to possess the ability to identify the life cycle phase of a particular technology, and the phase's implications with regards to decision making.

Before evaluating how a TLC analysis might assist efforts to commercialise MTRESs, there is a need to distinguish the TLC from the PLC and ILC, as the frequency with which these terms are used interchangeably has resulted in some confusion. One cause for such confusion is attributed to the interconnectedness of technologies and products, with it being commonplace to refer to technology as products, and vice versa. The lines between the three life cycles are blurred further due to the close relationships they share through their graphic illustrations, (conceptual) nature, and associated diction. (Taylor & Taylor, 2012)

The PLC is commonly depicted as a bell-shaped curve (see Figure A.1), measuring the change in sales quantity or revenue over time of an individual[92] product or service. It consists of four life cycle phases: introduction, growth, maturity, and decline. During introduction, a product is launched into the market, with low consumer sales due to a lack of familiarity with the product. The growth phase sees increased consumer recognition of the product, together with greater levels of sales and competition in the marketplace. At maturity, the sales of a product level out, before starting to fall in the decline phase. (Taylor & Taylor, 2012)

[92] Or group of individual products and services (Kim, 2003).

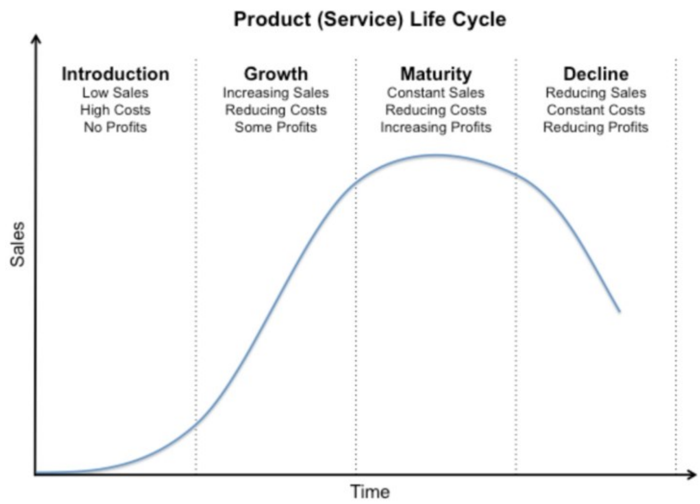


Figure A.1: Product life cycle
(Source: Business Set Free Ltd, 2013)

The PLC is used primarily as a tool to aid the marketing decision-making process, yet has also found use in managing certain aspects of the supply chain[93]. In addition, it is able to support other strategic business decisions. While this sounds promising from a commercialisation tool perspective, there are a number of aspects to consider regarding the positioning of a (new) product in its correct life cycle phase. The time duration, and level of product sales, of each life cycle phase, as well as the overall shape of the PLC curve, differ from product to product, depending on the respective industry. Furthermore, the curve does not differentiate products based on their class, type, and brand. These aspects complicate the identification of the correct life cycle phase, affecting the choice of appropriate marketing strategy to deploy. (Taylor & Taylor, 2012)

The ILC, on the other hand, analyses the development of industries over time through the rate of diffusion of product innovations, the emergence of new market segments, and the change in consumer and market behaviour (Shahmarichatghieh & Haapasalo, 2015; Taylor & Taylor, 2012). Klepper (1997), as cited in Taylor & Taylor (2012), models the ILC as an inverted U shape consisting of three phases: embryonic/exploratory, growth, and maturity. During the embryonic phase, low quantities of a product exist in the market due to a large degree of uncertainty. Product design is simple, as is the production process behind it, leading to the introduction of many companies into the market. The growth phase sees a more regular form of product design, together with the use of more complex production processes, and a decrease in the number of new and competing companies. The amount of firms participating in the market decreases even further in the maturity phase as the level of growth falls rapidly. (Taylor & Taylor, 2012)

The predominant use of the ILC has been to assist managerial decision-making (Taylor & Taylor, 2012). Many managers are interested in the rates of entry and exit of companies during the different life cycle phases, as well as the nature of those companies that prove the most competitive in their respective industries (Taylor & Taylor, 2012). These factors provide useful insight for commercialisation efforts, such as the competition a technology, and its associated commercialisation, may face. In addition, the ILC provides guidance as to which strategies should be implemented based on the current life cycle phase, and (targeted) consumer type (Shahmarichatghieh & Haapasalo, 2015).

However, the ILC encounters problems similar to those faced by the PLC. The length and nature of each life cycle phase are difficult to gauge accurately. This makes it tough to

[93] Inventory control, choice of business partner, and demand forecasting (Shahmarichatghieh & Haapasalo, 2015).

determine the exact life cycle phase of an industry, or draw comparisons between different industries. These issues present a challenge to managers with respect to locating a company in an emerging or maturing industry, namely: the time and manner of approach to enter or exit an industry. (Taylor & Taylor, 2012)

The ILC also ignores the technological change of a product through time, concentrating only on the life cycle phase in which a product is introduced into the market. It is important to remember that despite the strong emphasis on products in both the PLC and ILC, every product possesses a (complex) technological foundation. Indeed, both the PLC and ILC are simply functions of an underlying technology, with its own unique life cycle. Thus, it can be said that the PLC and ILC are mere substitutes of technological development, and that the TLC is better suited for analysing such progress with regards to technology management. (Taylor & Taylor, 2012)

There are two principal viewpoints held in the theory on TLCs: the macro view (see Figure A.2), and the s-curve (see Figure 2.1). The macro view consists of four stages: technological discontinuity, era of ferment, dominant design, and era of incremental change. The technological discontinuity is characterised by the breakthrough of an innovation[94] that affects products and/or processes. During the era of ferment, several variations of the breakthrough innovation emerge. This is a period of conflict between the variations, one which leads to the dominance of a single design. The dominant design[95] stage is evident in the broad industry adoption of a single design, one which establishes itself as the standard in the respective industry. The final stage involves the incremental improvement of the dominant design, following which the entire cycle repeats itself. The reason behind the block representing the era of ferment touching that of the technological discontinuity is to indicate that it happens immediately afterwards. The same is true for the era of incremental change and dominant design stages. (Taylor & Taylor, 2012)

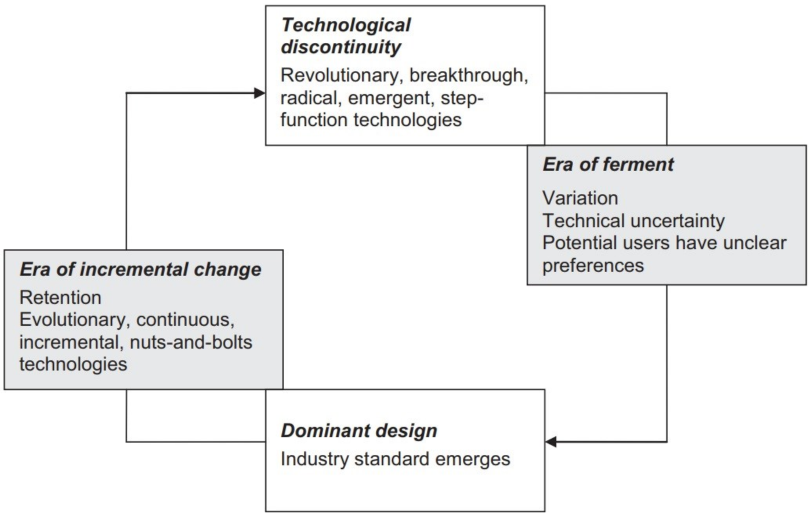


Figure A.2: Macro view of the TLC
(Source: Taylor & Taylor, 2012)

The macro view provides a useful classification of the different life cycle stages a technology moves through, with the change in focus from the (innovation) product to the process behind it being well suited for the commercialisation process. Early efforts are typically aimed at technological development, following which the emphasis shifts towards expanding the market

---

[94] This innovation may take the initial form of an idea, product, or technology (Shahmarichatghieh & Haapasalo, 2015).

[95] See Chapter 2.1.

(applications) for a technology, and ensuring that there is sufficient supply to meet the forecasted demand. (Taylor & Taylor, 2012)

Use of the macro view is also given weight when considering the relationship a TLC shares with the idea of a technology paradigm, namely: "*a technology platform for successive generations of technology*" (Kim, 2003). Each generation has the potential to contribute many products and services, with each product and service possessing their own PLC (Kim, 2003). This relationship provides insight into the relationship that a technology shares with its associated products and services, and how such a platform might be leveraged to assist commercialisation efforts. However, it fails to mention the effect that the (change in) rate of adoption by consumers may have on a technology's development, nor clarify how the boundaries between the life stages may be determined.

The second TLC viewpoint, an s-curve, is based on the idea that the TLC forms an s-shaped curve, one which consists of four phases: embryonic, growth, maturity, and ageing (Cetindamar *et al.*, 2010:90). Taylor & Taylor (2012) acknowledge a lack of consistency with this model, particularly with respect to the information displayed on the axes. There is disagreement over whether the y-axis should represent the diffusion of a technology, quantified by the sum of a technology's usage over time, or be based upon some measure of technological performance or improvement, such as patent applications. The same is true for the x-axis. While time would appear to be the most appropriate independent variable, there is a strong argument to use a parameter indicative of the investment or work contributed towards the development of a technology, such as the available budget, hours spent, or number of researchers used. The s-curve of Figure 2.1 attempts to harmonise these different views on the respective axes. (Taylor & Taylor, 2012)

There is also debate over the validity of the s-curve model. Sood & Tellis (2005) dispute the use of the model for a TLC, arguing that *"the field does not enjoy a single, strong, and unified theory of technological evolution".* Their findings support a step function model for technological growth instead, one in which technologies remain at the same life phase for long periods of time, before experiencing a sudden jump forward in terms of technological performance (Sood & Tellis, 2005).

Another issue relating to the use of the s-curve model is raised by Murmann & Frenken (2006), who consider the case where a complex technology or product is developed based on numerous other technologies, namely: "*nested hierarchies of technology cycles at a single point in time*". Each technology at each level within the hierarchy possesses its own unique s-curve. This hierarchical structure makes it difficult, if not impossible, to imagine a single s-curve for a complex technology or product. This has led some experts to argue that a TLC approach should concentrate more on the use of a technology than on its internal composition of technologies. (Taylor & Taylor, 2012)

However, despite all of these issues, the s-curve model presents an easy-to-understand illustration of the TLC, and associated dominant variables (time, technological performance, number of adopters, rate of adoption over time). As such, it has come to enjoy greater use and acceptance by management practitioners (than the macro view). (Taylor & Taylor, 2012)

Grobbelaar *et al.* (2014) present an overview of MTRESs and their TLCs (see Figure A.3), demonstrating the use of an s-curve TLC supplemented with energy data. The various technologies are positioned based on their current TLC phase, documenting the transition towards a state of maturity. Moreover, the inclusion of energy data proves useful for highlighting the immediate steps and policy objectives required to facilitate progress up the s-curve. Thus, it provides insight into how commercialisation activities may differ between MTRESs based on their respective life cycle stage.

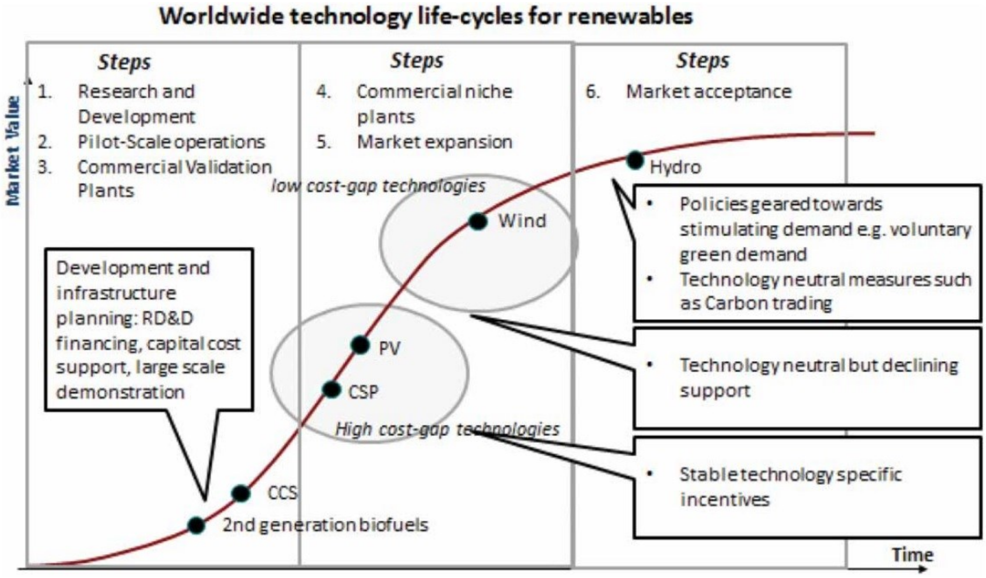


Figure A.3: MTRESs' technology life cycles
(Source: Grobbelaar *et al.*, 2014)

The use of a TLC analysis as a suitable means of commercialising MTRESs is debatable. While it undoubtedly has value in guiding commercialisation efforts through identification of the current life cycle phase, it requires integration with other methods to present a complete overview of the respective technology, as well as access to sufficient, accurate, and reliable data. Furthermore, debate will always exist around the choice of TLC model (s-curve, macro view, or other), as well as the metrics and methodology used to determine the applicable lifecycle phase of a technology, such as patent citation and application data (Park *et al.*, 2015).

As with most strategies, access to sufficient, accurate, and reliable data is of great importance, and may limit the effectiveness of the tool in question (Pearson & Wegener, 2013; Redman, 1998). MTRESs, with their hierarchy of technological cycles, typically require a more diverse set of data, in addition to an increase in the pure size of data needed (Murmann & Frenken, 2006). The difficulties involved in gaining access to such data need to be weighed against the benefits such an approach may offer to the commercialisation process (Lomborg, 2014). Therefore, while a TLC analysis has value in assisting the decision-making process, its independent use as a tool for commercialising MTRESs is deemed inadequate.

Appendix A.5 Technology assessment

Given the multi-faceted nature of the commercialisation process, a technology assessment (TA) approach may hold greater value than a TLC analysis, as an approach for commercialising MTRESs. The origins of TA can be traced back to the 1960's in the United States, where the original idea, proposed by the U.S. Congress, was to develop a system aimed at providing early warning of the possible risks that new technologies may pose to society (Coates, 2001). Since then, the field of TA has grown to encompass a multitude of analytical tools and methods (see Figure A.4) (Peach, 2010), finding numerous uses in both the public and private sectors, as well as academia (Tran & Daim, 2008). The evolution of TA from its initial focus on government policy-making to a wider range of applications is also recognised by Musango & Brent (2011), who state that TA is "*a process aimed at appraising technological progress; analysing socio-technical systems; analysing the social impact of technology; evaluating technologies; studying technological futures; and controlling and managing technology*".

Economic analysis
- Cost benefit Analysis
- Cost effectiveness analysis
- Lifecycle cost assessment
- Return on investments
- Net present value
- Internal rate of return
- Breakeven point analysis
- Payback period analysis
- Residual income
- Total Savings
- Increasing returns analysis
- Technology value pyramid
- Real options
- Technology balance sheet

Decision analysis
- Multicriteria decision analysis
- Multiattribute utility theory
- Scoring
- Group decision support systems
  - Delphi/group Delphi
  - Analytic hierarchy process
  - Q-sort
- Decision trees
- Fuzzy logic

Systems engineering/system analysis
- Technology system studies
- Simulation modelling and analysis
- Project management techniques
- Systems optimization techniques
  - Linear, integer and non-linear programming
- Technology portfolio analysis

Technology forecasting
- S-curve analysis
- Delphi/Analytic hierarchy process/Q-sort
- R&D researcher hazard rate analysis
- Trend extrapolation
- Correlation and causal methods
- Probabilistic methods
- Monte Carlo simulation
- Roadmapping

Information monitoring
- Electronic database
- Internet
- Technical/ scientific lit reviews
- Patent searches
- IP asset valuation

Technical performance assessment
- Statistical analysis
- Bayesian confidence profile analysis
- Surveys/questionnaires
- Trial use periods
- Beta testing
- Technology decomposition theory
- S-curve analysis
- Human factors analysis
  - Ergonomics studies
  - Ease-of-use studies
- Outcomes research
- Technometrics

Risk assessment
- Simulation modelling and analysis
- Probabilistic risk assessment
- Environ, health, and safety studies
- Risk-based decision trees
- Litigation risk assessment

Market analysis
- Fusion method
- Market push/pull analysis
- Surveys/questionnaires
- S-curve analysis
- Scenario analysis
- Multi-generational tech diffusion

Externalities/impact analysis
- Externalities analysis
- Social impact analysis
- Political impact analysis
- Environmental impact analysis
- Cultural impact analysis
- Integrated impact assessment
- Life cycle analysis

Figure A.4: TA tools and methods[96]
(Source: Peach, 2010)

Exploring the application of TA with energy technologies, Musango & Brent (2011) reviewed the use of TA in the energy sector. Initially, TA of energy technologies focused on efficiency in both energy production and consumption. This assisted policy-makers to understand the impact of their decisions in the short- and long-term. Since then, energy TA has evolved to incorporate other types of analysis, such as ecological, economic, and social impact, as well

[96] This figure does not include all TA tools and methods that exist today, merely attempting to summarise them into broad categories for easy review.

as the identification of sustainable solutions to energy-related issues, and the incorporation of such solutions into long-term energy policies and strategies. (Musango & Brent, 2011)

However, despite the progress made in energy TA theory, there remains a lack of a standardised and systematic energy TA methodology, one that incorporates the many interrelationships, networks, and feedback loops within the field to effectively assess an energy technology (Musango & Brent, 2011). The absence of a strong and unified approach to energy TA ensure that debate will continue to persist over the choice of TA tools(s) for a given (energy) application or technology. In light of this, the use of a comprehensive list of TA tools and methods, such as that presented in Figure A.4, from which technology management practitioners may select tools to suit their needs, may prove to be the best option with respect to MTRESs at the moment.

The past emphasis on energy TA for use by decision makers in energy policy and strategy is problematic, with questions raised about the effectiveness of energy policy in the context of conflicting (political) goals (Musango & Brent, 2011). Following a review of energy TA tools and methods, Musango & Brent (2011) highlighted the need for a shift in focus from policy-making to technology management. However, while such a need may exist, not all decision makers in the commercialisation process are technology managers. Furthermore, the issue of energy policy, and the wider energy sector, being subject to political agendas is unlikely to be resolved anytime soon. As such, any approach aimed at increasing the rate of commercialisation would be advised to include means of addressing these (potentially conflicting) interests.

Another issue worth mentioning is that of data. Given the sheer number of TA different tools and methods, a large amount of data is required for the different analysis types (Pearson & Wegener, 2013). Gathering data is made more difficult in the case of MTRESs, given their relative novelty compared to traditional energy systems (Akella *et al.*, 2009). Management practitioners are forced to use their discretion regarding the costs and (potential) benefits involved (Lomborg, 2014). As such, it may be unlikely that the full range of TA tools and techniques of Figure A.4 would ever be implemented together.

Appendix A.6 Government action and policy

Government policy has traditionally been a key driver in the commercialisation of MTRESs, with governments' ability to establish energy markets affording them a prominent position in the process. In the past, governments have typically commercialised energy technologies in-house through a number of different plans and policies, with varying levels of success (Solomon & Krishna, 2011). However, this is changing with the increase in the number of IPP programmes globally, where governments establish the energy market through acting as the customer, with the responsibility of developing MTRES allocated to the private sector. As a result, government is now seen as an implementer of policy and initiatives designed to encourage the adoption of MTRESs by the private sector (Balachandra *et al.*, 2010). Hence, this evaluation will examine the different strategies available from a policy-making perspective to drive the creation of markets for MTRESs.

Lund (2009) classifies policy into two principal types: technology-push (R&D measures focused on technological innovation to improve supply), and market-pull (market-based measures aimed at fostering demand for the respective technology through various incentives). Haas *et al.* (2004) elaborate on market-pull type policies by dividing them into two additional categories: price-driven (see Figure A.5), where the price is fixed and the quantity (quota) determined by the market; and quantity-driven (see Figure A.6), where the quantity is fixed and the price determined by the market. These classifications offer policy-makers different options to meet their needs and objectives.

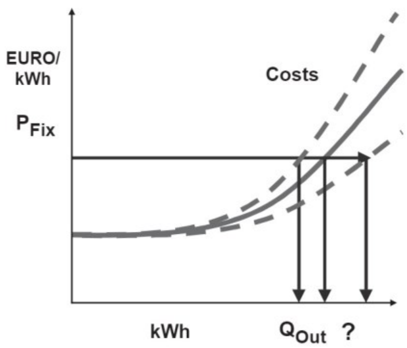


Figure A.5: Price-driven measures
(Source: Haas *et al.*, 2004)

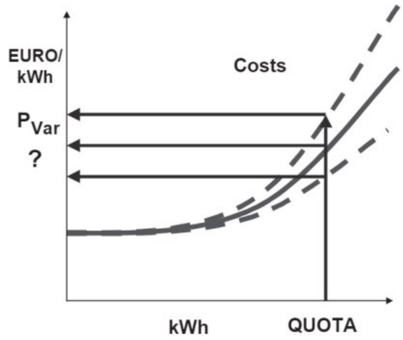


Figure A.6: Quantity-driven measures
(Source: Haas *et al.*, 2004)

Haas, Panzer, *et al.* (2011) provide a more detailed classification of market-pull type policies used for the promotion of MTRESs (see Table A.1). Direct policies are those which attempt to increase the adoption of MTRESs in the short-term. Indirect policies concentrate on the long-term conditions required for successful commercialisation. Voluntary approaches typically describe users' preference to pay a higher rate for electricity produced by renewable energy sources. These policies continue to highlight the various strategies available to policy-makers to achieve their goals. (Haas, Panzer, *et al.*, 2011)

Table A.1: MTRES promotion strategies

		Direct		Indirect
		Price-driven	Quantity-driven	
Regulatory	Investment focused	Investment incentives Tax credits Low interest/soft loans	Tendering system for investment grant	Environmental taxes Simplification of authorisation procedures Connexion charges, balancing costs
	Generation based	(Fixed) Feed-in tariffs Fixed premium system	Tendering system for long term contracts Tradable green certificate system	
Voluntary	Investment focused	Shareholder programs Contribution programs		Voluntary agreements
	Generation based	Green tariffs		

(Source: Haas, Panzer, *et al.*, 2011)

The primary discussion of market-pull policies revolves around the choice of FITs (price-driven) versus tradable green certificates (TGCs) (quantity driven). A FIT is a set price per unit of electricity (typically kWh) that a utility, supplier, or grid operator has to pay for by law. The price is determined by government, and can take shape in two ways:

1. A fixed amount is paid per unit of electricity produced, or;
2. A set amount is added to the existing electricity price; this approach tends to be more volatile due to the changing market price of electricity.

FITs are able to target specific MTRES technologies. A particularly popular variation is a stepped FIT, where the amount paid to MTRES developers decreases over time as the technology achieves greater cost reductions, increased profitability, and higher levels of commercialisation. (Haas, Panzer, *et al.*, 2011)

Quantity-driven TGCs operate on a system where the government establishes a set quantity or percentage of electricity to be generated from RE sources by one or more players in the electricity value chain, such as generators, retailers, or end-users. A market is typically developed to assist the role players of a TGC system, one where green certificates can be traded. The price of the certificates is determined through market forces, such as supply and demand. Each certificate represents the price paid for one unit of electricity (normally 1 MWh) produced from MTRESs, with the total capacity being equal to the quantity set by the government. Players have the option of either producing electricity from RE sources themselves, or buying a certificate from a green electricity supplier to meet their quota.

Penalties are enforced should the quota not be met within the allocated time span in the form of a buy-out price. (Haas, Panzer, *et al.*, 2011)

One issue with TGCs is the lack of focus on individual technologies. One could introduce separate TGCs based on different MTRESs, but this would result in smaller markets with lower liquidity. An alternative is to add weightings to the certificates to distinguish electricity supplied from different MTRESs (biofuel = 1, wind = 6, solar = 3 etc.). However, this raises questions regarding what the optimal mix of weightings is, bearing in mind it is likely to change over time, as well as what mix would be considered most acceptable to different stakeholders. (Haas, Panzer, *et al.*, 2011)

Another popular quantity-driven approach is a tender system. Two types of tender system exist:

1. Investment focused. A fixed quantity of electricity to be generated from RE sources is announced, followed by a bidding process where contracts are awarded to the winners. These contracts provide an advantageous investment environment, such as financial grants per installed kW; and
2. Generation focused. A similar process to the investment focused bidding process, except that in place of immediate financial support, government offers a bid price per kWh of electricity generated for a defined period of time.

Tender systems have placed a greater focus on the role provided by the private sector, challenging them to deliver the lowest economically feasible price possible. It is worth mentioning that some tender processes, such as the REI4P in South Africa, have included certain conditions that potential bidders need to fulfil, such as utilising local content for increased socio-economic growth. However, many of the systems have encountered lower levels of success than FITs, partly as a result of unrealistic winning bid prices, and the inability to secure the necessary operational permits. (Haas, Panzer, *et al.*, 2011)

A comparison of the experiences gained from the implementation of the two above mentioned measures in Europe (price-driven and quantity-driven) found that the use of a FIT structure is favoured over green certificates (Haas, Panzer, *et al.*, 2011). This is due to the ease of implementation and revision, lower administrative and societal costs, greater price certainty (more stable investment environment, lower financial risks), and the ability to distinguish between strategies applicable to existing and new capacities (Haas, Panzer, *et al.*, 2011). Furthermore, FITs present an effective and economic means of promoting a new technology, being able to focus on specific MTRESs (Haas, Resch, Panzer, Busch, Ragwitz, *et al.*, 2011). In an analysis of policy mechanisms implemented in Europe, Haas *et al.* (2004) presented similar findings, identifying FITs as the most popular option followed by rebates, tax incentives, tender systems, and green tariffs.

However, it needs to be acknowledged that a significant benefit of quantity-driven systems is that they permit governments to maintain control of the amount of additional electricity (sourced from RE systems) introduced into the national grid through the quota set (Haas, Panzer, *et al.*, 2011), and, perhaps more importantly, allows greater management of the sustainable growth of a (domestic) RE industry. Indeed, Geroski (2000) cautions against the rapid, unsustainable growth of a technology, stating that often overwhelming enthusiasm for a seemingly 'superior' technology may result in neglect of other, better technologies, resulting in an inferior or second best technology securing prominent status in the long term.

It is interesting to note how the use of market-pull policies differs between developing and developed countries. FITs, particularly those greater than the cost of generating electricity from RE sources and that meet investors' ROI requirements (Haas, Panzer, *et al.*, 2011), have encountered a significant degree of success in developed countries, partly due to their promotion of (market) surety through a fixed price, and ease of understanding and implementation. In comparison, many developing countries lack the financial reserves necessary to deploy FITs. They possess smaller RE markets, partly as a result of large rural populations, and often prioritise socio-economic considerations over the development of expensive RETs. (Eberhard, 2014)

The inability to implement FITs has led to the adoption of alternative mechanisms, such as TGCs and tender programmes. The REI4P in South Africa is one such example. Although some tender systems, such as the REI4P, have proved to be very successful, it is necessary to be aware of some of the challenges that exist. These include large transaction costs, as well as required resources and sufficient institutional capacity, elements which are frequently lacking in developing countries. (Eberhard, 2014)

Government action is not limited to market-pull policies. Many research institutions and centres of learning, such as universities, funded by governments, are focused on technology-push initiatives, which typically involve R&D into new MTRESs. The role played by these institutions in fostering learning, new knowledge, and innovation should not be underestimated, as the development of new ideas has resulted in start-up companies that have gone on to be successful, contributing greatly to the technological capabilities and socio-economic growth of many countries. (Taylor, 2008)

There has been some confusion regarding which government policies are termed market-pull, and which are technology-push (Taylor, 2008). In a bid to clarify matters, Taylor (2008) advocates the use of the term *'upstream investment'* for technology push policies, and *'market creation'* for market pull policies. Furthermore, she presents a third category of government policy, that of 'interface improvement'. Interface improvement is defined as: "*government actions which share a focus on improving the boundary space between innovators and technology consumers"* (Taylor, 2008).

Interface improvement policies concentrate on the players responsible for the installation of MTRESs, those who act as '*middle-men*' in ensuring that knowledge is transferred from the manufacturers to the final consumer (as well as to government through the legislative processes involved). Such actors are especially relevant to distributed solar energy technologies, where the technology's location is in close proximity to the consumer. These policies can also improve the rate of innovation by encouraging a bi-directional flow of knowledge, where manufacturers and designers receive feedback from installers and end-users for the purposes of product improvement. (Taylor, 2008)

Although the impact of government policies on the commercialisation of MTRESs cannot be understated, government cannot manage nor finance the entire MTRES industry. The private sector needs to work together with government to ensure a suitable environment is created conducive to the development of a sustainable MTRES industry. Furthermore, as stated by Musango & Brent (2011), sound energy policy is often affected by conflicting political agendas and interests. Thus, any commercialisation approach needs to provide some input on the role and capabilities required of the business sector. As such, it may be that any approach towards increasing the rate of commercialisation should attempt to limit government's role to market creation, while leaving technology management to the private sector.

One possible solution to this issue is raised by Hillman, Nilsson, Rickne & Magnusson (2011), who argue for the use of governance instead of policy, based on the assumption that "*the coordination necessary to achieve, for instance, sustainable innovations, relies on forms of social initiatives that often take place outside traditional policy instruments, which are implemented in a top-down fashion solely by nation state"*. The use of governance over policy offers the potential for a more inclusive management approach, one that incorporates other important stakeholders from the business sector and civil society into key decision-making processes. (Hillman *et al.*, 2011)

Appendix A.7 Technology roadmap

Another potential commercialisation approach for consideration is a technology roadmap (TRM) (see Figure A.7), defined by Jeffrey *et al.* (2013) as:

"a *medium to long term action plan to forecast the direction of future markets and developments in technology and help make strategic decisions, providing a critical link between technology investment decisions and business planning, and providing a structured approach for mapping the evolution and development of complex system*".

The strengths of this approach reside in its ability to address the many different type[97] of challenges faced by a technology before realising a commercialised state. (Amer & Daim, 2010).

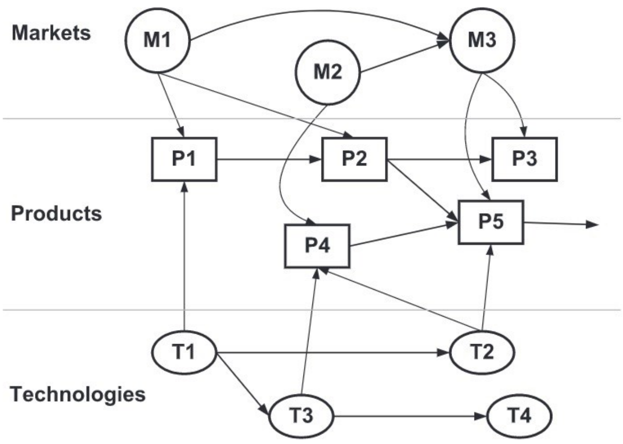


Figure A.7: Common TRM
(Source: Rinne, 2004)

TRMs frequently involve the integration of business thinking with science and technology into the development of complex systems, marking it a useful strategic device to improve the ability of management practitioners to oversee a technology's development towards a state of maturity (Amer & Daim, 2010). TRMs are able to be combined with different management techniques, such as technology portfolio methods, SWOT analysis, and innovation matrices, to solve complex issues in all industries, and with all types of technologies (Amer & Daim, 2010). This has seen it become a favoured tool for many firms, organisations, partnerships, and governments (Jeffrey *et al.*, 2013). Furthermore, TRMs possess the ability to create, and strengthen, relationships between different stakeholders, allowing for improved dialogue between parties due to stronger communication channels (IEA, 2010)

The role played by TRMs has changed over time. While they remain a popular and valuable managerial tool for single organisations, TRMs have experienced increased use by multiple organisations working together towards a common vision at an industry or sector level (Amer & Daim, 2010; Jeffrey *et al.*, 2013; Phaal, 2004). These organisation seek to leverage the benefits of mutual information sharing, establishment and strengthening of (new) partnerships, and efficient resource use (Amer & Daim, 2010; Jeffrey *et al.*, 2013; Phaal, 2004). This shift from single to multi-organisation TRMs is particularly useful in the context of the commercialisation process, where the improved coordination and communication between stakeholders, and more effective use of (limited) resources, is likely to increase the existing rate of commercialisation.

[97] These challenges are often of a technical, political, industry, or commercial nature (Amer & Daim, 2010).

An important distinction between single and multi-organisation TRMs lies between those who develop the TRM, and the target audience who make the decision to implement it. Single organisation TRMs are frequently able to obtain a high degree of commitment for their (practical) application, due to the involvement of all relevant stakeholders, including the target audience, in the TRM's development. The prospective target audience of multi-organisation TRMs, on the other hand, typically plays no role in its development. As such, multi-organisation TRMs have encountered the need to be more persuasive in nature, convincing the target audience of the respective TRM's strengths in order to ensure that the decision is made to adopt and implement the TRM, and its proposed actions. This proves particularly challenging in cases where the target audience may not agree with the TRM's recommendations, or may be pre-opposed to any actions sought. (Jeffrey *et al.*, 2013)

The emergence of multi-organisation TRMs has also seen a shift in the nature of TRMs. Whereas in the past, TRMs fulfilled the role of merely providing decision makers with strategic information relevant to their goals and objectives, present day TRMs attempt to influence policy-makers' decision-making, convincing them to implement the roadmap's recommendations. This strong focus on government policy, and the individuals behind it, takes a proactive stance on the development of policies favourable to the respective technology, which is particularly relevant in the case of MTRESs, where policies are required to generate energy markets. (Jeffrey *et al.*, 2013)

To date, many of the TRMs developed for the public sector have focused on energy technologies, with a significant percentage targeting MTRESs (Amer & Daim, 2010). One of the main benefits regarding the use of TRMs lies in its ability to provide a platform for the engagement of multiple stakeholders, giving individuals and organisations alike an opportunity to make their voice heard (Jeffrey *et al.*, 2013). Considering that the RE industry is one in which cooperation and coordination between stakeholders is essential, given the critical role of energy everyday life, a TRM appears to be well suited as a strategy for commercialising MTRESs. Furthermore, the focus of TRMs on R&D, and the practical implementation of any proposed actions, is likely to benefit their widespread adoption in the energy sector (Amer & Daim, 2010).

It is also worth considering how TRMs differ based on their level of application. Amer & Daim (2010) investigated the use of TRMs with MTRESs on a national, industry/sector, and organisational level. Although the majority of roadmaps are implemented at an industry/sector level, an overview of the objectives and drivers of each roadmap is presented in Tables A.2 - A.4, illustrating some of the key differences between the three levels (Amer & Daim, 2010). In the context of MTRESs, an industry/sector level TRM is most appropriate, although a national level TRM may also be considered (Amer & Daim, 2010). Table A.5 compares the key differences between these two TRM types.

Table A.2: Overview of a national level TRM

Objectives	Drivers
• Energy policy formulation at national/regional level • To ensure energy security of the country or region • Identify and prioritize key technologies for future development • Presenting insight information to the policy and decision makers • Give direction to the national energy sector • Becoming a world leader in Renewable Energy Technologies • Renewable energy portfolio planning • Establishing future targets of obtaining energy from renewable resources	• Increasing cost of energy • Increasing price of oil • Fossil fuel depletion • Energy independence • Global warming and CO_2/greenhouse gases emissions • Pollution reduction • Compliance with International agreements e.g. UNFCCC etc. • Reducing reliance on imported energy • Avoiding proliferation of nuclear technology

(Source: Amer & Daim, 2010)

Table A.3: Overview of an industry/sector level TRM

Objectives	Drivers
• Establish common vision of the industry	• Change in government policies (favoring renewable energy technologies)
• Provide future direction to the industry	• Increasing energy cost
• Increase collaboration within entire industry and with government	• Mandatory renewable portfolio standards
• Propose conducive policy framework to the government	• Exploit new business opportunities
• Identify key industry challenges and barriers from technical & commercial aspects	• Environmental concerns
• Forecast future energy markets	• Become a competitive industry globally
• Identify industry needs to become competitive	• Seek benefit from emerging technologies
• Develop industry standards and future technology performance milestones	• National renewable energy targets
• Formulate action plans and strategies to accelerate industry growth and rapid technology deployment	• Achieve energy independence
• To ensure availability of skilled workforce required to support technology growth	• Harnessing available renewable energy resources
• Assess availability of supply chain infrastructure to supports future growth	• Creation of green jobs
• Assess long-term financing requirement for the industry	
• Create positive perception among public related to green energy technologies	

(Source: Amer & Daim, 2010)

Table A.4: Overview of an organisational level TRM

Objectives	Drivers
• Communicate vision of the company	• Increasing price fossil fuel
• Link business and technology planning	• Pressure from government to generate renewable energy
• Provide a meaningful direction to the R&D efforts	• Compliance with mandatory renewable portfolio standards
• Prioritize R&D projects for the company	• Become a technology leader
• Identify technologies to invest in order to remain competitive	• Enhance competitiveness
• Identify key technical barriers and market challenges	• Environmental concerns
• Better resource allocation	• Creating positive image of company among customers
	• Seize new business opportunities
	• Exploiting new technologies

(Source: Amer & Daim, 2010)

Table A.5: National vs industry level TRMs

National Roadmaps	Industry Roadmaps
Address multiple renewable energy technologies suitable for country	Focus on one sector or technology with an in-depth analysis
Give guidelines to the entire energy sector of the country	Identify future direction for a particular technology or industry
Energy security, high energy cost, global warming, environmental degradation, and enhancing national competitiveness are the main drivers for national roadmaps	Increasing energy cost, changing governmental policies, new business opportunities, desire to exploit new technologies and available resources are the main drivers for industry roadmaps
Strategies are mentioned at a broad level	Detailed strategies are formulated and action items are identified
Technical and commercial barriers are briefly mentioned	Detailed technical and market analysis is performed and key challenges & barriers are identified
There is not much focus on the supply chain issues	Supply chain issues related to the introduction /deployment of new technologies are also considered
Overall targets for energy generation from various sources/technologies are established	Detailed technology performance improvement targets and technology cost reduction milestones are established

(Source: Amer & Daim, 2010)

The need to measure the success achieved by a commercialisation approach is often overlooked (Rinne, 2004), yet without which, it is difficult to draw accurate and reliable conclusions regarding an approach’s strengths and weaknesses. TRMs are frequently assessed according to whether the stated objectives have been met by the relevant organisation, or group of organisations, in the form of actions and policies (Jeffrey *et al.*, 2013), or milestones and metrics (IEA, 2010). In the context of multi-organisation TRMs, Jeffrey *et al.* (2013) identified nine metrics for measuring the progress achieved, presented in Table A.6, together with an explanation of how each metric is to be assessed. While applicable to primarily to TRMs, these factors have the potential to be adapted to other commercialisation strategies, allowing for comparisons to be made between them.

Table A.6: Multi-organisation TRM measurement metrics

Type	Metric	How metric is assessed
Metrics assessing the architecture of the TRM and how it was prepared.	1. Author	Scored depending on the reputation of the author and who they selected to be a part of the TRM process (this is a traditional success factor for compiling a roadmap).
	2. Target audience	Scored based on how well the roadmap addresses its entire target audience.
	3. Roadmap message, effectiveness of delivery	Analyses a roadmap's message and how well it is delivered, taking into account format consistency and language.
	4. Are the stakeholders adequately addressed?	Measures how well, and how evenly, the stakeholders relevant to the roadmap are addressed.
	5. Ease of use – method used	Measures how easy to follow the roadmap is for readers from a range of backgrounds.
Metrics assessing the results of the TRM and whether it has achieved its objectives.	6. Status of suggested policies	Scored based on whether the roadmap's suggested policies have been implemented or are in the process of being implemented.
	7. Citations and references	Scored based on the number of times the roadmap has been cited (highest weighting for citations by another roadmap or by government).
	8. Technology	Scored based on whether the roadmap's technology recommendations have been, or are in the process of being developed.
	9. Supply chain	Scored based on whether the roadmap's supply chain recommendations have been or are in the process of being implemented.

(Source: Jeffrey *et al.*, 2013)

The process of developing and implementing a TRM is no simple matter, especially with complex technologies such as MTRESs (Daim & Oliver, 2008). Figure A.8 displays the process followed in the development and implementation of a typical TRM. The division of the activities based on their stage in the overall process (planning and preparation, visioning and so forth) is valuable for those wishing to understand the entire process, together with the common time interval and number of people per activity, as well as the classification of the activities into two types: expert judgement and consensus, and data and analysis.

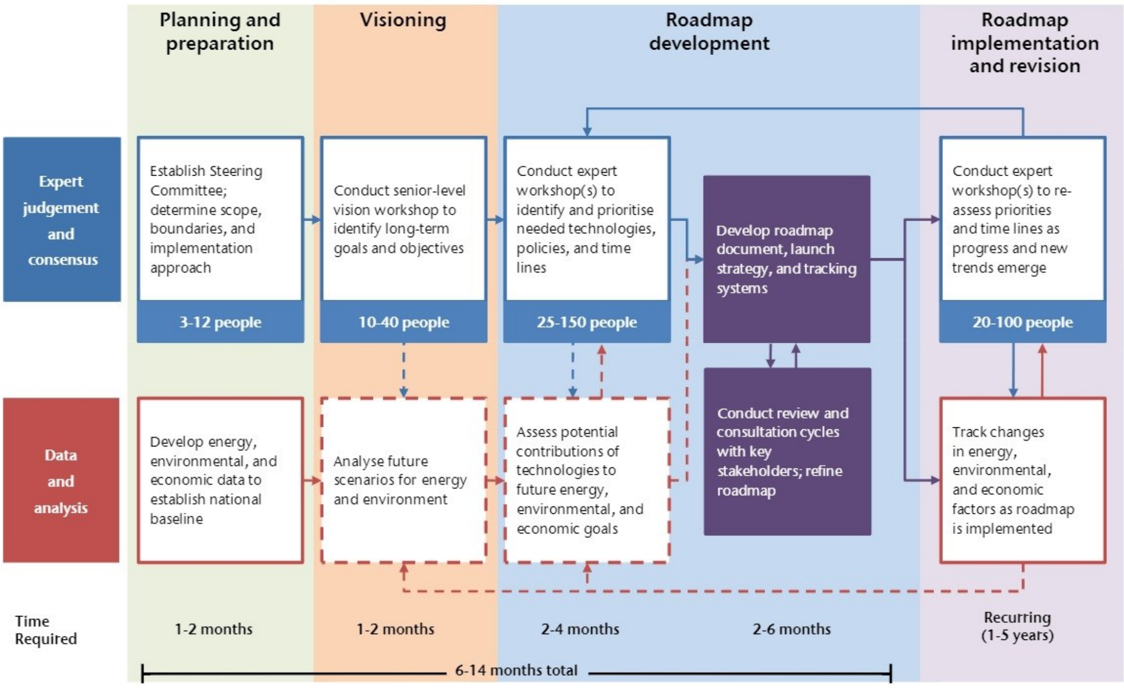


Figure A.8: TRM development process
(Source: IEA, 2010)

Following the application of the nine metrics of Table A.6 to four MTRES case studies, Jeffrey *et al.* (2013) established eight success factors to be considered in the design of a multi-organisation TRM (see Figure A.9). These success factors advocate the need for public-private partnerships, while highlighting aspects to be addressed to improve the chances of success in the TRM's development and implementation. The need to regularly revise and update the TRM is especially important, with many energy TRMs lacking this feature (Amer & Daim, 2010).

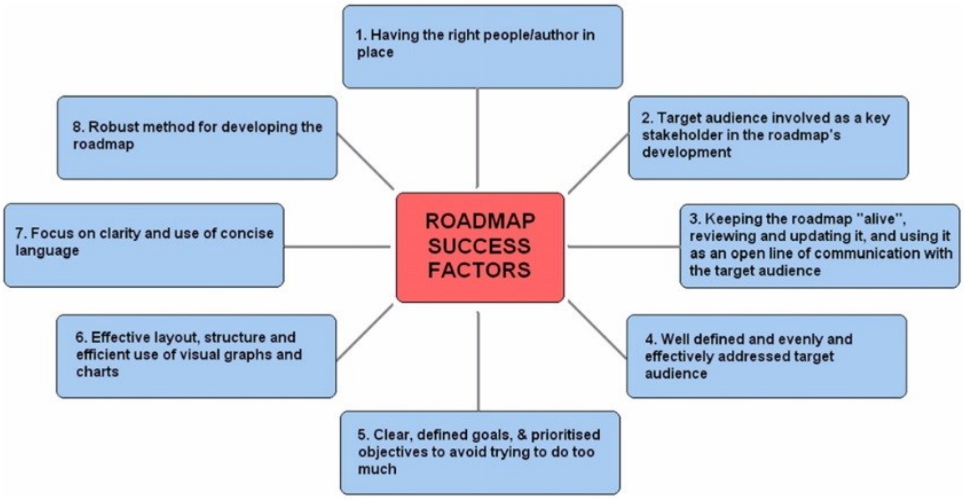


Figure A.9: Multi-organisation TRM success factors
(Source: Jeffrey *et al.*, 2013)

Although (multi-organisation) TRMs have many strengths that underline the tool as a viable commercialisation strategy, the strong focus on persuading policy-makers to implement the TRM's recommendations may prove both necessary yet challenging in situations where political agents are strongly opposed to MTRESs, favouring other energy technologies instead. Furthermore, the tendency for policy decision-makers to focus on short-term goals in order to support their bid for re-election, rather than medium- to long-term goals which may ultimately be of greater benefit for the MTRES commercialisation process is problematic to say the least. TRMs also face the risk of being made redundant on a regular basis should the environment in which the commercialisation of MTRESs be subject to rapid (political) change. As such, the use of a TRM as a commercialisation tool may be more applicable should an elementary approach be employed, one which allows for the creation of new TRMs on a rapid basis in response to any significant changes that occur, and which may affect the rate at which the commercialisation of MTRESs takes place.

Appendix A.8 Architecture framework

Having evaluated a number of different commercialisation strategies and approaches so far, it is clear that a more appropriate method may be one which is able to accommodate the strengths of this discussed, and mitigate the weaknesses identified. However, any strategy that seeks to integrate a number of tools and methods needs to carefully consider the impact that the interfaces between the different tools and methods may have on the collective whole. For this reason, it is perhaps better to utilise an architecture framework approach for commercialising of MTRESs.

An architecture framework is a systems engineering tool used to analyse complex systems, dealing *"not only with the form and function of systems themselves, but also with interfaces between systems and with external factors and processes"* (Davis, Mazzuchi & Sarkani, 2012). The key role played by architecture frameworks lies in the ability to handle problems containing inherent uncertainty and poor organisation, by simplifying the problem, and concentrating on the primary issues (Davis *et al.*, 2012). Such a tool is therefore of special interest to MTRESs, which currently possess a significant degree of uncertainty in the energy sector (Santos, Soares, Mendes & Ferreira, 2014). Furthermore, it offers benefits to management practitioners, as it "*does not so much pursue an optimal solution, but instead supports integrated decision-making and thinking in terms of systems"* (Davis *et al.*, 2012).

Davis *et al.* (2012) present an architecture framework (see Figure A.10) focused on the transition to, and development of, MTRESs through the use of a portfolio of projects. It comprises seven major aspects: Administrative, Analysis, Projects, Current State, Future States, Objectives, and Stakeholders. The framework proposed is extensive, addressing numerous aspects of the commercialisation process, such as the key objectives, views and roles of different stakeholders, and the fact that these aspects are likely to change over time. (Davis *et al.*, 2012)

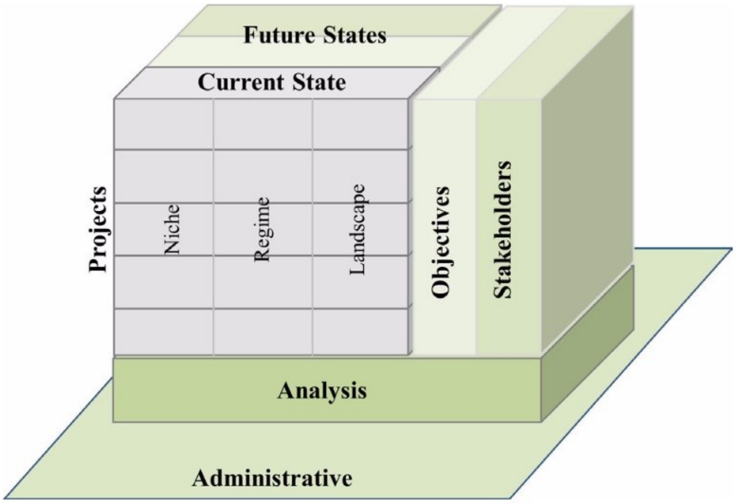


Figure A.10: Architecture framework
(Source: Davis *et al.*, 2012)

Another advantage of the architecture framework is its iterative nature, designed to accommodate and organise new data, while recognising the ongoing structural evolutions with reference to the existing technological system. Furthermore, the forward-looking nature of this tool is particularly useful regarding the decision-making process, allowing for decisions to be made that will provide short-, medium-, and long-term benefits, as well as measuring progress towards various objectives. Finally, the tool's graphic portrayal allows for easy visualisation of the aspects described, and how they, and their interfaces, interact. (Davis *et al.*, 2012)

One criticism of the architecture framework presented here is the lack of mention given to the organisational capabilities required to manage the commercialisation process successfully, with the central focus being on the technological nature of MTRESs. Greater input relating to (novel) mechanisms aimed at market expansion and finance would also strengthen this tool for use in commercialising MTRESs, and overcoming the technology valley of death. Finally, the inclusion of specific objectives and metrics would contribute towards gauging the progress achieved in the commercialisation process.

Appendix A.9 Business model

Balachandra *et al.* (2010) present a business model approach (see Figure A.11) for commercialising MTRESs. In addition to a strong focus on the role that the business sector has to play, the model addresses many features necessary for the commercialisation process, such as the development of partnerships between stakeholders[98], the use of innovative financial[99] schemes to overcome some of the high initial costs of MTRESs, innovative

[98] Techno-entrepreneurs, education, research, enterprise, finance, government (Balachandra *et al.*, 2010).
[99] Leasing, venture capital, micro-credit, government loan guarantees (Balachandra *et al.*, 2010).

marketing[100] and incentive[101] schemes to support the expansion of the existing consumer market, and regulatory policies to promote an environment conducive to the commercialisation of MTRESs (Balachandra *et al.*, 2010). Indeed, one may argue that this approach presents the most complete strategy thus far, with the greatest possibility of increasing the rate of commercialisation of MTRESs, one which provides greater practical advice than the other approaches evaluated so far.

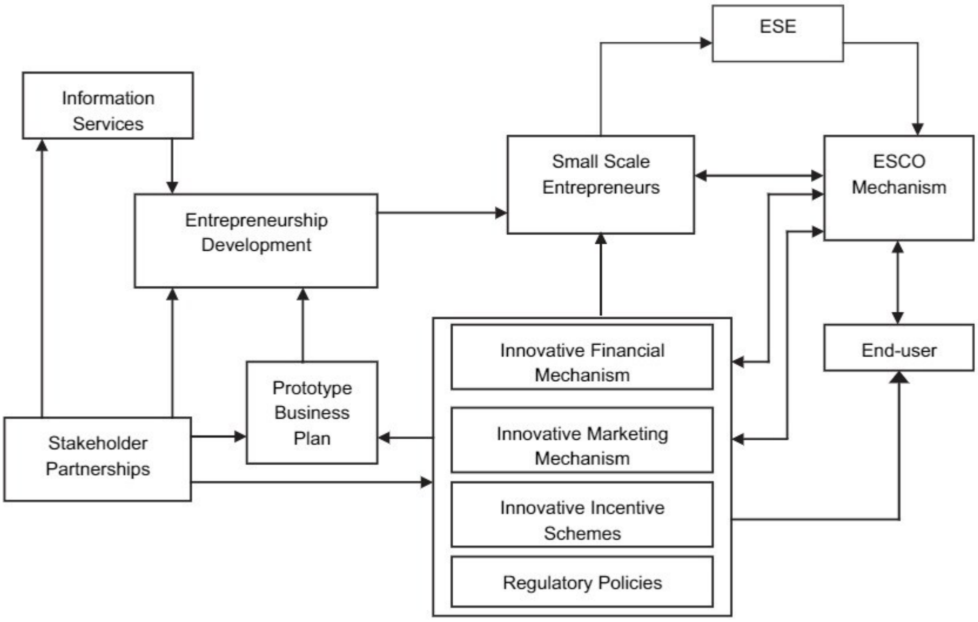


Figure A.11: A business model for technology commercialisation
(Source: Balachandra *et al.*, 2010)

However, the business model is faced with several shortcomings. Although the information services component does discuss the importance of information diffusion with respect to the commercialisation process, it lacks the comprehensiveness of other TA tools that allow for the development of a more solid understanding of MTRESs, and the underlying hierarchy of technologies (Murmann & Frenken, 2006). The model lacks sufficient mention of the organisational capabilities required to achieve significant progress towards a commercialised state, nor does it possess the persuasive nature of multi-organisation TRMs. Furthermore, businesses often focus on maximising the ROI offered to shareholders at the expense of long-term sustainability (Rotmans, Kemp & Van Asselt, 2001). Finally, while the illustration of the model in Figure A.11 provides some indication of the relationships between the various components, it does not describe these interfaces in any great detail, or offer insight into how the model as a whole may be implemented.

It is important to acknowledge that there is no single universal business model for the RE industry. Hence, it may be worthwhile examining the process behind the development of such models. Figure A.12 presents an extensive framework by which an organisation can develop a structure suited for the RE industry. Each organisation can utilise the building blocks of the framework, and adapt them to suit their own needs and objectives. The purpose of this framework is to assist management practitioners in establishing a structure that allows for success within the RE industry, both on an organisational and partnership level. The process remedies the lack of recognition given to the capabilities required for commercialisation of

[100] Involvement of energy service providers to provide all energy-related services, combined and advertised as a single product (Balachandra *et al.*, 2010).

[101] Reimburse expenses incurred on MTRES purchase, mortgaging, green energy credits, tax incentives, energy price discounts (Balachandra *et al.*, 2010).

MTRESs. However, being a business model, it is understandably geared towards generating a ROI, and as such, neglects aspects of the commercialisation process such as the role played by government, the impact of peoples' decision making to suit their own interests and agendas, and other social phenomenon such as local opposition to such projects if considered undesirable.

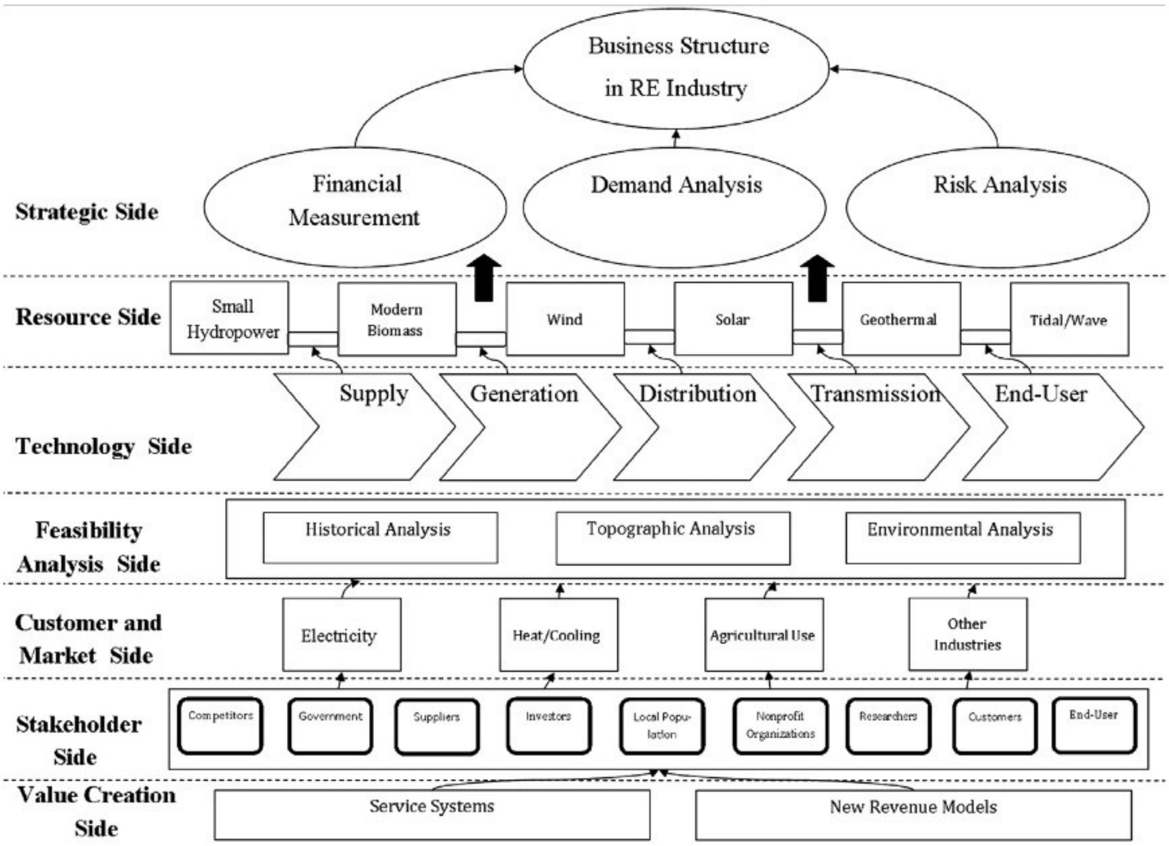


Figure A.12: Framework for creating a business model for the RE sector
(Source: Aslani & Mohaghar, 2013)

Appendix A.10 Applicability to CSP technologies in South Africa

Having evaluated several strategies, approaches, and techniques for the commercialisation of MTRESs, we now consider the applicability of each method to the case of CSP technologies in South Africa, the focus of this research study. These strategies are positioned in the current CSP environment in South Africa, where it appears that there is little interest on a national government level in pursuing CSP on a large-scale in the country's future energy mix. A brief commentary is provided on each strategy.

The first strategy, in-house development, is likely to have limited applications, with its potential limited to basic CSP technologies, with a greater focus on intangible CSP technology, such as the development of solutions to any operational issues encountered as more CSP plants commissioned through REI4P come online and production processes. The second strategy, joint commercialisation, is heavily dependent on whether any new CSP projects are allocated based on REI4P. It is more likely to experience use in the form of alliances with external partners who have an interest in developing CSP technology for an external market.

The third strategy, technology transfer, is arguably the commercialisation strategy with the greatest potential for use in South Africa, whereby CSP technologies developed in the country can be transferred to international markets. This may prove feasible as a result of research conducted by specialised CSP research groups, such as STERG at Stellenbosch University.

In addition, the transfer of knowledge may also happen on an organisational level, thus overlapping with in-house development, being transferred from one department to another.

A TLC analysis is useful in positioning various CSP technologies into their current life cycle phase. However, without the inclusion of other information, and provision for influential entities such as government, it fails to present an adequate approach to the commercialisation of CSP technologies in South Africa. While the use of TA provides a more systematic view of CSP technologies and related factors, both these tools are data-intensive. In the context of South Africa, a developing country, a potential lack of availability of date may make it difficult to accurate position CSP technologies on the s-curve.

Government action has achieved some measure of success in South Africa, such as REI4P. However, policy uncertainty continues to be a threat to investors' confidence, together with the higher priority that is frequently given to socio-economic goals. Policy making also remains centralised at national government, with provincial and local government afforded relatively little scope to enact their policies to advance the CSP industry. Therefore, relying on government policy alone for the commercialisation of CSP technologies will likely result in a persistent slow rate of commercialisation.

The use of TRMs with CSP technologies, both globally and in South Africa, has already received attention from energy experts and policy makers over the past decade (IEA, 2010) While the TRMs developed thus far deal with numerous technological and market-related factors concerning the commercialisation of CSP and other MTRESs in South Africa, there has been little effort to update and revise the TRMs on a regular basis. This is troublesome if one considers that "*roadmaps are more effective when developed as an ongoing process rather than a one-off document*" (McDowall, 2012). Moreover, the issues surrounding the absence of social acceptance and knowledge regarding CSP technologies features more prominently in South Africa. This may be attributed to the poor standard of education in the country, as well as a lack of public awareness of such technologies, and the advantages they offer compared to other energy technologies. Hence, any commercialisation strategy will require a greater focus on these people-related issues in the South African context.

The business model approach, while addressing many of the aspects required at overcoming the barriers to the commercialisation process, gives no indication of how it may be tailored to the specific needs of CSP technologies, given that the private sector in South Africa lacks widespread knowledge of CSP, and has relatively little experience with business models of a RE nature within the wider energy sector. In addition, the lack of attention given to the alignment of the different components and their interfaces may give rise to misunderstanding and conflict, which frequently results in violence and damage to property in South Africa.

It would appear that an architecture framework is likely to be the approach best suited for commercialising CSP technologies. CSP technologies are complex systems, requiring a systems engineering tool to be fully understood. As such, a tool similar to the architecture framework may prove a sound choice, one able to integrate several different elements into a single tool, and thus harmonise the strengths of the different strategies evaluated. The attention given to the various interfaces between CSP systems and the external environment is also of importance. Finally, the inherent uncertainty that faces the CSP industry in South Africa due to current government policy further supports the use of an architecture framework in the context of the commercialisation process. However, careful thought is needed regarding how the other strategies evaluated may be incorporated into a single approach, and to what extent.

Appendix B

Identification of barriers to the commercialisation of MTRESs

Appendix B presents the methodology used to identify barriers from literature currently limiting the rate of commercialisation achieved by MTRESs.

Appendix B.1 Present barriers to the commercialisation of MTRESs

A review was conducted of literature to identify barriers presently limiting the commercialisation process of MTRESs. Once identified, each barrier was categorised as technical (T), financial and economic (F & E), or organisational, institutional, and social (O, I & S) (see Table B.). In the case where the barrier identified was generic enough to be applicable to all these categories it was assigned a G. It is acknowledged that a more extensive review of the literature may have identified barriers not listed here. The following reference sources were used:

1. Aslani (2015)
2. Negro *et al.* (2012)
3. Suzuki (2013)
4. Stapleton (2009)
5. Grobbelaar *et al.* (2014)
6. Eleftheriadis & Anagnostopoulou (2015)
7. Stigka, Paravantis & Mihalakakou (2014)
8. Bhattacharyya (2013)
9. Pfeiffer & Mulder (2013)
10. Balachandra *et al* (2010)
11. Reddy & Painuly (2004)

Table B.1: Barriers to the commercialisation of MTRESs

		Reference source										
Barrier	**Categorisation**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Lack of funding & access to financial capital	F & E	X	X	X		X	X		X	X		X
Lack of (access to) information: RE market, demand, and potential	F & E	X										
Ineffective implementation of commercialisation plans	O, I & S	X								X		
Policy ambiguity & uncertainty; stop-and-go policies	O, I & S	X	X		X	X	X		X	X		
Low cost-effectiveness for end users	T, F & E	X		X				X			X	
High costs: investment, O&M, construction etc.	F & E	X		X		X	X		X		X	X
Lack of sufficient supportive government policies and incentives	O, I & S	X	X	X	X	X			X		X	X
Low public knowledge, awareness and acceptance (of MTRESs)	O, I & S	X		X			X	X		X		X
Lack of knowledge and familiarity with green financing mechanisms	O, I & S	X		X		X			X			
Lack of robust planning of RE development at strategic and planning levels (for medium- to long-term)	O, I & S	X		X	X		X			X		
Low storage capacity of MTRESs compared to fossil fuel technologies	T	X										

Gap between (university) research projects and market needs	O, I & S	X	X									
Low (technical) quality standard of MTRESs	T	X			X						X	X
Lack of specialised & skilled workforce and skills & training programmes	O, I & S	X	X	X	X		X				X	X
Existing market structure: dominance of fossil-fuel technologies and lack of competition	F & E, O, I & S	X	X	X			X		X	X	X	X
Site location selection	T, O, I & S	X						X				X
Inadequate/ineffective engagement & coordination between stakeholders	O, I & S	X	X		X	X	X	X	X	X		
Lack of (access to) grid infrastructure	T, O, I & S	X	X	X		X	X		X			
Economic and market instability	F & E	X		X						X		
Lack of start-up firm support through science and technology parks, incubators etc.	O, I & S	X				X						
Poor identification of potential adopters	O, I & S	X										
Poor post-adoption support	O, I & S	X			X			X				
Economies of scale	F & E	X	X									
Attitude, strategy, and dominance of established players; lack of political will	O, I & S		X									
Policy misalignment (between government departments)	O, I & S		X		X	X	X		X	X		
Lack of legitimacy	T, O, I & S		X					X				
Lack of (access to) information: technical and O&M	T		X	X	X	X						X
Lack of (strong) networks, platforms and associations for MTRES promotion & development	O, I & S		X		X							
Political instability	O, I & S			X					X	X		
Dominance of government over private sector involvement in energy sector	O, I & S		X	X	X	X						
Large risk profile	G		X				X		X			X
Lack of enabling regulatory environment	O, I & S			X	X	X						
Insufficient protection of IP rights	O, I & S			X								
Lack of (access to) information: regulations	O, I & S			X								
Lack of technical, operating and quality standards	T				X							
Lack of a strong supportive manufacturing industry	G					X	X					

Lack of technical/O&M experience with such technologies	T					X						
Lack of interest from public and private sectors	O, I & S						X	X			X	
Local opposition to plant construction	O, I & S						X	X				
Long payback period	F & E						X					
Administrative barriers	O, I & S							X				
Financial sustainability & bankability	F & E								X			

Appendix C

Technology assessment tools and methods

Appendix C provides a detailed discussion of the various TA tools and methods included in the initial strategic management framework. Six broad areas of analysis are covered: economic analysis, systems analysis, technical performance assessment, risk assessment, market analysis, and externalities/impact analysis.

Appendix C.1 Economic analysis

One of the most significant barriers to the commercialisation of MTRESs is cost. New technologies are frequently expensive due to a lack of widespread resources, such as knowledge and raw materials, and the benefits accrued through economies of scale. Thus, it is important to have a firm grasp of the economics surrounding MTRESs, and the means of measuring, and aiding, their economic development. Table C.1 presents the economic analysis tools and methods included in the strategic management framework.

Table C.1: Economic analysis tools and methods

Method/ tool	Description	Relevance to framework
Cost benefit analysis	Compares the costs associated with a technology versus the prospective benefits it presents (to stakeholders).	Useful in quantifying the benefits of MTRESs, and comparing them to the associated costs. Assists the decision-making process in deciding whether to proceed with a MTRES, namely: do the benefits outweigh the costs involved?
Lifecycle cost assessment	An assessment of the total cost involved in the entire lifecycle of a technology.	A lifecycle cost assessment is difficult to forecast accurately, especially with relatively new technologies such as MTRESs. While the costs of established technologies, such as turbines and pumps, may be fairly constant and easy to predict, newer technologies[102] within such systems are experiencing substantial price decreases, due to improved learning rates and economies of scale. Fortunately, the majority of the costs of MTRESs are incurred upfront, making this an easier exercise, with changing costs over time applying primarily to O&M . However, for those components sourced from abroad, volatile local currencies make cost estimation a challenging exercise.
Net present value	The time-discounted sum of the revenue and expenses of a technology over its lifespan, namely: the present monetary value MTRESs are able to offer (to investors).	Investment can be attracted more easily if MTRESs offer large positive net present value (NPV) values. NPV is useful as a means of tracking progress in the commercialisation process, as falling costs and the emergence of additional revenue streams result in higher NPV values.
ROI	The return that investors can expect to earn on their investment. Typically expressed as a percentage.	Investors will have certain ROI targets to reach, based on expectations relating to technological performance and their appetite for risk. If MTRESs are able to meet these target values, more capital will be available for further investment in the technology.
Payback period analysis	Analysis of the number of years it will take to pay back the initial (capital) investment	MTRESs typically have long payback periods due to the large upfront costs. As such, many investors prefer to pursue short-term returns in other industries. However, such payback periods are preferable when compared to other energy technologies (coal & nuclear). Furthermore, the sale of electricity represents a consistent form of revenue, mitigating the risks involved somewhat.

Appendix C.2 Systems analysis

MTRESs are complex systems, containing technologies that lie at different stages in their individual lifecycles. In the modern technological environment, a variety of software packages are available to model, simulate, and analyse the interaction between various technological

[102] An example is central receiver and heliostat technologies within CSP systems.

subsystems (of MTRESs). Table C.2 presents the systems analysis tools and methods incorporated into the strategic management framework.

Table C.2: Systems analysis tools and methods

Method/tool	Description	Relevance to framework
Technology portfolio management	A technology portfolio is able to generate, on average, a higher ROI than investments in a single technology, and at risk. The fundamental principle is that through diversity of investment, poorly performing technologies are offset by technologies that perform well. Important aspects to consider are the relevant patents and licenses that accompany the respective technology.	A technology portfolio can be used to leverage deployment of MTRESs within the commercial, industrial, and utility-scale market segments, and include uses other than pure electricity generation i.e. solar thermal heat in the case of CSP technologies. This will support the respective MTRES industry's development, lowering the level of risk and generating a higher average ROI for investors.
Simulation modelling & analysis	Model and analyse (through simulation) a variety of aspects, scenarios, and events that may affect a technology.	Model and analyse (through simulation) various performance aspects relating to MTRESs, thus highlighting future areas for R&D, contributing to the growing knowledge base, and improving the learning rate.
Systems dynamics	Analyse the different dynamics of a system, and how their interactions shape the overall performance.	Provide greater information regarding MTRESs' performance and resilience to varying market forces and externalities. Highlights future areas for R&D, contributes to the growing knowledge base, and improves the learning rate.

Appendix C.3 Technical performance assessment

Expanding the existing knowledge base of the various technical performance aspects of MTRESs can assist R&D efforts by identifying the key focus areas necessary to improve future system design and operation. Table C.3 presents the technical performance assessment tools and methods included in the strategic management framework.

Table C.3: Technical performance assessment tools and methods

Method/tool	Description	Relevance to framework
Trial use periods	A period of initial use of a (new) technology aimed at increasing the understanding of its functionality, and any issues arising from its use.	Can be used to improve understanding of the performance of MTRESs, and highlight areas for future research. Also used to assess the readiness of different MTRESs and their subtechnologies for market entry.
Human factor analysis – ergonomics studies	A tool originally used by the US Navy and Air Force to mitigate human error. People form a key element of any process. It is thus vital to understand the influence people may exert on (new) technologies.	People are responsible for making decisions that will either assist or limit the advancements of MTRESs. Ignoring such a crucial element in the commercialisation process will drastically reduce the possibility of MTRESs reaching market maturity. In addition, this tool can be used to minimise the possibility of human error with respect to the development, construction, operation and maintenance of different MTRESs, and so forth.
S-curve analysis	Used to measure technological progress as a technology moves through its life cycle.	By accurately positioning MTRESs in their respective life cycle phases,

Method/tool	Description	Relevance to framework
		it is possible to identify which activities may prove most beneficial in the rapid transition to market, and assist managers in implementing the appropriate (marketing) strategy.
Beta testing	Subsequent rounds of testing aimed at optimising certain aspects of a technology. Contributes to the knowledge of a technology's performance during extended, and often more stressful, periods of use. Can be used to link bridge theoretical with actual performance.	Beta testing, and subsequent optimisation, of MTRESs, such as the central receiver and heliostat subsystems, can result in greater electricity output at a lower cost.

Appendix C.4 Risk assessment

Risk assessment is a necessary analysis of any technology. By being well-informed of the risks associated with MTRESs, measures can be implemented to mitigate such risks, thus improving confidence in the technology. Table C.4 presents the risk assessment tools and methods incorporated into the strategic management framework.

Table C.4: Risk assessment tools and methods

Method/tool	Description	Relevance to framework
Simulation modelling & analysis	Model and analyse the various risks associated with a new technology.	MTRESs are subject to a variety of risks. The effect of these risks may be magnified due to the vulnerability of such technologies as a result of them lying in a growth phase.
Probabilistic risk assessment	Assesses the probability with which risks may occur. Used to prioritise those risks which have a greater likelihood of occurring.	Through identification of the risks with the greatest probability of occurring, it is possible to develop appropriate risk mitigation measures. This will reduce the number and severity of threats to MTRESs, and the overall commercialisation process.
Risk-based decision trees	Decision trees are used to incorporate the risks involved with a technology into the decision-making process.	Allows for a rational approach to be taken with regards to the assessment and management of risks to MTRESs, thus improving the decision-making process.

Appendix C.5 Market analysis

A market analysis is crucial to nurture a technology from an early growth phase towards maturity, aiding efforts to expand the existing market through new applications and consumers willing to adopt it. Table C.5 presents the market analysis tools and methods included in the strategic management framework.

Table C.5: Market analysis tools and methods

Method/tool	Description	Relevance to framework
Market push/pull analysis	Analysis of market push and pull forces associated with a respective technology. May form part of a broader industry analysis, demand- and supply-side analysis, or analysis of the relevant industry actors. In addition, the analysis may include a breakdown of the market into its different consumer segments.	Identify market segments available for different MTRESs. Identify a selection of market push and pull forces and initiatives that can be used to increase the rate of commercialisation of MTRESs.
S-curve analysis	Understand how technologies in a system contribute to the positioning of	Recognise the multi-technology nature of MTRESs. Decide on lowest

Method/tool	Description	Relevance to framework
	the entire energy system on its respective s-curve.	level of technologies in system to conduct analysis. Target those technologies of the system in a pre-commercial phase.
Competitor analysis	Although competitor analysis is not an explicitly stated tool of those listed by Peach (2010), it is crucial to possess knowledge of the strengths and weaknesses of competitors to a (new) technology within an industry. Includes means of limiting the influence of the competition, as well as the competitors' ability to remain relevant in a rapidly changing energy landscape. Analysis can be based on a technological and/or organisational basis.	A solid understanding of those firms within the energy sector whose energy technologies compete against MTRESs allows for the forecasting of their actions to some extent. Pre-emptive action can be taken to obtain a greater market share for MTRESs.
Multigenerational technology diffusion	Analysis of technology diffusion across multiple generations, based on units of time and new technologies.	Realisation that current models of MTRESs evolved from earlier designs, and that future technological versions of MTRESs may be different to the current designs.

Appendix C.6 Externalities/impact analysis

Considers the effect that externalities may have on MTRESs, and vice versa. While externalities are, to a certain extent, unpredictable, measures can nonetheless be implemented to limit the (detrimental) effect they may have, as well as harnessing the positive impacts of MTRESs to improve social awareness, and gain favourable public opinion. Table C.6 presents the externalities/impact analysis tools and methods incorporated into the strategic management framework.

Table C.6: Externalities/impact analysis tools and methods

Method/tool	Description	Relevance to framework
Social impact analysis	Analysis of the different ways a (new) technology may impact on society, and the potential for social events to influence technological development.	Use to ensure a positive social impact of MTRESs, increasing the rate of social acceptance of such technologies. Implement measures to predict, and mitigate, any negative effects of social events.
Political impact analysis	Analysis of the different ways a (new) technology may impact on the political sphere, and the potential for political events to influence technological development	Use as a means of gauging and improving political support for MTRESs. Implement measures to predict and mitigate any negative effects of political events.
Environmental analysis	Analysis of the environmental impact a (new) technology may pose, and the potential for environmental events to influence technological development.	By learning about the potential environmental impact of MTRESs, action can be taken to mitigate any detrimental influences, and realise positive environmental impacts.
Life cycle analysis	Analysis of the complete lifecycle of a (new) technology	Focus on how externalities may impact on the life cycle of MTRESs. Implement measures to make the technology more robust, and less susceptible to the negative effects of such externalities.
Integrated impact analysis	Analysis of how different events and impacts may	Recognition of the potential for seemingly unrelated events and circumstances to have an integrated impact on MTRESs can improve the

	combine to impact a (new) technology.	technology's design, and overall resilience, to market forces, and other externalities.

Appendix D

Market adoption, promotion and penetration strategies

Appendix D provides more detail behind the development of the four MAPPSs of the initial strategic management framework, namely: government policy, business sector, educational activities, and social acceptance.

Appendix D.1 Overview of government policy

Appendix D.1.1 Market-pull policies

The existing literature on market-pull policies was explored in an attempt to identify as many different policies as possible for inclusion in the strategic management framework, presenting management practitioners with a wide selection of policies from which to choose and implement as they see fit. Following identification of these policies, their past performance globally was also assessed to provide guidance regarding the choice of policy in the framework's implementation, as well as investigation into a respectable ROI that such policies should seek to provide as an incentive for investors.

Table D. lists the market pull policies identified, while the reference sources used are as follows:

1. Haas, Panzer, *et al.* (2011)
2. Taylor (2008)
3. Abdmouleh *et al.* (2015)
4. Eberhard (2014)
5. Harmelink, Voogt & Cremer (2004)
6. Solangi, Islam, Saidur, Rahim & Fayaz (2011)
7. Papapetrou (2014)
8. South African Institute of International Affairs (2012)
9. Msimanga & Sebitosi (2014)
10. Grobbelaar *et al.* (2014)

Table D.1: Identification of market pull policies

	Reference source									
Market-pull policy	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
FIT	X	X	X	X	X	X	X	X		X
Tender bid programme	X		X	X	X	X	X	X	X	X
Auction				X				X	X	
Reverse auction				X						
Tax/investment incentives	X	X	X		X	X		X	X	X
Carbon / environmental tax	X		X		X					
Carbon credits / CERs								X	X	
Loans and bonds		X	X							
TGCs	X	X	X		X			X		
Renewable portfolio standards / quotas	X		X		X	X		X	X	
Voluntary green pricing scheme			X		X					
Wheeling agreement							X			
Grid access legislation			X							X
(Installation) Rebate		X						X	X	

Haas, Panzer, *et al.* (2011) analysed various market-pull policies in Europe based on their effectiveness[103] and economic efficiency[104]. Data is often more readily available in developed

[103] The ability to increase the amount of installed power capacity of energy technologies relative to the addition potential e.g. the amount of additional installed capacity or electricity generated per year or per capita (Haas, Panzer, *et al.*, 2011).

[104] The optimal allocation of resources to minimise waste and inefficiency (Haas, Panzer, *et al.*, 2011), either by maximising output from a given set of inputs, or minimising input for a given set of outputs (Aslani *et al.*, 2013). In

countries than developing countries (Goldberg & Pavcnik, 2006), allowing for more extensive analyses to be conducted. While it is recognised that policy performance depends on many factors, such as country of implementation (developed vs developing), type of MTRES targeted, and the degree of government and societal support, the lessons learned still hold value for management practitioners concerning the choice of policy with respect to increasing the rate of commercialisation achieved.

Figure D. compares the average annual effectiveness of various market-pull policies implemented in European countries from 1998 – 2005. Although the figure reflects additional electricity generation predominantly from onshore wind and solar PV, it is assumed that the data would reflect similar results for other MTRESs, such as CSP. FITs appear to be the most effective policy implemented, followed by quotas/TGCs and tax incentives/investment grants.

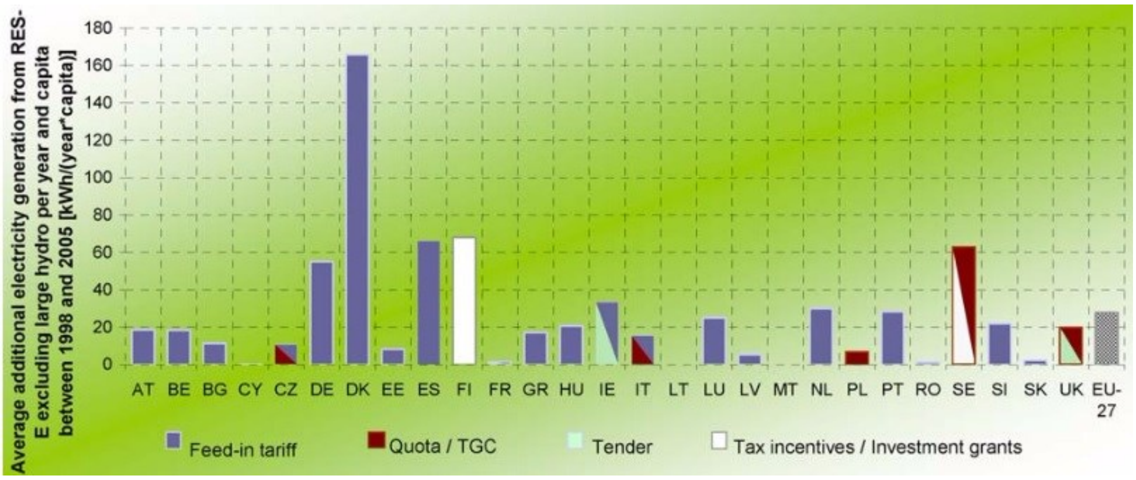


Figure D.1: Effectiveness of market-pull policies implemented in Europe (kWh/year) 1998 - 2005

(Source: Haas, Panzer, *et al.*, 2011)

The effectiveness of policies can also be measured through their respective support levels, represented by the levelised profit, as illustrated in Figure D.2. Surprisingly, FITs with low levels of support were fairly effective, while quotas and TGCs, which have high levels of support, were not as effective. One reason identified for this trend is the relatively low buy-out price of quotas and TGCs, offering an easy way out for companies unwilling to comply with the policy. (Haas, Panzer, *et al.*, 2011)

the context of energy technologies, this refers to the lowest cost of new electricity generation from RE sources (Haas, Panzer, *et al.*, 2011).

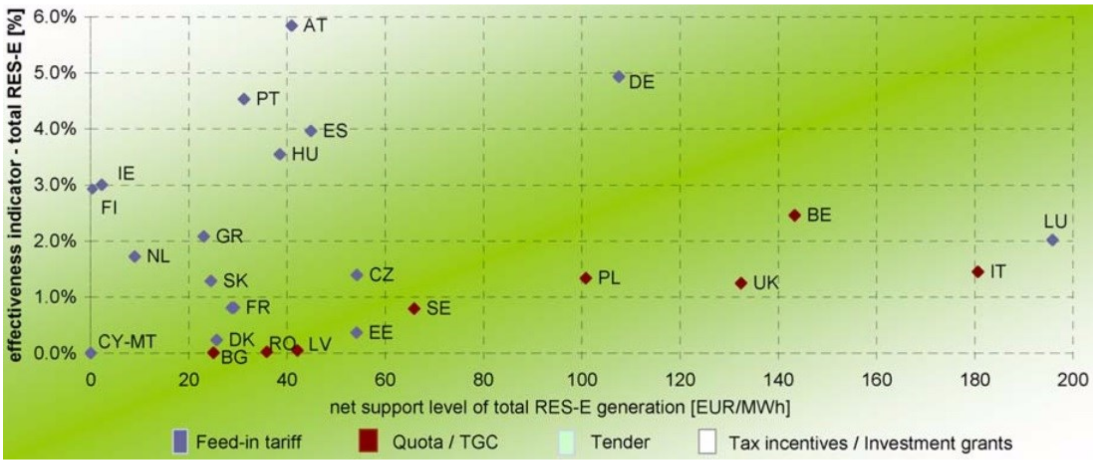


Figure D.2: Economic efficiency of market pull policies in Europe 2005-2006
(Source: Haas, Panzer, *et al.*, 2011)

There is some debate surrounding the ROI that governments should seek to incorporate into policy incentives to promote investment in RE projects. Many investors lack significant experience with the RE industry, increasing their level of risk aversion to such projects (Aslani & Mohaghar, 2013). To compensate for the increased risk, investors typically require a higher ROI (Fay & Kumar, 2013). Apart from investors' level of risk aversion, ROI is subject to many other factors, such as political stability and macroeconomic conditions (Zacks, 2017). In the now discontinued REFIT initiative, a real[105] ROI of 17% was offered for MTRES projects in South Africa (Eberhard, 2014). On the other hand, development institutions that assist with socio-economic growth and industrial development, such as the Industrial Development Corporation (IDC), and Development Bank of Southern African (DBSA), expect a ROI of 6-9% above the Johannesburg Interbank Average Rate (JiBAR), which is equivalent to 14-17% (Sager, 2014). Thus, for the purposes of the strategic management framework, a ROI of 15% will be offered through government policy incentives, decreasing over time in line with industry growth.

The market-pull policies analysed for inclusion in the final policy mix of the strategic management framework are presented in Table D.2, based on their potential use in South Africa, South Africa's own experience with such policies, and use in the framework.

[105] Real interest rates are adjusted for inflation, as opposed to nominal rates which are the interest rates at the time an item was produced.

Table D.2: Market-pull policies

Policy	Potential use in South Africa	South Africa's own experience	Use in strategic management framework
FITs	No possible deployment on a national level, as it violates laws of competitive procurement (Eberhard, 2014). There is also a lack of government funds available due to a greater focus on socio-economic goals, such as social grants and low-cost housing development. Can be implemented on a municipal level with green electricity sourced from (small-scale) CSP projects However, it is unlikely that municipalities will be able to commit to providing a FIT for the entire lifespan of a CSP plant, due to the factors such as municipal elections (may be voted out) and financial resources (may need to be allocated elsewhere at short notice).	In 2009, South Africa planned to implement a FIT called REFIT. REFIT was based on tariffs to meet electricity generational costs, plus a real ROE of 17%, adjusted for inflation. Initial tariffs were 15.6ckWh for wind, 26 c/kWh for CSP and 49c/kWh for solar PV. (Eberhard, 2014) A large degree of uncertainty existed regarding the legality of REFIT in terms of competitive procurement laws, and issues surrounding the signing of PPAs and grid connection agreements with Eskom. In the end, REFIT was abandoned in favour of a tender bid-based programme (REIPPPP). (Eberhard, 2014) On a local government level, several municipalities, such as Cape Town, Drakenstein, and Stellenbosch, have found innovative ways of implementing policies that closely resemble FITs, but differ enough not to violate any laws or legal processes. However, these new regulations apply predominantly to embedded generation, such as solar PV panels (Oxford, 2017). In 2013, the DoE established a CSP two-tier time-of-day (TOD)[106] tariff for	The decision to implement a FIT, or similar policy equivalent, will be left to each municipality. It is acknowledged that low-income municipalities are likely to be more concerned with poverty alleviation and other issues. Thus, the deployment of FITs will occur in mid- to high-income municipalities, possessing the financial strength to bear the cost of the FIT themselves without any support from national government. Furthermore, due to the risk of a municipality experiencing a change in governance over the tenure of the CSP plant's lifespan, it is recommended that only municipalities won a 65% or higher election vote, and high possibility of re-election, consider employing FITs. A fixed FIT will be used, one independent of the price of electricity sold by Eskom. It will be a stepped FIT, with the starting value based on prices achieved in REIPPPP and consultation with stakeholders. The subsequent price reductions will be implemented once every two years, allowing municipalities time to assess the feasibility of continuing to offer FITs for new projects. The price reductions will be based on cost reductions achieved due to technological growth, economies of scale, and learning curves. The FIT will be determined on a project by project basis. Municipalities also have the option of implementing a TOD tariff. The tariff can follow the two-tier structure introduced in the REIPPP Programme, with the same figures and time periods. The tariff prices can be reduced in line with the cost reductions achieved over time.

[106] A time-of-day tariff differentiates between electricity supplied during the day and during peak periods, usually by a higher price paid for peak-supplied electricity (Silinga *et*

Policy	Potential use in South Africa	South Africa's own experience	Use in strategic management framework
		CSP projects commissioned under the REIPPP Programme (Relancio *et al.*, 2016). The structure consisted of a base tariff of R1.65/kWh (05:00-16:30 / 21:30-22:00), and a second tariff increase of 270% during peak periods (16:30–22:00) to offset the additional storage costs involved and encourage electricity supply during this time (Relancio *et al.*, 2016). No payment was made for any electricity supplied during 22:30-05:00 (Relancio *et al.*, 2016). It is important to note that only a CSP fleet optimised for the two-tier tariff yields a profit (Silinga, Gauché, Rudman & Cebecauer, 2015).	The strategic management framework will assume an advisory position, offering extensive support to those municipalities who choose to implement FITs, as well as launching programmes to educate municipalities across South Africa about the benefits of FITs, and how they can support industrial growth and socio-economic development.
Tender bid programme	A willing market of IPPs exists to oversee the development of CSP projects. A tender bid programme doesn't violate any laws of competitive procurement. In addition, it allows government to maintain control over the quantity of new power installed, while supporting socio-economic goals (Eberhard, 2014; Relancio *et al.*, 2016). Potential to improve relationship between the public and private sectors.	World class REIPPP Programme focused primarily on utility-scale MTRES projects, although a small-scale embedded generation version of the programme also exists. Winning bids awarded based on price (70%) and socio-economic development through use of local content (30%). (Nhamo & Mukonza, 2016) A set quantity of power capacity is determined for each bid window, in line with targets established by the DoE. To date five bid windows have been successfully completed. (Nhamo & Mukonza, 2016)	The management of the REIPPP Programme lies firmly with the DoE and Eskom. There is thus very limited scope for the strategic management framework to have an influence on the REIPPP Programme, apart from private sector and civil society pressure for CSP to assume a more prominent role in South Africa's energy mix. The strategic management framework will assume an advisory role, promoting certain improvements to be made to the REIPPP Programme with respect to CSP. These include the following: • Continue to allocate new-build capacity for CSP technologies • One bid window every 6 months • Streamline the tender bid process (planning permission, EIA's, solar resource data etc.) • More ambitious (CSP) energy targets

al., 2015).

Policy	Potential use in South Africa	South Africa's own experience	Use in strategic management framework
		The future of CSP projects commissioned through the REIPPPP is uncertain, given that no provision was made for CSP in the recently released IRP-2016 (Creamer, 2016a). It is likely that such uncertainty will persist in the short- to medium-term.	• Greater attention to small scale REIPPPP[107]; one bid window every 6 months • Impose penalties on companies not implementing/fulfilling bid agreements[108] • Provide greater legal and advisory services support • Lower transaction costs • Revise local content requirements every 2 years (4 bid windows), implementing lessons learned about the effect of REIPPPP on socio-economic growth, and industry development. • Lower barriers to grid connectivity
Auction	Unlikely given South Africa's existing REIPPPP tender bid programme. Differs from a tender bid programme in that it is based solely on lowest price, whereas a bid programme incorporates both price and non-price criteria. Has the potential to be more time consuming and expensive than tender programmes, as well as needing considerable knowledge and skill to implement effectively. Furthermore, potential to promote underbidding to win bid will likely result in failure to reach programme's goals. (Eberhard, 2014)	No experience of such a programme.	Not considered for strategic management framework.
Reverse auction	Unlikely given South Africa's existing REIPPPP tender bid programme. However, possibility remains to experiment with the base design of a reverse auction, altering it to include weightings of non-price factors e.g. socio-economic growth. Likely to contribute to significant technology cost reductions based on the experience of other	No experience of such a programme.	Not considered for strategic management framework.

[107] Commercial and industrial market segments for CSP deployment

[108] Prevent companies bidding unrealistic prices to gain preferred bidder status, as well as ensuring projects are actually constructed and become operational on schedule.

Policy	Potential use in South Africa	South Africa's own experience	Use in strategic management framework
	developing countries (Brazil). (Eberhard, 2014) However, successful auctions may prove time-consuming, involve higher costs, and require significant capabilities. This policy option may also promote underbidding, resulting in risk of contract default. In addition, the experience and success gained with the REIPPPP makes it unlikely that a similar type of bid programme would supplant it. (Eberhard, 2014)		
Tax/investment incentives Major tax incentive policies: • Import/excise duty • VAT concession • Tax credit / accelerated rate of depreciation • Production tax concession • Tax break on generation income	Current economic conditions in South Africa have put pressure on the scope for tax incentives that government may offer, with a budget deficit to address, as well as issues such as funding a greater percentage of students in tertiary education. (Merten, 2017; PMG, 2014) Tax incentives are able to promote greater industrial growth and socio-economic development if managed correctly. Key to their deployment is the need for transparency relating to who may qualify, and how the incentive will assist industry and wider growth. Implementation largely reliant on political will.	The following tax incentives have been implemented by the South African Revenue Service (SARS): 1. RE accelerated depreciation (50:30:20) 2. R&D expenditure tax deduction: automatic 100%, extra 50% possible subject to approval of Minister of Science and Technology. 3. Tax exemption for CDM-project generated revenue 4. 12L Energy efficiency: tax break of R0.95 per kWh saved based on EE project implemented. (Green Business Guide, 2013; Green Power, 2017; SAPVIA, 2017) The Department of Trade and Industry (DTI) also provides certain production tax incentives yet these	Although government may be forced to lessen the number, and extent, to which tax incentive are offered for MTRESs, the following investment-based tax incentives are recommended: • Production tax exemption/reduction for CSP plants[109] • Accelerated depreciation of CSP capital assets: maintain existing depreciation ratio (50:30:20). Potential to extend depreciation to other assets of CSP firms. • R&D expenditure tax deduction: maintain existing figures (automatic 100%, potential for additional 50%) • Tax exemption for CDM-project generated revenue • Reduced import levies on imported CSP components by 10% for a period of five years. After the five-year period, the levy reduction can be reduced gradually, as improvements in R&D and technical knowledge and expertise

[109] Decision made not to proceed with a standard tax exemption for CSP components, as owners may lose interest in O&M after receiving tax benefits. An exemption/reduction in production tax encourages owners to maintain plants in order to continue receiving exemptions, and thus generate more electricity (Abdmouleh *et al.*, 2015).

Policy	Potential use in South Africa	South Africa's own experience	Use in strategic management framework
(Abdmouleh *et al.*, 2015)		come with specific requirements, such as the location of activities within an industrial development zone (IDZ) (Grobbelaar *et al.*, 2014)	allows for a greater percentage of CSP components to be manufactured locally.
Carbon / environmental tax	A useful means of addressing the nonmarket (social) costs of environmental pollution from energy production (Mbadlanyana, 2013). Requires political will to implement. Important that a fair and transparent process be used to measure CO_2 emissions, and that this is communicated clearly. Encourages companies to lower their carbon intensity to reduce taxes paid. Early adoption of a low-carbon growth path can result in competitive advantages in low-carbon technologies. Ensures incentives for R&D and increases levels of innovation, thus creating a resource-efficient economy. (Mbadlanyana, 2013) May face opposition from the private sector, especially fossil fuel companies and heavy polluters.	Two environmental taxes exist: (1) electricity levy, for non-environmentally friendly, and dangerous, sources of energy generation (Mbadlanyana, 2013), which is currently R0.35/kWh (SARS, 2014), and (2) fuel levy, recently raised to R3.15/l in 2017 (Wheels 24, 2017). A carbon tax is set to come into effect in 2017 (Nkabinde, 2016). The draft bill charge is quoted at R120/tCO_2, but is more likely to be R6-48/tCO_2 (Nkabinde, 2016). Other scenarios/National Treasury put it at R75/tCO_2, with an increase to R200/tCO_2 (Mbadlanyana, 2013). There will be a five-year exemption period for Eskom, offering relief to energy-intensive industries such as mining and manufacturing (Nkabinde, 2016). There will also be tax-free exemptions of 60 - 95% of total emissions (Nkabinde, 2016). As a result, the tax will only apply to 5-40% of the actual emissions during this period (Nkabinde, 2016). Uncertainty remains about any potential revenue-recycling measures to be implemented (Votteler & Brent, 2016).	The strategic management framework will have little influence over the pricing mechanism, or implementation, of any environmental taxes, which are the domain of the Treasury. While such taxes are supported, it is unclear what percentage of the revenue raised would be recycled and distributed towards supporting the CSP industry, if any at all, together with the means by which it will be done. The revenue raised is more likely to be allocated towards financing socio-economic development, addressing budget deficits, or other energy goals, such as the REIPPP Programme, which presently holds no further capacity for CSP technologies. Should any revenue be allocated to the CSP industry, it is recommended that it be distributed as follows: • 40% to R&D projects, • 20% to education programmes on a primary & secondary education basis, • 20% to funding of CSP-related grid infrastructure, and • 20% to provide tax relief for CSP companies

Policy	Potential use in South Africa	South Africa's own experience	Use in strategic management framework
		The carbon tax is anticipated to reduce the annual average growth rate of the economy by 0.05-0.15 percentage points, compared to a business-as-usual baseline. As an example, this would mean that the economy would grow at 3.3–3.4% per year, instead of 3.5% (Creamer, 2016b).	
Carbon credits/ CERs[110]	Potential to support South Africa's environmental goals, but requires political will to implement. May receive greater interest from the private sector with the upcoming carbon tax. Process of selling carbon credits would be assisted by establishing a carbon market trading platform. A strong carbon market could provide additional financing for CSP projects. However, such an instrument needs buy-in from multiple stakeholders to be a success.	Presently, no large-scale use of carbon credits in South Africa (Botes, 2012). Credible Carbon is a voluntary carbon market registry operating in the Southern African region that certifies and trades carbon credits. Price paid per tonne of CO_2 in 2012 was R43–250, with verification achieved through a third party. (Credible Carbon, 2016) There are a number of voluntary standards for carbon reduction certification in South Africa, such as the Gold Standard (used by Credible Carbon), VER Plus, and the Climate, Community, and Biodiversity Alliance. (Botes, 2012)	The formation of a national carbon agency could establish a trading platform for carbon credits in South Africa, along with a set of carbon standards based on existing voluntary standards. This would enable CSP technologies to gain access to an alternative revenue stream not available to fossil-fuel based energy technologies, offering a competitive advantage. However, a national trading platform would be the domain of government, and lie beyond the control of the strategic management framework. The focus of the strategic management framework will be on strengthening the existing voluntary trading registries by promoting awareness of such platforms. In addition, the strategy will place an emphasis on educating stakeholders, and society, about carbon credits, and their value in financing CSP projects.
Loans and bonds	Current events have placed a strain on the South African economy and National Treasury, such as the tax revenue shortfall in the 2016/2017 financial year, significant budget deficit and debt	Current loans are normally supplied by development institutions, such as DBSA and IDC (Nhamo & Mukonza, 2016). However, government has supplied loans for certain MTRES	Government can greatly aid the development of the CSP industry through low-interest loans. However, as mentioned, there are limited financial resources currently available to fund such projects, while such projects also seem not to be favoured

[110] One carbon credit represents the reduction of 1 tonne of CO_2 equivalent emissions.

Policy	Potential use in South Africa	South Africa's own experience	Use in strategic management framework
	servicing costs (Ensor, 2017), and credit downgrade to junk status (Joffe, 2017). These circumstances, together with the fact that CSP is a relatively new technology, will result in less government capital available for lending, as well as higher interest rates charged on loans to CSP project developers (Joffe, 2017). A higher interest rate forces CSP plants to charge a greater price for the electricity generated in order to recuperate the additional borrowing costs. This makes CSP less attractive than other energy technologies. As a result, government-based loan financing seems unlikely in the short- to medium-term.	initiatives in the past, such as the solar water heater programme in 2013 (South African Institute of International Affairs, 2012).	by government on a frequent basis. Therefore, any loans will likely have to be procured from other financial sources, such as banks and other (development) finance institutions.
TGCs	Significant potential exists, given a growing awareness of the need to support, and adopt, clean forms of energy production. The establishment of a national trading platform, and government-imposed quotas on businesses, would help facilitate the introduction of TGCs on a large-scale in South Africa. TGCs could be sold through local municipalities, establishing stronger ties between local government, communities and business. TGCs offer an alternative revenue stream to help offset some of the costs involved with CSP projects. However, such an instrument needs buy-in from business and the general public to be a success.	Currently entirely voluntary, and therefore more of a green pricing scheme; no legal mechanisms exist forcing companies or individuals to purchase TGCs to meet a quota (Brick & Visser, 2009; zaRECS, 2010). Implemented only on a local government level in some municipalities, such as the City of Cape Town, which currently sells TGCs sourced from the Darling wind farm at R0.25/kWh (Mckenzie, 2012).	The strategic management framework will focus on the use of TGCs by local government and the private sector. It is worth noting that the use of TGCs has not been that effective globally (Haas, Panzer, *et al.*, 2011), and without a credible large-scale market or trading platform are difficult to implement on a national, or international, level (Brick & Visser, 2009). TGCs will continue to be offered on a voluntary basis, with education of the mechanism seen as most important for increasing its use in the short-term. An initial starting price of R0.35/kWh is recommended for CSP-generated TGCs. Although this figure is higher than that presently charged by the City of Cape Town (for wind generated electricity), CSP technologies are currently more expensive. However, prices are expected to fall as use of the technology becomes more widespread.

Policy	Potential use in South Africa	South Africa's own experience	Use in strategic management framework
			TGCs will apply only to new installed capacity to prevent windfall profits for the power producers. Revenue raised should be distributed to the respective CSP plant, and towards CSP/TGC education initiatives. Municipalities could seek to enact quotas forcing local business to purchase a set amount of TGCs, or meet green electricity consumption targets. Severe penalties for noncompliance and high buy-out prices would be needed to persuade companies to meet the targets set, ensuring a high degree of effectiveness and economic efficiency.
REPS / Quotas	The degree of political will for setting REPS/quota targets by the South African national government is questionable, given a focus on socio-economic goals and pressure from agents favouring other energy technologies. This policy is typically used in connection with TGCs.	Quotas have found a role in the REIPPP Programme for increasing the amount of power generated from RE sources, rather than the independent use of such a policy.	Not considered given quotas are already set to a certain extent in the REIPPP Programme.
Voluntary green pricing schemes *Note: This policy is similar to TGCs, which are normally government sanctioned towards meeting a certain quota (Abdmouleh *et al.*, 2015).	Many South African consumers are already under significant pressure from rising food, fuel and other expenses. As such, it is unlikely the average consumer will willingly pay a premium for green electricity. Wealthy individuals may be persuaded to contribute, but they form the minority in the country.	The City of Cape Town has implemented such an approach, where residents are able to pay an extra R0.25/kWh for electricity sourced from the Darling Wind farm (Mckenzie, 2012).	See the TGC policy discussion; a similar approach is recommended.
Wheeling agreement	Eskom has legislation in place to accommodate wheeling agreements. However, a lack of large-scale awareness	PowerX (previously Amatola) is the sole licensed green power trader that facilitates PPAs between buyers and sellers of green electricity. One of	The strategic management framework will focus on facilitating wheeling agreements between CSP projects and prospective buyers, such as local government and the private sector. Being the sole

Policy	Potential use in South Africa	South Africa's own experience	Use in strategic management framework
	of such agreements prevents widespread use. The private sector is able to enter into such agreements with IPPs through use of licensed green power traders (City Energy, 2015).	their more notable agreements achieved so far is with Nelson Mandela Bay Municipality. (City Energy, 2015) Customers pay R0.80–1.40 per kWh, while RE generators receive R0.62–1.05 per kWh (Botes, 2013). In addition, a wheeling charge is also incurred for use of the electricity grid (20% of the power supplied over the grid) (City Energy, 2015). Power purchase agreements with IPPs for 1-20 years (Botes, 2013). The biggest challenge encountered with wheeling agreements is not the mechanism itself, but finding customers willing to sign PPAs for time periods of 10 years or longer. Banks and IPPs typically need long-term contracts to lower costs and provide revenue surety, while the buyers of such electricity prefer shorter periods (5yrs). (City Energy, 2015)	holder of the licence from NERSA, PowerX has a crucial role to play in such agreements. A key task will be to promote awareness of wheeling agreements through education initiatives. To address the issue of the long-term nature of PPAs, it is suggested that a group of buyers form part of a single PPA, committing to buying electricity from the CSP plant for a fixed time period. In effect, this group of buyers replaces the single customer of standard PPAs. Hence, instead of having one buyer for the entire lifespan of the plant, the group of buyers will commit (amongst themselves) to purchasing electricity for different time periods, be it successive five-year periods or smaller timespans, to allow them to manage the impact of the (additional) electricity expense more effectively.
Grid access legislation	Legislation relating to the upgrade and expansion of the grid is of vital importance, given the intermittent nature of MTRESs, and the objective of the South African government to provide the entire population with electricity.	Eskom has initiated plans to upgrade and expand the existing national grid (Eskom, 2016).	Current efforts and plans outlined by Eskom deemed sufficient, no need for any changes. Framework will merely provide assistance in the way of knowledge and expertise resources to assist with grid upgrade and rollout.

Policy	Potential use in South Africa	South Africa's own experience	Use in strategic management framework
Installation rebate	Designed to overcome high installation costs; applicable primarily to residential MTRESs such as solar PV rooftop panels and solar water heaters (SWHs) (Taylor, 2008). The cost of the rebate needed to encourage installation of CSP technologies will likely be excessive, and too great an expenditure for the South African government to afford in a single payment (as opposed to a higher cost of electricity spread over time).	A SWH rebate programme run by Eskom in 2008. Lead to the formation of a quality standard for SWHs in the country (Eskom, 2013)	Not considered due to the significant cost it would represent to the South African government.

Appendix D.1.2 Technology-push policies

Although government policy supporting commercialisation tends to be more market-pull orientated in nature (see Appendix A.6), there are several options available with respect to technology-push measures. Arguably the most important, and effective, are R&D policies, as well as mechanisms that promote innovation within the CSP industry, and wider energy sector, such as energy-focused institutions (Taylor, 2008). Hence, it is worth investigating which components of a standard CSP system should be targeted for R&D. While higher quality components will result in the generation of greater quantities of electricity, increasing the revenue earned, it is cost that is currently the chief argument against the wide-scale adoption of such systems (Grobbelaar *et al.*, 2014). Hence, it is necessary to identify those components of CSP technologies which offer the greatest potential for cost reduction. Cost reductions attained in the more expensive components will significantly assist progress towards competing with established energy technologies on a level cost basis.

Figure D.3 presents a cost breakdown of a typical CSP system. The solar field, as one may expect, is responsible for more than 50% of the total system cost, while the power block, (thermal) storage system and central receiver also form significant contributors to the cost. Thus, any cost reductions implemented should seek to target these areas to realise the greatest possible decrease in LCOE of the overall CSP system.

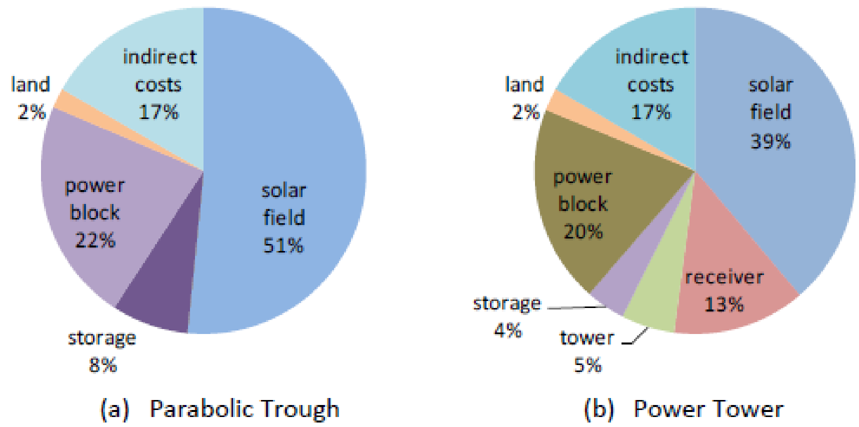


Figure D.3: Capital cost breakdown for a typical PTC and CR power plant

(Source: Hinkley, Curtin, Hayward, Wonhas, Boyd, Grima, Tadros, Hall, Naicker & Mikhail, 2011)

In 2010, South Africa's Departments of Science and Technology (DST), and DoE, published a Solar Energy Technology Roadmap (SETRM) (Nhamo & Mukonza, 2016). The roadmap recognised some of the issues confronting the solar energy industry in South Africa, and drew attention to the lack of policies and other promotional measures to quicken the rate of adoption of solar technologies in South Africa (Nhamo & Mukonza, 2016). Examining the research, development and innovation (RDI) possibilities for South Africa's national system of innovation as outlined in SETRM, Brent (2015) highlighted five RDI focus areas for the development of CSP systems (see Table D.3). These focus areas expand on the potential for cost reductions in CSP subsystems, while also contributing to the existing body of knowledge regarding the construction and operation of CSP plants.

Table D.3: CSP RDI focus areas

RDI focus area	Description
Systems analysis (performance, design & analysis)	Construction and operation of an outstanding CSP test centre. Design and model both CSP, and hybrid, systems' capability and capacity regarding system and plant optimisation.

RDI focus area	Description
Optical (reflector)	Design and develop the next generation of reflectors through partnership with global experts.
Thermal (receiver, heat transfer fluids, thermal energy storage)	Increase testing of CSP receiver technology in optimal settings found in South Africa to gain industry superiority. Concentrate on local resources (materials, systems, concepts) for HTFs and TES suitable for South Africa.
Cooling	Advance dry cooling technology capabilities to become suppliers of such technology to all actors in the supply chain (CSP owners, EPC contractors and component manufacturers).
Electrical (power block)	Evaluate non-Rankine cycles to increase efficiency and reduce water usage.

(Source: Brent, 2015)

In support of these five RDI areas, Brent (2015) outlines four important activities and their anticipated outcomes (in Table D.4). These activities are orientated towards support of the CSP value chain, as well as the technology's export potential. Tables D.3 and D.4 provide further evidence that sufficient know-how about the barriers faced by the CSP industry, and appropriate measures to overcome them, exists; it is merely a question of expressing the necessary leadership and (political) will, and securing adequate financial support, to implement such activities.

Table D.4: CSP research programme activities and anticipated outcomes

Research activity	Anticipated outcome
Support of South African up-stream operations for production of CSP materials and components to be used in utility, commercial, and industrial market segments.	Development of outstanding testing centres for all aspects of the CSP value chain.
Support of South African down-stream CSP sector, namely: systems distribution, O&M, and performance enhancement.	Modelling, simulation, and optimisation of CSP technology.
Transfer of CSP technology (hard & soft) to global markets.	Development of body concentrating on initiatives to help commercialise SA's CSP assets (technical knowledge, skills and physical technology).
Synergise and improve RDI capability and capacity of CSP technologies	Develop and improve required skills in fields of technology, science, and engineering through implementation of a human capacity development plan.

(Source: Brent, 2015)

Assessing the progress made in these RDI focus areas, Grobbelaar *et al.* (2014) provide an overview (see Figure D.4) of CSP-related research areas currently being investigated by universities, research councils, and the private sector in South Africa. While universities are involved in all fields, research councils and the private sector are more selective, perhaps due to limited funds or the choice of areas which offer the highest return, or greatest technological promise. Analysis of the production capabilities of the manufacturing sector in South Africa relating to the more expensive components of CSP systems, such as heliostats, central receivers and thermal storage, indicates the potential, and need, for a local CSP manufacturing hub, one able to produce these components and boost socio-economic growth (Grobbelaar *et al.*, 2014; SASTELA *et al.*, 2013).

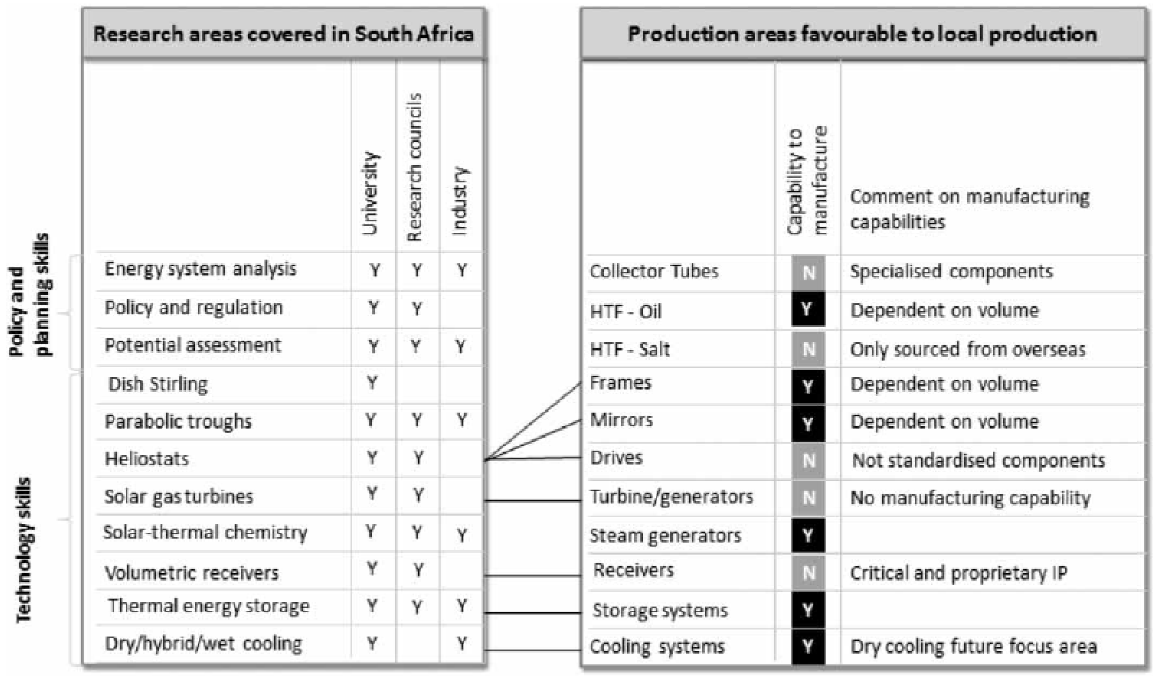


Figure D.4: South Africa's CSP research and potential manufacturing capabilities
(Source: Grobbelaar *et al.*, 2014)

Table D.5 presents the complete list of technology push policies identified from literature, while Table D.6 evaluates the policies identified based on their potential use in South Africa, South Africa's own experience with such policies, and use in the policy mix of the strategic management framework. The labelling of the reference sources used in Table D.5 is as follows:

11. Taylor (2008)
12. Grobbelaar *et al.* (2014)
13. Abdmouleh *et al.* (2015)
14. Solangi, Islam, Saidur, Rahim & Fayaz (2011)
15. Papapetrou (2014)
16. South African Institute of International Affairs (2012)
17. Msimanga & Sebitosi (2014)
18. Department of Energy (2003)
19. Edkins, Marquard & Winkler (2010)
20. Borrás, David & Richard (2005)

Table D.5: Identification of technology push policies

	Reference source									
Technology push policy	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Subsidies and grants	X	X	X	X	X	X	X	X	X	X
Loans	X		X	X	X	X	X	X		
Equity							X			
RDI centre		X						X		X
Demonstration projects		X	X					X	X	

Table D.6: Technology-push policies

Policy	Potential use in South Africa	South Africa's own experience	Use in strategic management framework
Subsidies and grants Note: subsidies may take a number of forms, such as funding and local content requirements (Papapetrou, 2014).	The current economic climate[111] in South Africa, and increased focus on socio-economic goals, may limit the funds available for allocation as subsidies and grants. Seeking grants and subsidies from the private sector and development institutions to support CSP RDI may be more feasible. Furthermore, allocation of financial resources may prove more effective if targeted at specific activities or components, such as heliostats, central receivers, and energy storage.	Subsidies are awarded on a case-by-case basis by the Renewable Energy Finance and Subsidy Office (REFSO), and the Renewable Energy Subsidy Governance Committee (SGC), under the DoE (Department of Energy SA, 2015). The Green Fund, established by the Department of Environmental Affairs (DEA), aids the change to a low-carbon economy by providing financial assistance (Department of Environmental Affairs SA, 2015). Attention is placed on projects targeting green cities and towns, a low carbon economy, and environmental and natural resource management (Department of Environmental Affairs SA, 2015). DEA provides the capital, while the DBSA acts as the implementing body (Msimanga & Sebitosi, 2014). Several grants aimed at the manufacturing industry are available, such as the Manufacturing Competitive Enhancement Programme (MCEP) (7-10% of manufacturing value added), and the Manufacturing Investment Programme (MIP) (15% of qualifying project costs) (South African Institute of International Affairs, 2012). Other grants include a R1.5 million grant given to Stellenbosch University by the National Research Foundation (NRF), small grants offered by the Global Environment facility (GEF), and approximately R1.5 million of the parliamentary grant given to CSIR, which is used for CSP R&D (Grobbelaar *et al.*, 2014) (Msimanga & Sebitosi, 2014).	Outline RDI areas in which subsidies and grants could be distributed for maximum effect. Assist REFSO in offering a more streamlined, and easier-to-understand, application process, as well as promoting awareness and education of REFSO and the SGC. Utilise funding from the Green Fund to help finance CSP projects and R&D activities aimed at achieving greater cost reductions. While manufacturing is important for technological progress and industry growth, a greater share of grant capital needs to be directed towards R&D. Such expenditure should focus on achieving increased cost reductions in CSP technologies, with the added benefit of improved intellectual capital, and technology export potential. Due to the current economic climate in South Africa, no targets will be set as the amount of grant capital available is uncertain.
Loan	Current events have placed a strain on the South African economy and	Loans offered by associated institutions and development banks (DBSA, IDC Green Energy	Outline specific RDI initiatives (to investors) that require loan financing. Provide clarity on how

[111] Credit junk status, budget deficit, and tax revenue shortfall (Ensor, 2017; Joffe, 2017).

Policy	Potential use in South Africa	South Africa's own experience	Use in strategic management framework
	National Treasury, such as the tax revenue shortfall in the 2016/2017 financial year, significant budget deficit and debt servicing costs (Ensor, 2017), and credit downgrade to junk status (Joffe, 2017). These circumstances, together with the fact that CSP is a relatively new technology, will result in less government capital available for lending, as well as higher interest rates charged on loans to CSP project developers (Joffe, 2017). Given their strong R&D nature, technology push initiatives are normally only able to offer a return in the long-term, making government loan financing unlikely.	Efficiency Fund & Gro-E Scheme) are primarily aimed at RE projects, with a lesser degree given to R&D efforts (Baker & Wlokas, 2015) (Msimanga & Sebitosi, 2014).	such initiatives will be able to generate revenue in the future, reducing uncertainty regarding the ROI that can be expected.
Equity	Similar to loans, amount of capital available for equity investment may be limited in the short- to medium-term. While still an option, equity financing may be provided in greater amounts by the business sector than government.	The IDC Gro-E Scheme offers equity financing to support sustainable development (Msimanga & Sebitosi, 2014).	Continue with existing equity avenues offered through the IDC Gro-E Scheme
RDI centre	Good potential to build on existing CSP technological research, to support growth of the industry (SASTELA *et al.*, 2013).	None presently exist, although SU and CSIR (and maybe NWU) each have plans to develop a small regional centre (SASTELA *et al.*, 2013).	Aid development of centres through provision of financing and necessary technical expertise. The centre should be supported initially by universities and other learning institutions. Once operational, it can contribute towards various educational and social programmes.
Demonstration projects	Demonstrate the practical applications of CSP technologies to various stakeholders (SASTELA *et al.*, 2013).	Some early demonstrations of CSP technologies; insufficient thought given to future of technology in post-demonstration phase (Balachandra *et al.*, 2010; Brent & Pretorius, 2011; SASTELA *et al.*, 2013).	Promote the use of demonstration projects to provide working models of CSP technologies, thus presenting opportunities for learning and future system improvement.

Appendix D.1.2.1 Institutional support

South Africa's institutions (see Table D.7) have a key role to play in the technology-push initiatives of the strategic management framework, particularly with respect to the improvement in technological learning curves, and associated knowledge, skills, and resources, achieved through RDI (Nhamo & Mukonza, 2016). The assistance offered by these institutions for the development of the CSP industry could be improved through increased government support, notably in the areas of funding and support from key role players.

Table D.7: South African institutions

Institution	Description
Department of Energy	Responsible for energy policy in South Africa. Dictates the future energy composition of the country through its policies and strategies.
Department of Environmental Affairs (DEA)	Responsible for the assessment, control, and mitigation of activities that impact (negatively) on the environment. Power producers, such as Eskom and IPPs, need to complete EIAs before proceeding with the construction of a new energy plant.
Department of Science and Technology (DST)	Responsible for the development, deployment, and assessment of science and technology policy and programmes, as well as technology R&D.
Department of Trade and Industry (DTI)	Oversees the progress and implementation of the Industrial Action Policy Plan, which has recognised the energy sector as a key feature of the country's industrial policy. Assists the DoE in setting targets relating to local content, namely: the use of materials and skills that support domestic socio-economic growth.
Energy Development Corporation	Assists the expansion of the RE and alternative fuel industries.
National Treasury	Allocates a portion of the national budget to the development of new energy projects to meet growing energy demand, while implementing taxes to support environmental goals.
Local government	Although responsible for implementing national policy, does possess some scope to set policies on a municipal level.
National Energy Regulator of South Africa (NERSA)	Responsible for the regulation of electricity tariffs, and approval of licences for the generation, transmission, and distribution of electricity in South Africa.
South African Local Government Association (SALGA)	Possesses an interest in the deployment of RE policies at a local government level. Assists research into the ability of South Africa to transition towards a green economy.
South African National Energy Development Institute (SANEDI)	Organises and conducts research into energy development and use, namely: new and existing energy technologies, human resources, and a culture of innovation within the energy industry.
Council for Scientific and Industrial Research (CSIR)	A science and technology research, development, and implementation body whose mandate is to help solve South Africa's issues. Seeks to assist development in solar energy to allow improved matching of electricity supply and demand.
Renewable Energy Centre of Research and Development (RECORD)	Conducts research and partners with other organisations to assist progress in South Africa's solar industry, such as data gathering for use in solar maps.
SASTELA	Association of actors (developers, manufacturers, utilities, engineering etc.) within Southern Africa with an interest in promoting the growth of the solar thermal energy industry, particularly CSP.
Sustainable Energy Society of Southern Africa (SESSA)	Advocates and supports the development and use of sustainable forms of energy, such as bioenergy, solar, and hydro, in Southern Africa.
South African National Energy Agency (SANEA)	Encourages cooperation between various stakeholders by presenting a platform for common dialogue to recognise and deploy sustainable energy solutions.
Eskom	The South African state utility responsible for the generation, transmission, and distribution of electricity.

Institution	Description
South African Renewable Energy Council (SAREC)	Umbrella body that manages the activities of its members in line with its stated objectives.
South African Renewable Energy Technology Centre (SARETEC)	Offers training (installation, operation, and maintenance) to prospective technicians in solar PV and wind turbines. Potential to increase offering to include training in CSP technologies.
Southern African Solar Thermal Training and Demonstration Initiative (SOLTRAIN)	Supports countries in the Southern African region in transitioning from fossil fuel energy technologies to MTRESs, especially solar thermal technologies. Focuses on raising awareness of solar thermal technology possibilities, establishing competency in the technology, building solar thermal technology platforms, and demonstration of the use of solar thermal technology.
CRSES	Renewable energy research institution at Stellenbosch University that promotes R&D into, and use of, RETs such as CSP technologies.

(Source: Nhamo & Mukonza, 2016; SOLTRAIN, 2016; Votteler & Brent, 2016)

A product of the R&D endeavours of South Africa's institutions is the improvement in the learning curves[112] of CSP technologies, achieved through technological progress, such as changes in production processes (process innovations, learning effects and scaling effects), products (innovation, design standards and redesign), learning by doing, decrease in input prices of financing costs and improved organisational efficiency (Brent & Pretorius, 2011; Kumbaroğlu, Madlener & Demirel, 2008). These have had a beneficial impact on the commercialisation process by improving the quality of CSP technologies and lowering costs, while also allowing for the projection of future cost reductions based on historical relationships (Kumbaroğlu *et al.*, 2008). Existing CSP learning curves are thought to be anywhere in the range of 5 to 32%, for PTC systems, and 2 to 20%, for CR systems (Brent & Pretorius, 2011).

Appendix D.1.3 Interface improvement policies

The principal focus of interface improvement is on the players responsible for the installation of MTRESs, transferring knowledge from the manufacturers to the final consumer. This field offers the potential for service-orientated firms to offer advisory services relating to the financing, installation, and O&M of MTRESs in a consulting capacity. This knowledge diffusion will assist the commercialisation process by promoting greater awareness and experience of such technologies, leading to increased social awareness, and wider market adoption. (Taylor, 2008)

The implementation of interface improvement policies takes on added importance when considering the preference shown by investors for service-driven business models (Loock, 2012). Hence, it is expected that a growth in the number of firms offering service-based products within the RE industry globally will attract a greater degree of financial capital, fuelling progress in the commercialisation process.

Table D.8 presents all the interface improvement policies identified from literature, while Table D.9 analyses their potential use in South Africa, South Africa's own experience with such policies, and use in the policy mix of the strategic management framework. The reference sources used in Table D.8 are as follows:

1. Taylor (2008)
2. Solangi, Islam, Saidur, Rahim & Fayaz (2011)
3. Papapetrou (2014)
4. Msimanga & Sebitosi (2014)
5. Energy *et al.*(2016)
6. Grobbelaar *et al.* (2014)
7. Department of Energy (2003)

[112] Also called experience or progress curves, a learning curve is often expressed as the decrease in (unit) cost of a technology due to improved knowledge gained through R&D, manufacturing, production, and use of the respective technology (Lund, 2006; Rao & Kishore, 2010).

8. Borrás, David & Richard (2005)
9. Monstadt (2007)
10. SASTELA *et al.* (2013)

Table D.8: Identification of interface improvement policies

	Reference source									
Interface improvement policy	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Certification and technical standards	X			X		X	X	X	X	X
Regulations	X	X	X	X	X	X	X	X	X	
Consultancy firms			X	X						X
Project assessment centre					X					
Training and certification programmes	X			X		X	X	X	X	X

Table D.9: Interface-improvement policies

Policy	Potential use in South Africa	South Africa's own experience	Use in strategic management framework
Certification and technical standards	Need exists for a set of standards relating to procurement, design, testing, installation, O&M, and health & safety aspects of CSP technologies (Stapleton, 2009). These standards can promote trust in the technologies, and act as means of quality control (Stapleton, 2009). Standards will require input from multiple stakeholders, as well as being devised by a trustworthy organisation or institution	Although certification and technical standards do exist for some MTRESs, such as solar PV panels, wind turbines, and solar water heaters (Department of Energy, 2015b), no set of common standards currently exist for CSP technologies (SASTELA *et al.*, 2013).	Numerous stakeholders (manufacturers, suppliers, end users, South African Bureau of Standards) will be engaged with to develop standards relating to the development and use of CSP technologies in South Africa. International standards can be used as a guideline in this regard. It is important that all stakeholders agree to abide by these standards. Standards can be adopted by government in time, or used as a foundation to establish their own.
Regulations	Experience and knowledge already exists that could be used to establish, and improve, regulations for CSP projects, such as environmental licenses (procedure) and planning, construction, and operating licenses (Department of Energy, 2015b; Edkins *et al.*, 2009; Papapetrou, 2014). Inspection programs and warranty requirements could also form a key part of these regulations (Taylor, 2008), although it is questionable whether sufficient expertise exists in this regard in South Africa	Regulations and legislation already exist relating to CSP technologies, and MTRESs (Department of Energy, 2015b; GreenCape, 2016). However, there is a need to streamline these regulations, and make them easier to implement. For example, the current EIA is very time-consuming and costly to complete (Retief & Chabalala, 2009), and may discourage future investment in the CSP industry..	Streamlining the respective regulations may prove difficult given government opposition to CSP technologies (Creamer, 2016a). Although a united front representing the entire RE industry may prove effective in amending legislation, the strategic management framework will focus on taking an advisory role that assists CSP projects in complying with all applicable regulations.
Consultancy firms	A significant degree of uncertainty exists regarding the processes that need to be followed to execute CSP projects. Consultancy firms can help mitigate such uncertainty (Peters,	Some consultancy firms do exist to assist with technical, financial and legal matters, but there is sufficient work for this number to grow. (Papapetrou, 2014; Peters *et*	Promote awareness of private sector opportunities available in this space to expand the number of companies offering the required consultancy services. Through increased competition, a higher standard

	Lotz & Brent, 2014).As such, there is potential for growth.	*al.*, 2014; Relancio *et al.*, 2016).	of service can be realised, meeting the needs of the industry.
CSP project assessment centre	An extensive list of documents is required for each bid of the REIPPPP tender programme (Eberhard *et al.*, 2014). Assessing the documents is time-consuming and could be managed by a single specialist centre or department.	An IPPPP office was established at the national Treasury for the purposes of evaluating the tender bids of the REIPPP Programme and awarding preferred-bidder status (Department of Energy *et al.*, 2016).	The IPP office is sufficient for the evaluation of the tender bids. It is expected that the office will improve as more experience is gained with subsequent bid windows.
Training and certification programmes	Good potential, which will grow as more people become aware of CSP technologies and the associated benefits. Will be a strong need for skilled personnel as the CSP industry grows (SASTELA *et al.*, 2013).	Various training & certification programmes are presently offered by training centres, such as SARETEC and SANEDI (Nhamo & Mukonza, 2016).	Assist South Africa's training centres in ensuring the skills and knowledge transferred are in accordance with the current needs of the country's CSP industry. This will require a process of extensive engagement and collaboration between all stakeholders. In addition, emphasis should be placed on the design and implementation of programmes producing competent graduates ready for work in the industry.

Appendix D.1.4 Policy mix design

Grobbelaar *et al.* (2014) present four principles (in Table D.10) for the design of an energy policy mix. These principles act to address both supply- and demand-side measures in overcoming existing barriers (economic and non-economic) to the commercialisation process, as well as the expected impact that MTRESs may have on elements such as the existing energy system. Thus, the policies that comprise the proposed mix (market-push, technology-pull, and interface improvement) need to address each of these four principles to ensure the greatest chance of success.

Table D.10: Energy policy principles

Principle	Key actions and description
Economic and non-economic barriers	Identify key non-economic barriers to industry development, creating a more predictable stable environment that may contribute to technology development and decreasing cost
Demand-side measures	Develop and implement incentives in order to stimulate demand for technologies and their implementation based on technology maturity
	Design a predictable and transparent support framework in order to attract investments
Supply-side incentives	Transitional incentive to decrease over time but to stimulate technological innovation and the development of technologies towards maturation
Impact assessment	Ensure that the impact of large-scale penetration of renewables is clearly analysed and what impact it may have on the system

(Source: Grobbelaar et al., 2014)

Kern & Howlett (2009) compare the different relationships that emerge during the development of a policy mix (see Table D.11), based on whether the goals set are coherent or incoherent, and the policy instruments used consistent or inconsistent. These interactions result in the development of one of four possible processes: replacement[113], conversion[114] drift[115], or layering[116]. Although replacement is typically the desired process, many policy mixes are instead developed through policy layering, or repeated implementation of conversion and/or drift processes (Kern & Howlett, 2009). Awareness and knowledge of these processes is important for policy makers, as many countries have implemented various policies over the past decade (Balachandra *et al.*, 2010), which are likely to impact on the design and implementation of any future policy mix, such as that proposed for the strategic management framework.

Table D.11: Policy mix development process

	Instruments	
	Consistent	Inconsistent
Goals		
Coherent	Replacement	Conversion
Incoherent	Drift	Layering

(Source: Kern & Howlett, 2009)

Appendix D.2 Business Sector

Appendix D.2.1 Commercialisation activities

Table D.12 presents a discussion of the set of commercialisation activities to be implemented by the business sector.

Table D.12: Business sector commercialisation activities

Activity	Discussion
Increase demand for MTRESs	The uncertainty of future RE projects commissioned through government programmes means that demand for MTRESs needs to be established in alternative market segments, thus ensuring continued progress in the commercialisation process. The business sector needs to actively engage in fostering new demand through increased awareness of MTRESs, and their potential applications, as well as identifying new consumer groups within the commercial and industrial market segments. Ideally, increased demand would lead to the establishment of a pipeline of projects, creating a sustainable industry that increases the rate of commercialisation realised. However, this demand is likely to be dependent on MTRESs reaching cost-parity with other energy technologies, be it through technological improvement or the use of financial mechanisms.
Finance R&D into MTRESs	The business sector, while already conducting its own R&D, need to harmonise efforts with other R&D institutions nationally to focus efforts on those components of MTRESs that offer the greatest potential for cost reduction, and increased energy output. The long-term nature of this activity suggests that institutional investors, such as green funds, insurance companies, and pension funds, may be more appropriate as chief financers.
Finance and develop MTRES power plants	The business sector needs to provide the capital and expertise for the construction of MTRESs. New and innovative financial mechanisms, as well as alternative streams of revenue, need to be harnessed to assist with project finance, thus increasing the number of MTRES projects that can be constructed

[113] "*A conscious effort made to re-create or fundamentally re-structure policies through the replacement of old goals and means by new ones*" (Kern & Howlett, 2009).

[114] "*New instrument mixes evolve while holding old goals constant*" (Kern & Howlett, 2009).

[115] "*New goals replace old ones without changing the instruments used to implement them*" (Kern & Howlett, 2009).

[116] "*New goals and instruments are simply added to old ones in an existing regime without abandoning previous ones*" (Kern & Howlett, 2009).

	on an annual basis. The long-term nature of this activity suggests that institutional investors, such as green funds, insurance companies, and pension funds, may be more appropriate as financers.
Skills training	To support the growth of the RE industry, the business sector needs to provide skills training to individuals, contributing to the global intellectual capital regarding MTRES, and ensure that there are sufficient human resources available to cope with any additional projects, and the accompanying industry expansion.
Develop a local manufacturing hub (s)	A local manufacturing hub for MTRESs and their subcomponents needs to be established, aiding the transition from R&D into a commercialised state of such systems. The hub would be ideally located near a major port, allowing for ease of material supply and technology export. The manufacturing hub could be used to support MTRESs by improving the strength of the supply chain, and reducing the need for component imports. In time, the hub could be expanded to include services and operations, as well as the distribution and sales of the technologies developed.
MTRESs technology export	There is significant potential for the regional and global export of MTRESs, given the increasing focus on such technologies and international clean energy agreements.
National grid (transmission and distribution) infrastructure	Certain countries, such as South Africa, allow for the national grid to be accessed by IPPs in return for a wheeling charge tariff. However, should the number of MTRES power plants accessing the grid grow substantially, and existing utilities start to lose significant revenue, swift opposition and possible changes in grid legislation can be expected. In order to pre-empt such action, future means of financing and installing (mini) distribution and transmission grids independent of utilities is worth investigating.

Appendix D.2.2 Financial mechanisms for bridging the cost gap

The majority of the financial mechanisms recommended for bridging the cost gap have already been discussed and analysed in Appendix D.1. However, one of the more innovative mechanisms proposed which the reader may not be familiar with, crowdfunding, is presented below.

Appendix D.2.2.1 Crowdfunding

Crowdfunding is defined by Ordanini, Miceli, Pizzetti & Parasuraman (2011), as cited in Vasileiadou, Huijben & Raven (2015), as: "*the collective effort by people who network and pool their money together, usually via the internet, in order to invest in and support efforts initiated by other people or organizations"*. The idea behind the concept is that large numbers of people (the crowd) each make a small monetary contribution, which collectively forms a large sum with which to finance new projects, thus removing obstacles to the initial investment required.

Crowdfunding offers a unique and innovative means of raising financial capital, if adopted on a large scale by the population. This business model of organisational innovation, while not new, has grown into a unique means of raising investment capital though cooperation and microfinancing due to the emergence of new avenues, such as social media, that allow for the access of large numbers of people in a relatively short period of time. (Vasileiadou *et al.*, 2015)

The potential of crowdfunding with respect to MTRES projects is not limited to merely securing the financial capital needed. Consumers now have the option to become financers and producers of energy themselves, creating new classes of customers, such as those interested in testing innovative online financial mechanisms. Increased societal support can be fostered due to crowdfunding's extensive engagement with a large percentage of the population. This support that can be used to leverage the political will necessary to incorporate MTRESs into energy mixes on a larger scale worldwide. (Vasileiadou *et al.*, 2015)

The encouragement of public involvement in the early growth stage of MTRESs can assist the creation of long-lasting ties, as well as provide legitimacy, a necessary catalyst in the commercialisation process, through its democratic process of choice[117] (Vasileiadou *et al.*, 2015). In addition, crowdfunding has been shown to develop new forms of communicating with clients, and aiding community development (Vasileiadou *et al.*, 2015). These factors position crowdfunding as a new type of model, one that can greatly aid the commercialisation of MTRESs through new and innovative means of managing transactions with clients, supporters, and suppliers, subsequently establishing a positive feedback loop which supports the shift to a clean energy system.

Table D.13 examines five common models of crowdfunding, although in practice there are many variations to these elementary models. Vasileiadou *et al.* (2015) find that reward or donation models seem to attract a primarily green crowd. These models, while appealing to green energy supporters, are likely to be small-scale if implemented in developing countries such as South Africa, as the majority of the nation's citizens have very little disposal income that they could contribute, with any net sum gathered likely to be relatively small compared to the total cost of a (MTRES) power plant. Furthermore, it will likely take too long to raise the large initial capital required through such models.

Table D.13: Crowdfunding models

Model	Description
Donation	Donors gain no direct benefit from their donation, with the focus being on charitable projects.
Reward	Donors receive a token for their contribution, but hold no stake in any earnings or shares of the project.
Pre-purchase	Similar to the reward model, except that the donor receives the product that the financed project produces in place of a token.
Lending / Peer-to-Peer	Donors receive a return of the monetary amount invested. The capital may or may not yield interest over the lifespan of the project.
Equity	Donors are able to purchase shares in the project's profits or the business behind the project.

(Source: Vasileiadou *et al.*, 2015)

The lending and equity models represent common debt and equity finance mechanisms, where the donor expects a financial return of some kind for their investment (Vasileiadou *et al.*, 2015). These investment models tend to be more dominant in practice (Vasileiadou *et al.*, 2015). In the context of MTRESs, it may be that developers prefer larger institutional investors, minimising the number of stakeholder agreements to be negotiated, as well as obtaining favourable lending conditions and working with experienced individuals.

The choice of model is left to the management practitioners of the partnership. However, the recommendation is made that while the donation and reward models should be included to a certain degree, with a token given in the form of a certificate for the reward model, the primary emphasis should be on a pre-purchase model, with the money paid being equivalent to a pre-sold TGC, namely: consumers are paying a premium for a unit(s) of green electricity. This model gives the consumer the satisfaction that they are supporting MTRESs, and the transition to a low carbon economy, while receiving a usable good in return (electricity).

It is worth examining the different motivations behind the decision to contribute financially to a project through a crowdfunding platform. Table D.14 presents the primary motivations for crowdfunding. Understanding the diverse motivations that cause individuals to act is useful in determining the best approach to follow in order to attract a greater level of crowdfunding support for RE-related projects.

[117] If members of the population don't like a technology, they can choose not to support it by not contributing funds.

Table D.14: Crowdfunding motivations

Motivation	Description
Hedonic goal frames	Individuals want to improve their feelings at a point in time.
Gain goal frames	Individuals seek to expand or safeguard their resources.
Normative goal frames	Individuals behave in a moral or ethical way to fulfil the norms placed on them by themselves or their community.

(Source: Vasileiadou *et al.*, 2015)

Appendix D.3 Educational Initiatives

Appendix D.3.1 Primary education

Table D.15 lists the primary education initiatives of the strategic management framework. The central aim is to foster an initial interest in MTRESs among primary school learners, which will be expanded upon through further education programmes at a secondary education level. It is important that students not be overloaded with information, as this might generate a negative reaction to, and perception of, MTRESs.

Table D.15: Primary education initiatives

Initiative	Description
MTRESs operation	Concentrate only on the basics of MTRESs' operation through easy-to-understand illustrations, such as posters.
Site visits (location dependent)	Take learners on MTRES site visits if possible (time, location, budget dependent)

Appendix D.3.2 Secondary education

Table D.16 lists the secondary education initiatives of the strategic management framework. The main objective is to build on the interest developed on the primary education level, and equip learners with greater knowledge regarding the operation of MTRESs, as well as the existing RE industry and broader energy sector. Once again, the amount of information provided to learners should be handled with care, continuing efforts to generate a favourable response to, and perception of, MTRESs.

Table D.16: Secondary education initiatives

Initiative	Description
Integration of RE source material into school syllabus	Learners need to be able to ▪ Compare 'green' vs 'dirty' energy technologies: (basic) differences in basic operation, strengths and weaknesses, and so forth. ▪ Identify/recognise different MTRESs (from a given list of images) and list some of the basic differences ▪ Discuss efforts to promote renewables both worldwide and in the learner's respective country. ▪ Name institutions that support promotion of MTRESs, both globally and in the learner's respective country.
Site visits (location dependent)	Take learners on site visits if possible (time, location, budgetary constraints).

Table D.17 presents a subject breakdown by which the integration of RE source material, through the five learning outcomes (see Table D.16), could be achieved. Learners will be assessed on the source material through tests and/or exams, which should consist of a mix of multiple choice and written questions.

Table D.17: Secondary school syllabus - subject breakdown

Subject	Subject material
Technology	▪ Core principles of MTRESs operation (energy transfer). ▪ Future technological innovations ▪ Technology economics e.g. falling MTRESs costs, alternative revenue streams. ▪ Energy and electricity supply and demand patterns ▪ Experience with energy modelling software, those with free or cheap licenses. Preferably those that are widely used, such as Plexos. ▪ Efforts to promote MTRESs. ▪ Institutions that support and promote RE and MTRESs.
Life Orientation	▪ Identification of different MTRESs from a given list of illustrations. ▪ Knowledge of key differences between energy-producing technologies.
Physical Science	▪ Core principles of MTRESs operation (energy transfer). ▪ Distinguish between MTRESs in terms of operation, present cost, future cost reductions, and different market applications based on size (power output), temperature range and so forth.
Geography	▪ Identification of different types of solar resources available for site selection. ▪ Use of a solar (radiation) map to identify viable MTRES project sites.

Appendix D.3.3 Public education

Table D.18 presents several public education initiatives to be implemented through the strategic management framework. The following value propositions should form part of any initiative deployed to improve the public's knowledge of MTRESs:

- 'Clean' nature of MTRESs; environmental and health benefits along with the infinite resources
- Basic technology operation; simple illustrative displays such as posters placed in community centres.
- 'Novelty' aspect; new technologies are often exciting, representing a departure from the known.
- Safety; should a MTRES power plant break down, there is no safety risk posed to the local surroundings and community. In contrast, nuclear technology, despite being a mature technology, has the issue of nuclear waste that needs to be disposed of safely (World Nuclear Association, 2016), and could present a health hazard should the plant break down .
- Rapid lead time; MTRESs have been proven to be faster to develop and construct than other energy technologies, such as nuclear (Sager, 2014).
- Local content advantages; socio-economic benefits gained through greater employment opportunities and poverty alleviation.

Table D.18: Public education initiatives

Initiative	Description
Demonstration projects	Slightly different from the technology-push policies of Appendix D.1.2, these demonstration projects are more geared towards public education than scientific research (for optimising future designs).
Cell phone applications	▪ 360º camera angle shot of MTRES power plants ▪ Video apps capturing the daily operation of different MTRESs. ▪ Tools used to promote MTRESs (government policy, financial mechanisms and so forth). ▪ Can reach large amounts of people quickly in a cost-effective manner.
Virtual reality	▪ Use of VR headsets to provide an immersive experience of MTRES power plants, their construction, and daily operation; ▪ Can integrate VR headset with cell phone technology, such as the recent Samsung S7 VR and Oculus rift headset combination.

Appendix D.4 Social acceptance of MTRESs

Appendix D.4.1 Underlying principles and factors

Social acceptance of MTRESs differs from other (energy) technologies in several ways. Although there is widespread support for such technologies from the general public, due to growing awareness of the negative impact of climate change, such support cannot be taken for granted. MTRESs are often smaller in size that their fossil-fuel counterparts, resulting in a higher number of projects required to achieve the same power output. These additional plants lead to an increase in the number of project site decisions to be made. (Wustenhagen *et al.*, 2007)

Project site decisions of MTRESs affect numerous stakeholders. One of the chief issues raised is the possible visual impact of the energy system on the surrounding landscape (Wustenhagen *et al.*, 2007). The visual impact of MTRESs is influenced by the fact that its resource-gathering takes place above ground, and in close proximity to local communities, whereas fossil fuel and nuclear plants have a significant degree of their operations underground, and away from human settlements (Wustenhagen *et al.*, 2007). In addition, the higher initial costs commonly encountered with MTRESs often makes the decision one of short-term costs versus long-term environmental and health benefits (Wustenhagen *et al.*, 2007). These differences highlight that conventional methods of improving social acceptance may prove ineffective, and that any (new) approaches implemented should include recognition of the differences mentioned above.

Wustenhagen *et al.* (2007) identified three dimensions of social acceptance (see Figure D.5) regarding MTRESs. Socio-political acceptance represents social acceptance on the largest and most generic scale. It can be best observed on a policy level, where action taken to support MTRES is often at odds with the broader social acceptance these systems receive. Despite support from the public, the backing offered by key stakeholders and policy-makers does not feature as strongly, presenting a barrier to the large-scale adoption of MTRESs. Improved dialogue between these groups is needed, particularly on a local versus national level, together with the institutionalisation of frameworks that seek to support socio-political (and market) acceptance of MTRESs through greater financial support, and integrative and fair decision-making processes. (Wustenhagen *et al.*, 2007)

Figure D.5: Social acceptance dimensions of MTRESs
(Source: Wustenhagen *et al.*, 2007)

Community acceptance describes the acceptance of projects and location decisions by local residents and authorities. It is based on factors of procedural justice[118], distributional justice[119], and trust between the community and external individuals, such as investors and government officials. The dimension of community acceptance is complicated when one considers that different (groups of) individuals within a community may have their own views regarding procedural justice, distributional justice, and trust. Perceptions of unfairness based on poor information diffusion regarding the (potential) risks and involvement of (non-community) individuals can lead to (violent) protests, communication breakdowns, and community divisions, all of which act to limit the rate of community acceptance of MTRESs. To improve the level of community acceptance, local residents and authorities should be incorporated into the decision-making process of policy-makers regarding potential projects and their locations, allowing them to voice any concerns relating to planning regulations and local factors. (Wustenhagen *et al.*, 2007)

Wustenhagen *et al.* (2007) recognise that trust is not limited solely to community acceptance, instead forming an integral component of all the dimensions of social acceptance. It is something that can be easily destroyed, while taking a long time to build. Trust can be fostered through open and transparent communication with a community regarding all relevant knowledge of a MTRES and the associated risks, together with the involvement of any outside individuals. In terms of promoting measures to improve the social acceptance of MTRESs, it was found that NGO's were trusted the most, and the business sector the least, by the general population. Thus, it is recommended that NGO's be seen to drive any social acceptance measures to aid the commercialisation process. (Wustenhagen *et al.*, 2007)

Two trends have been noted within communities: acceptance of MTRESs either increases or decreases once construction begins, based on the phenomena of please-in-my-back-yard (PIMBY) or not-in-my-back-year (NIMBY) (Wustenhagen *et al.*, 2007). The case of NIMBY is especially prevalent with wind and solar PV technologies, which tend to have a strong visual impact on the landscape near local communities. While (large-scale) MTRESs are more likely to be located away from human settlements, local community support should still be sought in cases where the plant is likely to have an impact on their daily lives. This support should entail engagement with the local community by informing key actors about MTRESs, and the due project processes, as well as collaborations with any regional learning institutions, and local associations, to boost awareness and acceptance of such technologies. (Yun & Lee, 2015)

Experience has shown that community acceptance possesses a time aspect, and can often be depicted by a U-shape, where acceptance of a MTRES is high initially, drops to a low level during project development, and then increases back to a significant level once the community starts to reap the rewards of the MTRES once operational (Wustenhagen *et al.*, 2007). Awareness of this relationship can assist project developers in creating trust with local communities through open and transparent communication, placing them in a better position to handle disputes should they arise.

The third dimension described by Wustenhagen *et al.* (2007) is that of market acceptance. Market acceptance refers to the scale at which a (new) technology is adopted by the market. There are many initiatives aimed at improving the market acceptance of MTRESs. One useful mechanism is the separation of supply and demand through green marketing, such as TGCs, where consumers are able to contribute to the generation of green electricity without being directly involved in the production process. However, such marketing may have a detrimental influence on social acceptance, particularly in cases where there may exist strong demand in a country for green electricity, yet be insufficient social acceptance to build the corresponding

[118] Are all relevant stakeholders allowed to engage in a fair and transparent decision-making process? (Wustenhagen *et al.*, 2007)

[119] The distribution of associated costs and benefits (Wustenhagen *et al.*, 2007).

supply infrastructure. This underlines the intricate nature of market, and social, acceptance, and the need to view any decision from a systematic perspective. (Wustenhagen *et al.*, 2007)

Market acceptance recognises the fact that social acceptance is not limited to consumers. One needs to consider other role players in society, such as investors and large energy corporations. Energy companies are also significant stakeholders, possessing the ability to shape energy policy, and control decisions made, regarding project finance and grid access. Thus, in order to improve the market acceptance of MTRESs, it is necessary to engage with all market-based stakeholders, lest strong action be taken against the RE industry's expansion. (Wustenhagen *et al.*, 2007)

Analysis of these three dimensions reveals a need to incorporate the multiple interests of different stakeholders into the decision-making process. These stakeholders vary from local communities, who can disrupt on-site operations, to government officials, responsible for policy-making and planning, to investors, who provide the capital required. Furthermore, careful consideration should be given to institutional frameworks designed to foster clear and concise communication between all relevant parties, utilising the input received to lay the foundation for a stable investment and support system, on both a local and national level. (Wustenhagen *et al.*, 2007)

Yun & Lee (2015) present a socio-technical framework (see Figure D.6), based on the theory of planned behaviour (TPB), exploring social and technical factors that influence consumers' usage of MTRESs, with the aim of increasing market demand for such technologies. It was found that consumers' actions are strongly influenced by their attitudes (positive or negative feelings towards acting in an intended way), subjective norms (a desire to act similarly to social groups or as society would act), and perceived behavioural control (the belief that an individual has the ability through knowledge, money and time to control their own behaviour). Social trust and support were found to have a positive influence on attitude and subjective norms, realised through the demonstration of fairness, transparency, and credibility in experts, institutions and social communities. These groups are supportive of, and responsible for, the adoption of MTRESs within society. (Yun & Lee, 2015)

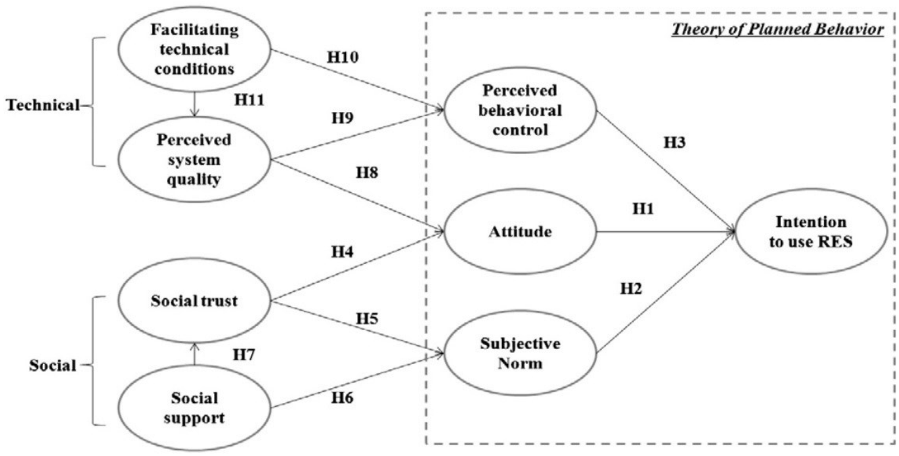


Figure D.6: Socio-technical framework
(Source: Yun & Lee, 2015)

Facilitating the technical condition of MTRESs was shown to have a significant impact on the perceived behavioural control and system quality of such systems (Yun & Lee, 2015). It was interesting to note that simply promoting product or technology reliability alone did not serve to address consumers' concern over control of the technology (Yun & Lee, 2015). Instead, consumers required specific technical support, guidance, and input from professional groups, for the purposes of improving perceptions relating to reliability and control (Yun & Lee, 2015).

Thus, in order to increase social acceptance, reliability, technical support, and simple and clear guidance are needed for the market expansion of MTRESs.

Yun & Lee (2015) made an interesting observation with respect to the sources from which people obtain information about MTRESs. As one might expect, mass media (42.6%) was the source cited most often. However, the subsequent sources included friends and co-workers (14.9%), government organisations (12.6%), education institutions (11.7%), family (10.6%), and individuals from their local neighbourhoods (6.1%). Knowledge of these different sources, and incorporation into any social acceptance strategy, will allow for more effective communication of information regarding MTRESs to the public.

Stigka *et al.* (2014) delved deeper into the community dimension of social acceptance, investigating communities' respective preferences and attitudes towards investment in, and perceived use, of MTRESs. They reasoned that attitudes form the basis for behaviour, which places greater emphasis on understanding consumers' attitudes relating to MTRESs as a means of influencing behaviour. Behaviour demonstrated by the public can be attributed to three factors: current information held, perceptions and positions relating to a technology, and fear that increases with ignorance. While a positive attitude was shown towards MTRESs, a lack of sufficient information and familiarity with such technologies led to a sense of wariness displayed by the public. (Stigka *et al.*, 2014)

The cost that consumers are willing to pay for energy is subject to a number of factors. Stigka *et al.* (2014) examined the use of the contingent valuation method (CVM) to assess the financial value attached to green forms of energy, based on an individual's willingness to pay (WTP) for maintaining an environmental good, and the relationship that exists between socio-economic and demographic factors, and consumers' WTP. Their findings indicated that although consumers are willing to accept a higher tariff for electricity generated from MTRESs, the amount in question was dependent on factors such as the level of disposable income, payment method, geographic location, physical distance from the MTRES project, and priority given to environmental concerns. (Stigka *et al.*, 2014)

It is interesting to note which aspects positively influence an individual's WTP for MTRESs. Through a summary of studies aimed at this question, Stigka *et al.* (2014) noted a relationship between WTP and socio-economic traits, knowledge and awareness of MTRES, and an interest in environmental issues, especially climate change. WTP grew with an increase in an individual's income and level of education, as well as those with underage children. A difference in WTP was also observed between rural and urban communities, although this was related to perceptions about the benefits associated with MTRESs, such as distribution of economic benefits in the way of jobs and resources.

Appendix D.4.2 Social acceptance tools, methods, and techniques

Following investigation into social acceptance and its different aspects, the decision was made to prioritise the promotion of knowledge and awareness of MTRESs, and wider environmental issues, in the social acceptance MAPPS of the strategic management framework. Table D.19 presents a list of the tools, methods and techniques considered to promote social acceptance as part of the strategic management framework.

Table D.19: Social acceptance tools, methods and techniques

Tool, method or technique	Use in promoting social acceptance
Decision-making process	By ensuring a fair, transparent, credible, and inclusive decision-making process, society feel they have a say in any decisions made, and an influence in a technology's future development. Can also be used to address any concerns relating to the technology at hand, and satisfy the broader society interest.

Tool, method or technique	Use in promoting social acceptance
Information diffusion	Equipping society with all the relevant facts relating to a technology empowers them to form their opinion (of the technology), and make informed decisions.
Green marketing	Useful in separating the supply and demand of an energy technology; provides an avenue for society to contribute directly to the inclusion of MTRESs into a country's energy mix without being directly involved.
Labelling and technical standards	Provide technical support, guidance, and input relating to the reliability and control of a technology to consumers, and other members of society.
Cell phone applications	The majority of the global population access the internet through cellular devices
Media	Use of mass and social media to reach all members of the population through a variety of platforms, such as Facebook, TV, radio, public demonstrations and celebrity endorsements.

(Sources: Wustenhagen *et al.*, 2007; Yun & Lee, 2015)

Appendix E

Strategic Management Framework Partnership

Appendix E discusses the structure and development of the partnership formed to implement the strategic management framework, providing guidance to management practitioners and prospective partnership members regarding aspects and issues to consider in the design of the partnership. In addition, a list of recommended activities that the partnership should consider with respect to the three secondary level components is presented. The list presented is not assumed to be comprehensive, and is likely to change over time as the different MTRESs progress through the commercialisation process, and as a result of local and global externalities.

Appendix E.1 Partnership development

Glasbergen (2010) present a ladder of partnership development (see Figure E.), describing it as an interactive and iterative process consisting of several key activities. These activities allow for objectives to be reached faster and more effectively, improving the chances of long-term success and sustainability in the modern era.

Figure E.1: Ladder of partnership activity
(Source: Glasbergen, 2010)

To proceed up the ladder, partnerships need the support of strong companies or industry leaders, those who have considerable market power and influence, and who are able to change the nature of a market if necessary. NGOs can provide professional knowledge and expertise, while it is often useful to have personnel available to attend to the administration, and other internal matters, of the partnership. Furthermore, it is important to gain rapid trust and legitimacy in the eyes of the respective industry, as well as ensure sufficient confrontational power is held as a means of driving the process of partnership development towards its goals. (Glasbergen, 2010)

As one might suspect, achieving the formation of a successful partnership is no simple matter. The formation and development of a partnership towards commercialising MTRESs is outlined below, based on the ideas of Glasbergen (2010), with a focus on the five activities presented in Figure E..

1. Building trust

   The first step in any partnership is to build trust. Building trust often involves a significant degree of exploration, where prospective partners seek to establish common ground on which further dialogue can take place. The primary objective of this stage is to address the transformation of (potential) adversarial interaction into collaborative interaction through trust, with the aim of achieving added value for all those involved.

   To achieve partnerships between agents with widely different goals, agendas, beliefs, and identities, it is necessary for each agent to perceive the potential opportunities that exist to achieve additional value with respect to their own operations, opportunities that can be (best) realised through collaboration. These opportunities include: a larger market for MTRESs and their components (business sector), meeting the energy demands of the nation's citizens and diversifying the current energy mix (government), and the environmental benefits that MTRESs offer (civil society).

Perhaps more important than interdependence between partners for the purposes of establishing trust, is the need for partners to exhibit a basic will and attitude to collaborate. Without a firm interest shown in collaboration, sometimes even with direct competitors, no partnership will progress beyond this initial stage. It needs to be recognised that trust is not something that instantly exists. It is a social process, one that needs to be carefully fostered, managed, and supported through time by ensuring that partnership members share positive experiences, both internally and externally, throughout the entire process. In some instances, it may even be necessary to persuade or encourage parties to demonstrate a willingness to collaborate in order for the process of trust building to begin.

The development of trust between partners can be enhanced by establishing a basic framework designed to create the conditions necessary to promote trust. Such a framework needs to be based on principles relating to security, transparency, equality, and fairness. It is also recommended that a set of rules be established pertaining to the following:

- Provision of surety regarding the legitimacy of partners' presence. Partners need to be secure in the knowledge that their voices and opinions will be heard and addressed, regardless of any differences in status or authority that may exist, and that all members will be respected and treated with dignity;
- Capacity for the accomplishment of substantial collaboration. This requires that rules be implemented relating to agenda building, provision of valid information, confidentiality, and a code of conduct;
- Communication channels, both between partners (internal) and the outside world (external). Without strong means of communication, dialogue between partners and other external stakeholders is limited, reducing the speed at which the partnership may be developed, and commercialisation of MTRESs realised.

2. Creating collaborative advantage

Collaborative advantage is created by harnessing the strengths of the individual partners in order to accomplish goals which the partners may not be able to achieve acting on their own. It is necessary that each partner holds an interest in seeing the objectives of the partnership met in order to ensure their buy-in. Otherwise, they might be unwilling to collaborate, and the partnership will fail as a whole. In the context of the commercialisation of MTRESs, these interests may entail establishing a wider market for such projects and their system components (business sector), diversifying the current energy mix, increasing socio-economic growth to create additional employment opportunities for poverty alleviation (government), and the health and environmental benefits that clean energy technologies offer (civil society).

Gain alone is often insufficient to guarantee that partners will collaborate towards reaching a partnership's objectives. A second underlying factor is fairness. Partners need to be convinced that the benefits and costs involved will be dispersed in a fair and transparent manner among all partners. The share of benefits and costs will likely differ based on the varying degrees to which each partner is involved in the partnership. A perceived lack of fairness among partners acts as a barrier to collaborate, and will likely reduce any trust that may have been established so far.

A final point to address relating to collaborative advantage is the recognition of the different and competing interests which may exist between partners. Such interests have the potential to create conflict in the future, and should be handled in an open and fair manner. It is important to distinguish whether such interests have a direct impact on the partnership and its goals, or whether such disagreements could be handled separately. Each conflict that begins to arise due to competing interests should be resolved in a harmonious manner, promoting continued interest in remaining in the partnership, and collaborating to meet the relevant objectives.

3. Constituting a rule system

   Having built trust among partners, and established the will to collaborate for individual and collective advantage, the next stage in partnership development is the formation of a rule system. A rule system constitutes a set of rules and common definitions of a problem that a partnership aims to solve, together with a list of relevant objectives. It is based on a contract between all partners, one that formally recognises the investment, obligation, and commitment made by the partners to each other and the partnership, and binds all members towards supporting the partnership's goals. It also specifies how external interactions with other bodies and organisations will be handled.

   The contract acts to implement and enforce the rule system, containing the transactional and procedural aspects of the partnership, particularly those relating to the allocation of tasks and resources, relevant procedural & performance standards and metrics, the decision-making process, and means of tracking and enforcing such decisions. It provides a guide for conflict resolution and management of unanticipated events, and can be used to prevent, and handle, any potential misunderstandings.

   By agreeing to the rule system outlined in the contract, and abiding by it, partners can ensure and enjoy continuity in the trust and collaborative advantage fostered so far. This is especially important in instances where partners may be heading into unknown territory outside of their comfort zone. In the case of the commercialisation of MTRESs in South Africa, a great deal of uncertainty exists regarding the future direction of the energy sector (Odendaal, 2017), as well as the impact of externalities, such as the 2008 global financial crisis (Hofman & Huisman, 2012). By instituting the rule system outlined in the contract, a measure of stability can be established, especially involving the potential future path of the country's energy sector. However, for those who fail to abide by the contract, they risk expulsion from the partnership, along with the loss of any potential benefits and credibility that the partnership may afford to its members.

   Elements of dynamism can be introduced into the partnership when necessary, or desired, as circumstance change through the introduction of new partners, both internally and externally. The contract should contain provisions that outline how such transitions are to be managed. It is also worth noting that as the partnership grows through new members, who adopt the problem definition and set of rules, and change their practices, it may gradually institutionalise a new management practice within South Africa's RE industry. This places greater emphasis on ensuring that the contract is well designed to support the growth of both chains, and the industry as a whole.

4. Changing a market:

   Changing a market is never easy. It typically involves efforts on a large scale, and is normally driven by strong public or private sector action. To affect significant change in the energy sector in South Africa, and expand the market for MTRESs, the focus of the partnership needs to shift from internal to external interactions. On a structural level, this transition involves a change from the relative horizontal nature of the partnership, to the vertical and hierarchical structure found in large-scale socio-technical systems.

   Strong entrepreneurial leadership is required to produce effective change in a market. Leaders need to be able to change the management of process chains that exist in an industry, by using authority and power to determine how resources are distributed and moved in the chain. Legitimacy is a key leadership trait for achieving such changes. Legitimacy describes the process by which a partnership, through its rule system, is acknowledged as a viable alternative within the existing supply chain. It can be established through the development of functional relationships with other market actors and political bodies that exert significant influence over the market.

The measure of success achieved by the partnership in changing South Africa's energy industry depends on its ability to engage with, and move as necessary, the most powerful actors in the market, among other factors. Partnerships that gain legitimacy are able to alter and align market conditions of operation and political influence with their goals. These two aspects are vital in gaining a greater market share of the energy sector, thus establishing MTRESs as dominant energy technologies within South Africa, and increasing the contribution of RE sources to the country's energy mix.

5. Changing the political order

   The final activity on the ladder of partnership activity is the influence of partnerships on the political order, and society in general. Partnerships often grow to form part of networks that govern social order, where political power is divided between agents from the private and public sectors. Partnerships are frequently comprised of members from both sectors, presenting an opportunity for dialogue to take place away from formal decision-making spaces. This in turn leads to the realisation of social power[120], where partnerships are able to influence policy, and other societal forces.

   Social and political power are key to expanding the market for MTRESs in South Africa. Social power acts as a strong incentive for government to increase their investment in a new technology, particularly amidst international pressure, and the risk of losing support in upcoming elections. Hence, it can form a significant force in promoting the transition from traditional fossil fuel technologies to RE sources. Political power, on the other hand, is necessary to ensure policies are developed and implemented that favour MTRESs, such as those that allocate a greater percentage of future power capacity to such technologies.

Appendix E.2 Partnership activities

Appendix E.2.1 TA

- Identify all data required for the different analytical tools and methods (see Appendix C)
- Establish strong data collection & analysis processes, be they internal (in-house) or external (outsourced). In the case of a lack of, or unreliable, data, the partnership should engage with relevant stakeholders, experts, and other knowledgeable individuals through group discussions and brainstorming sessions to compensate for this lack of data, and thus complete the data set required. Any assumptions made need to be relatable to the respective MTRES and commercialisation process, and preferably be based on similar sets of existing data;
- Focus attention on those subsystems of the MTRES that are still in a pre-commercialised state, with the greatest potential for technological improvement.

Appendix E.2.2 MAPPSs

- Engage with government officials across all levels (municipal, provincial & national) in order to implement the policies presented in Chapter 5.6.1. On a local government level, focus on medium to high-income municipalities, as well as those municipalities who express interest in renewable energy;
- Assist the business sector in becoming the primary driver behind the commercialisation of MTRESs by performing the activities highlighted in Chapter 5.6.2;

[120] Social power is defined by Glasbergen (2010) as: "*the ability to influence the outcome of societal processes relevant for the solution of public issues, independent of political institutions*".

- Ensure the necessary data is obtained to continually update the model for bridging the cost gap (Table 5.7), thus tracking progress towards cost-parity with traditional energy technologies;
- Engage with public and private schooling bodies to incorporate the educational initiatives raised in Chapter 5.6.3 into the academic curriculum;
- Seek the assistance of a software developer for the development of VR and cell phone applications for promoting social acceptance of MTRESs;
- Establish strong relationships with the South African media to exert influence over the energy debate in South Africa, fostering a positive public perception of MTRESs; and
- Seek input from all relevant stakeholders for the establishment of a set of legal and technical standards pertaining to MTRESs' development, installation, and operation.

Appendix E.2.3 OA

- Engage with all partnership members to analyse how their existing organisational capabilities compare to the level of those required for the commercialisation process, and suggest changes based on the findings;
- Adapt the internal organisational structure of the partnership to suit the strategic needs of the commercialisation process through the use of clear and concise objectives that are communicated to all relevant parties;
- Ensure the strategic management framework is implemented effectively by allowing the partnership's internal structure to evolve as the commercialisation needs of MTRESs, and the RE industry, change over time; and
- Establish a policy and culture for the partnership following consultation with the relevant partners.

Appendix F

Validation of the Strategic Management Framework

Appendix F presents a number of documents that formed part of the validation process. These include: (1) the request for participation in the validation process, sent to prospective candidates in academia, the public and private sectors, and civil society; (2) the questionnaire used to obtain feedback from participants during the interviews conducted; and (3) the final version of the strategic management framework post-validation. In addition, the grid expansion and integration plan developed following the lack of a detailed plan highlighted by Participant 1-1 during the first iteration round is also included.

Appendix F.1 Request for validation

A strategic management framework for the commercialisation of multi-technology renewable energy systems: The case of concentrating solar power technologies in South Africa

by Greg Prentice

Introduction to the research

In a response to a growing social, environmental, and economic challenges, world leaders have recognised the need for sustainable development to safeguard the planet for future generations. One of the key elements of sustainable demand is energy, with increasing attention placed on clean energy technologies, such as renewable energy technologies (RETs). In order to ensure a sustainable supply of energy for the future, there is a need to increase the rate of adoption of these technologies into the global energy mix. One of the ways this may be achieved is by increasing the rate of commercialisation of RETs, on the premise that individuals are more likely to adopt a technology that is commercially mature, while it is to be expected that if cost-parity is reached with other established energy sources, the environmental benefits of RETs will establish them as a preferable energy technology.

To assist the development of strategies towards increasing the rate of commercialisation of RETs, a strategic management framework was developed. The choice of such a framework acknowledges that the process of technology commercialisation is one that takes time, and needs to be managed effectively to achieve success, while addressing the multiple elements required for the commercialisation process. Concentrating solar power (CSP) technologies in South Africa was chosen as a case study due to its energy storage capabilities, offering the potential for dispatchability, together with the immense solar resources found in South Africa. Finally, the use of the term multi-technology renewable energy systems (MTRESs) acknowledges the inherent complexity of RE systems, as well as the fact that different technologies within these systems lie at different stages in the commercialisation process, and thus require different commercialisation-based efforts.

The strategic management framework

Figure F.1 illustrates the strategic management framework developed. The primary level component, people, are responsible for all the decisions made, which can either aid the commercialisation process, or ensure that the MTRES remains in an early growth phase. The three secondary level components consist of (1) technology assessment (TA), aimed at understanding the MTRES at hand; (2) a selection of market adoption, promotion, and penetration strategies (MAPPSs), designed to increase the rate at which MTRESs are accepted and adopted by the broad market and society in general; and (3) an organisational analysis (OA), highlighting the organisational capabilities required to achieve an increased rate of commercialisation of MTRESs.

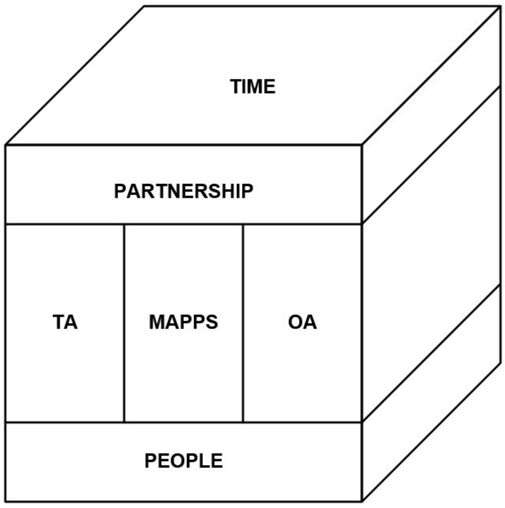


Figure F.1: Strategic management framework

The primary and secondary levels of the strategic management framework act to support the tertiary level, a partnership. The partnership is responsible for implementing the framework, thus driving the commercialisation process. Such a task is presently made more difficult by the existing structure of the energy industry in South Africa, and stance of the South African government and state-owned enterprises (SoEs). Attention is also given to the interfaces between the three levels of the strategy, ensuring that all components act together towards increasing the rate of commercialisation achieved.

Conclusion

This document serves as an initial guide to the strategic management framework developed as part of the research study. The researcher is currently involved in the validation of the framework. You have been identified as being an expert in the field(s) of technology management, technology commercialisation, renewable energy, and/or concentrating solar power, and are thus invited to play an additional part in the validation process.

The validation process aims to answer the primary questions:

- Are the views and thoughts of the researcher on the commercialisation of CSP technologies in South Africa, embodied by the strategic management framework, shared by experts in the field?
- How may the strategic management framework be refined to better address the needs of the CSP commercialisation process in South Africa?

Should you agree to participate further in the validation process, it will involve the following:

1. A short presentation of the strategic management framework expanding on the description given above; and
2. An interview with the researcher immediately after the presentation, consisting of a Q&A session aimed at obtaining feedback on the strengths and weaknesses of the strategic management framework.

If you are interested in assisting the commercialisation of CSP technologies in South Africa, and would like to continue with the validation process, please contact the researcher:

Greg Prentice
M. (Eng.) Engineering Management
Stellenbosch University
16086643@sun.ac.za; gskprentice@gmail.com
+27-724418336

Appendix F.2 Interview questionnaire

Questions:

Strategic management framework approach to commercialisation:

Q: The commercialisation of CSP technologies is a complex subject, especially in the South African context. In your opinion/experience,
What are some of the key challenges currently slowing the rate of commercialisation of CSP technologies in South Africa?
What is the best/preferred approach(es) to increase the rate of commercialisation of CSP technologies, and why?
Does/should this approach differ in the South African context? Why/Why not?
Q: Do you agree/disagree with the strategic management framework approach presented here for the commercialisation of CSP technologies in South Africa? Why/Why not?
Q: Do you agree with the positioning of people as the foundation of the strategic management framework? Why/why not? If not people, what would you suggest should form the base element of an approach to increase the rate of commercialisation of CSP technologies in South Africa?
Q: What is your opinion of the three secondary level components of the strategic management framework? Do you believe them appropriate choices in the context of the objectives of the strategic management framework?
Q: What are your thoughts on the future direction of the CSP industry, both globally and in South Africa?

Technology assessment (TA):

Q: Do you agree with the premise behind the inclusion of a TA component in the strategic management framework, namely: that it is necessary to understand the underlying technology in order to increase the rate of commercialisation achieved? Why/why not?
Q: Do you agree with the six broad areas of TA selected for the TA component of the strategic management framework from literature? Why/why not?
Q: Which other TA areas, if any, would you have recommended for use in the strategic management framework, and why?

Market adoption, promotion and penetration strategies (MAPPSs):

Q: What, in your opinion/experience, is the best/preferred way to foster and promote a (large) market for CSP technologies in South Africa?
Q: Do you agree with the four focus areas of the MAPPS component, namely: government, the business sector, educational initiatives and social acceptance? Why/why not?

Q: Which other focus areas would you have included as part of efforts to increase the market promotion, penetration and adoption of CSP technologies in South Africa? Would you have included them in addition to, or as a replacement for, any of the four focus areas identified under the MAPPS' component?

Organisational analysis:

Q: It is proposed that in order for an organisation to oversee an increased rate of commercialisation of a (new) technology, it needs to possess certain strengths (divisions of manufacturing, marketing etc.). In your opinion, which key capabilities does an organisation require to achieve an increased rate of commercialisation of CSP technologies in South Africa? Why?
Q: Do you agree with the selection of the organisational capabilities presented in the strategic management framework? Why/why not?

Partnership:

Q: Do you agree with the form chosen for implementation of the strategic management framework, namely: a partnership? Why/why not? What alternative means of implementing the partnership may you have suggested?
Q: Do you agree with the objectives and target values set out for the partnership, with their associated time frames? Why/why not? Which objectives should/should not have been included?
Q: Do you agree with the list of key stakeholders identified for inclusion in the partnership? Which stakeholders may you have included and/or omitted, and why?
Q: Do you agree with the structure selected for the partnership? Why/why not? What alternative structure may you have suggested?
Q: Do you agree with the monitoring metrics selected to measure progress achieved in the commercialisation process by both the partnership and strategic management framework? Why/why not? Which alternative metrics may you have suggested?

Strategic management framework interfaces:

Q: Do you agree with the relationships highlighted between the primary and secondary level components of the strategic management framework? Why/why not? Which other (potential) relationships would you have mentioned?
Q: Do you agree with the relationships highlighted between the secondary level components of the strategic management framework? Why/why not? Which other (potential) relationships would you have mentioned?
Q: Do you agree with the relationships highlighted between the secondary and tertiary level components of the strategic management framework? Why/why not? Which other (potential) relationships would you have mentioned?

Appendix F.3 Participant responses

This section summarises the responses of all the participants who took part in the validation process.

Appendix F.3.1 Round one

Table F. presents a summary of the participants' responses during round one of the validation process.

Table F.1: Round one participants' responses

Framework component	Participant 1-1	Participant 1-2	Participant 1-3
General commentary on strategic management framework approach & CSP industry in SA	▪ Good integration of different partners and different aspects in strategic management framework. However, missing inclusion of a sufficient grid integration component. ▪ South Africa is one of the best sunspots on earth, with export potential for CSP technologies. ▪ Greater cost reductions required for CSP components, together with reliability of technology.	▪ Government policy is vital for creating consistency, together with a long-term programme for the business sector. ▪ Strategic management framework suitable, includes all major components. ▪ Alternative means of energy storage, such as PV with battery storage and supercritical CO_2, pose a large threat to CSP technologies, particularly if they become cost-competitive or even cheaper.	▪ Size and certainty are crucial factors for the commercialisation process. Commercialisation occurs when there is massive demand, or required government application. ▪ Good approach proposed, but it needs to distinguish what is being commercialised; CSP is too broad a technology to commercialise. Also, who is behind the commercialisation, and who is it going to benefit? Who is going to use the technology? ▪ Presently, a greater focus on technology application than commercialisation (REI4P). ▪ Approach needs to focus on sustainable demand and practicality as core components, everything else will follow afterwards; technology should be left to the free market.
Key challenges to commercialisation process of CSP	▪ Politics and politicians' actions are key barriers to achieving progress in the commercialisation process	▪ Government strategy, technological readiness of CSP systems, and the viability of the technology in terms of construction issues and performance standards are key barriers to achieving progress	▪ Political interference is to blame for the mess that the CSP and RE industries find themselves in.

Framework component	Participant 1-1	Participant 1-2	Participant 1-3
		in the commercialisation process.	
People	▪ People are a good choice as a base component. However, impression received that most people in South Africa do not know about CSP technology. Once informed, they express positive attitudes towards it, which can be used to pressure politicians to adopt it into the country's energy mix.	▪ People are necessary; however, they have to be trained and educated in CSP technology.	▪ Suitable foundation; consider previous point of who is behind the commercialisation, and who is it going to benefit? Who is going to use the technology?
TA	▪ Always necessary to understand the technology and have working models in place. ▪ Six broad areas of TA selected suitable for the commercialisation process ▪ Need to analyse how CSP fits into South African electricity supply system; role played by Eskom requirements for IPPs and CSP power plants.	▪ Level of technology understanding depends on respective need, but a general understanding is still necessary. ▪ The six broad areas appear suitable.	▪ Good selection of tools, but very broad.
MAPPSs	▪ DoE understands benefits of CSP but unable to act for a number of reasons. ▪ Integration of different South African industrial sectors (boiler, construction, steel etc.) needed. ▪ Education initiatives needed to meet high local labour content requirements. ▪ Ensure longer-term plans with respect to social acceptance of CSP plants in local communities, and prioritising different objectives. ▪ Issue of job losses with respect to coal mines ▪ Suitable selection of four MAPPS focus points.	▪ Government policy is necessary, but will never be the sole tool to achieve an increased market expansion. ▪ Champions in industry are required to really push the use of a technology for it to reach a commercialised state. ▪ Four focus areas cover the most important aspects.	▪ Business sector won't take lead role because CSP is too expensive and the projects too big. Lack of a pipeline of projects is also a factor, together with project guarantees. Otherwise would have been done already. Realistically, and from experience in the energy sector, it has to be government. ▪ Businesses concerned with profitability first, sustainability second. Not interested in commercialisation, but they should be. ▪ Sustainable government policy is key for creating demand: substantial investment in REI4P has proven that the policy itself is fine; it is political interference that is the main issue, and poor implementation of policy, ▪ Mining sector hasn't adopted CSP because of cost and uncertainty regarding the future operation and value

Framework component	Participant 1-1	Participant 1-2	Participant 1-3
			of their mines; they all know about CSP from their (energy) resource assessments. ▪ Hybrid plants not currently feasible due to small scale (20 MW) – CSP has a technical limit in order to be possible. ▪ Wheeling and dealing / willing-buyer willing-seller deals of PowerX unlikely given need for guarantees; business sector can't guarantee such multi-billion dollar projects.
OA	▪ Entrepreneurship is the most important organisational capability. Decisions need to be made with a mid- to long-term mindset to benefit the future of the CSP industry. ▪ The other capabilities presented are valid. ▪ Strategic positioning is important with respect to the development of a pipeline of CSP projects for the future, proving surety to industry players, such as suppliers and manufacturers.	▪ List of capabilities sufficient.	▪ Capabilities need to be in support of sustainable demand; if there is sufficient demand these capabilities will be developed and strengthened on their own.
Partnership	▪ Partnerships are a popular option for many different stakeholders in the CSP industry, both in South Africa and globally. ▪ Short-term objective of 100 MW/year is only one CSP plant. Likely need greater additional installed capacity on an annual basis to support CSP industry in South Africa. ▪ Business sector stakeholders could be expanded upon in the way of suppliers and construction companies. ▪ In general, stakeholders listed is sufficient. ▪ Overseeing the partnership and commercialisation process is too much work for a single person. Need a group of people, or a board, to interact with the different partners.	▪ Objective target values seem suitable, price will have to come down to around R1/kWh to be competitive in the long-term. ▪ List of stakeholders is fine. ▪ A more detailed structure is required with respect to the different relationships. ▪ Need for more people to oversee the partnership than just a single manager, whatever the term. ▪ LCOE as a metric is not necessarily a good indication of economic efficiency; the	▪ The size and scope of projects proposed are too small, much larger projects in size and scope are needed to drive a sustainable industry. ▪ Very low LCOE values, potentially unrealistic. ▪ Need a more unified approach/partnership between different industries/sectors to encourage government to adopt CSP. ▪ A specific custodian is needed to drive commercialisation process. ▪ Need to include South Africa people as stakeholders. ▪ Need to consider other forms of economic efficiency such as job creation,

Framework component	Participant 1-1	Participant 1-2	Participant 1-3
	▪ Number of CSP plants built could also be a metric for the increase in government knowledge and understanding of such technologies and the associated benefits. ▪ Surveys are a good tool for measuring social understanding and acceptance of CSP technologies. However, care should be given to the specific questions asked. ▪ Could include additional metrics such as number of companies involved in CSP, as well as percentage contribution of CSP to South Africa's gross domestic product (GDP).	inclusion of a variable pricing block with CSP and storage technologies can offer higher profits, albeit with higher LCOEs. This needs to be taken into consideration here, with perhaps another metric used instead.	manufacturing, sustainable development etc. can't only focus on electricity sales through LCOE. Also need to consider effects of peaking tariffs. ▪ Need to elaborate on measuring perception: of people, government etc.
Interfaces	▪ People are a necessary part of the commercialisation process, possessing voting power in a democracy that affects government's policies and decision-making. ▪ Partnerships will likely develop on their accord, without any external effort, based on the partners' self-interest, such as those between technology providers and manufacturers.	▪ Diagram implies relationships at the borders between the different components. However, it does not show some of them, such as the TA-OA relationship. ▪ Clear alignment between people needed to ensure they work towards the same objective(s).	(Not covered due to a lack of time – Participant 1-3 had a flight to catch)

Appendix F.3.2 Round two

Table F.2 presents a summary of the participants' responses during round two of the validation process.

Table F.2: Round two participants' responses

Framework component	Participant 2-1	Participant 2-2	Participant 2-3
General commentary on strategic management framework approach & CSP industry in SA.	▪ Greater clarity needed on time dimension. ▪ Large focus on what we measure over time. ▪ CSP a desirable technology in terms of dispatchability.	▪ Different strategies and approaches required at different stages in technological and industry development; no 'one size fits all'.	▪ REI4P approach followed by government so far has been successful; centralised approach probably the best one, although ideally commercialisation would be driven by demand.

Framework component	Participant 2-1	Participant 2-2	Participant 2-3
	▪ CSP a good job creator, as opposed to other technologies such as PV ▪ Good solar resources; better suited to CSP than PV.		
Key challenges to commercialisation process of CSP	▪ Cost is largest barrier to CSP at the moment. Hence, need any approach should be directed primarily at cost reduction. ▪ Declining electricity sales also a consideration	▪ The change in priorities of decision-makers; a growing interest in nuclear. No longer such a demand for new plants as new supply comes online, together with rapid drop in PV prices. ▪ Lack of knowledge of CSP's potential as a baseload energy source.	▪ Key barriers are political interference and a lack of knowledge of CSP.
People	▪ People are ok, but ultimately it will be about the lowest cost solution; cost-reduction needs to be arguably the centre point of any such framework.	▪ People as foundation is good, but greater clarity is perhaps needed.	▪ Good selection of people as the foundation; definite need to consider the entire population.
TA	▪ Extremely wide range of areas/tools presented, too many to ever be implemented practically.	▪ Suitable range of tools selected, but perhaps more of a focus needed on those specific to MTRESs and CSP, such as water requirements.	▪ Greater clarity needed on boundaries between systems analysis and technical performance assessment.
MAPPSs	▪ Inclusion of how supply and demand are incorporated into the strategy, how the two are matched, peak electricity provided etc. ▪ Utilise government policy as enabling environment; business should provide more investment. ▪ Issue of declining electricity sales. ▪ Financial mechanisms proposed for bridging the cost gap not going to be very effective. Crowdfunding, equity, and low interest rates have limited potential; bringing down the cost of components more important.	▪ Need commitment for a large-scale build programme for rapid expansion of CSP market. ▪ Need to consider grid connectivity, access to water, learning curves to drive cost reductions. ▪ Need to specify which policies to implement at which stages during the commercialisation process, and to what degree; can't implement all of them at same time, would be ineffective.	▪ Job creation and local manufacturing vital for developing the CSP industry, together with investment and (political) buy-in. Also consider the power of trade unions in influencing policy. ▪ Policies within policy mix need to be integrated with each other on a departmental level; need someone overseeing and driving the entire policy mix to ensure that the departments responsible for the respective policy do indeed implement it. Coordination and alignment of

Framework component	Participant 2-1	Participant 2-2	Participant 2-3
	▪ Education initiatives and social acceptance not as important as efforts aimed at cost reduction.	▪ Useful to provide time dimension to proposed business sector activities. ▪ CSP industry needs to make business sense in terms of real demand before business sector will invest in R&D, manufacturing capabilities etc. ▪ Consider alternative educational initiatives, such as country-wide science challenges; school syllabus an unlikely option. ▪ Perhaps revise selection mechanisms used to identify policies, business activities etc. ▪ Export potential – need multiple markets; case of Danish wind turbine industry.	policies, and their implementation, will result in a more unified mix. ▪ Need to make CSP attractive for business sector in the short-term. Which is difficult as CSP has a long-term nature. ▪ Map the various business sector activities; export won't happen in the short-term. ▪ Cell phones applications certainly viable. Can also consider open days, school visits. Need to consider education in a broader sense, applied to renewables and energy in general, not just CSP. ▪ Good use of wide range of media sources – access different age groups within the population. ▪ Gap exists in population for people to become more aware about CSP and its benefits. Persuade/get trade unions and politicians on your side. But stick to the facts, keep a clean image.
OA	▪ Appears to be a good selection.	▪ Appears a good selection ▪ Revise selection mechanisms used to identify capabilities.	▪ Production management – a strong skill of South African people.
Partnership	▪ A balanced scorecard method is often used for strategy development & implementation → can tie all the partnership elements together ▪ Might be useful to include a greater breakdown of local content/ empowerment, such as ownership, community investment, and local production.	▪ Establish more of a link between objectives and metrics, possibly divide into primary and secondary. ▪ Consider other objectives such as local manufacturing, security of supply, and export potential; don't need only quantitative parameters, can use qualitative as well.	▪ Need to consider trade unions and research councils, such as CSIR, as partners. ▪ TCB a good choice to drive commercialisation and partnership. More specifics needed on its composition; should be representative of government, business etc. ▪ Numbers selected for short-term objectives ambitious and slightly

Framework component	Participant 2-1	Participant 2-2	Participant 2-3
		▪ Discuss means of partnership development[121]; needs and interests of different partners. ▪ Include research councils and labour organisations. ▪ Perhaps revise selection mechanisms used to identify partners, objectives, metrics etc.	unrealistic; perhaps consider revising. Long-term figures are fine. ▪ Clarify business sector stakeholders; businesses can also be investors, conduct R&D etc.
Interfaces	▪ Need to define 'commercialisation universe' → show that all elements that could be considered are indeed able to be represented by the model; boundaries need to be explicitly and carefully set to include any possible factor or component not presented in the model thus far.	▪ Consider the interdependencies between them all and how they inform and support each other → flows of information. Use the objectives to guide them,	▪ Consider who is to drive the interfaces. Won't be done by the TCB, need lower level personnel within the partnership.

Appendix F.3.3 Round three

Table F.3 presents a summary of the participants' responses during round three of the validation process.

Table F.3: Round three participants' responses

Framework component	Participant 3-1 Participant 3-2	Participant 3-3
General commentary on strategic management framework approach & CSP industry in SA	▪ Very coherent approach presented here, fits together & makes sense. ▪ Big challenge to have lots of people working together. But anything is possible with large groups of people working in a coordinated way ▪ Technology advancement happens at a rapid pace, with PV and battery systems posing a strong threat to the future of CSP. ▪ CSP a regional technology; only works in certain parts of the world, SA being one of the best one in terms of DNI. ▪ CSP has great localisation potential. ▪ Benefit of dispatchability	▪ Geographic location is very important for technology commercialisation; difficult to commercialise something that's not for your market. Need to understand local challenges faced by the technology where it is to be implemented. ▪ Technology needs to be profitable; commercialisation goes hand-in-hand with profit. ▪ Eskom is the market for CSP in SA; small CSP projects are probably easier to commercialise, but there is no market for

[121] This is an aspect that had already been covered in the development of the framework; however, was not mentioned in Rounds 1 and 2 of the validation process due to time constraints.

Framework component	Participant 3-1 Participant 3-2	Participant 3-3
	▪ Belief the CR might be the CSP technology of the future, becoming the dominant design. ▪ Need to develop critical mass in the CSP industry in SA for it to really take off. Can be assisted by a steady pipeline of projects to ensure consistent CSP demand for a long period of time – will assist efforts to increase localisation of the technology.	it. So, you have to look toward exportation even though CSP is not mature, which is difficult. ▪ Difficult to sell small- and medium-scale energy technologies in SA. ▪ Difficulty with following an export strategy (as part of the framework) is the need to have contacts abroad who can speak the language, as well as logistics and timing. Together with certification; lack of individuals able to certify such technologies here in SA. ▪ Need to privatise Eskom to open up the market; ensure the best economic decisions get made.
Key challenges to commercialisation process of CSP	▪ Bankability is a key issue, together with the risks involved for the lender. Need to prove different CSP technologies; presently PTC is most bankable. ▪ Lack of surety of demand – need for a pipeline of projects. ▪ Cost is also a significant obstacle.	▪ Lack of a significant market; only one buyer (Eskom) ▪ Overregulation is also a challenge; should make provision for easier implementation of small-scale projects. Particularly with respect to grid code compliance.
People	▪ Agreement with people as a foundation, but they have a long-term indirect effect e.g. people vote in governments, so indirect effect on policy. ▪ Technology improvement beginning to allow people to make their own decisions – can opt for PV instead of Eskom electricity. Support solar instead of coal or nuclear. ▪ Need to describe processes that involve people, ensure their cooperation. Some people have more of a say than others; only a fraction will have a real impact on commercialisation.	▪ Good focus as a foundation ▪ The understanding of people varies based on geographic location. In SA, people tends to refer to the community. In Europe it's all about the citizen. In the USA it's about the consumer. Need to be more specific here. ▪ Responsible for policy- & decision-making.
TA	▪ Good selection of tools. ▪ Still technical aspects to be understood and improved on e.g. effect of mirror cleanliness and O&M 's relationship with power output and cost, time it takes to reach full power output. ▪ Human factor analysis: greater automation will lower employment. ▪ Consider issue of water scarcity somewhere. ▪ Market analyses: industry actors' role(s) are changing, utilities and developers becoming involved and taking on different roles. ▪ Many companies lack a technical performance model – may have difficulty with that part of TA.	▪ Good range of important tools listed ▪ Safety and economics probably the most important ▪ Power quality measurements together with grid code regulation compliance and testing also vital.

Framework component	Participant 3-1 Participant 3-2	Participant 3-3
MAPPSs	▪ Government policy a key driver in the commercialisation process, potential for a long-term outlook. However, can also be a hindrance. For example, the new IRP first draft – no provision for CSP. Need for long-term, stable policy. Without government support for CSP, unlikely that technology will survive in SA. ▪ Issue of curtailment; policy must remain as it is now, that whatever electricity is generated from RE sources must be bought by Eskom. This will change with a greater penetration of RETs. ▪ Existing peak period tariff of 2x too low, power worth more then. Potential exists for a morning peak tariff to be introduced as well. ▪ Municipalities have limited scope to enact their own policies, have to follow public-private partnership regulations and secure backing from National Treasury. Not supported unless they are bankable. Suitable focus on wealthy municipalities. ▪ Issue of having Eskom as backup – need to improve reliability of RE, or pay Eskom for providing power on standby. Benefits CSP due to its dispatchability ▪ Business is flexible, can leave the country if needs be. Unwilling to invest in unproven technology. Need demand in the way of power plants to get business interested. ▪ Need local CSP companies, especially manufacturers, to remove risks and reduce costs; international companies encounter currency exchange risk – want their profits in foreign currency (euros, dollars etc.) ▪ Mechanisms for bridging the cost gap more to do with financing; consider renaming the purpose for what the mechanisms are to be used for. Also consider long-term individual PPA's/contracts where people pay for electricity sourced from a CSP plant; similar to a mass ownership model. ▪ Need to ringfence any capital raised for CSP, be it from the public or private spheres, to prevent it from being used for other RETs or purposes. ▪ Consider challenge posed by grid decentralisation - PV & wind. ▪ Revision of grid expansion and integration plan; consider varying voltage levels of transmission and distribution lines with respect to connectivity, as well as Eskom's grid code. Also consider availability	▪ Government policy is important; in the commercial stage government can kill any technology they're not happy with through regulation. ▪ Policy takes a long time to change, due to the approval processes. Need municipal approval, then Eskom/grid approval and so on – no centralised point. ▪ Many government officials scared to make any decisions, default answer is always no. ▪ Business involvement important, but dependent on government incentives; need for technology-focused, not business-focused, incentives. ▪ Education necessary; many people don't know what CSP is. Inclusion into school syllabus on a broad scale, not just Science and Technology Tests but also English tests etc. ▪ Technology must be socially acceptable; reference to NIMBY case – CSP's mirrors and light concentration, avian deaths. Close relationship with education.

Framework component	Participant 3-1 Participant 3-2	Participant 3-3
	of nearby water resources. Future lines will only be bought if they can service multiple plants. ▪ Continue with hybridisation into the long-term. ▪ Locating CSP in mining areas not optimal – dust etc. ▪ Need for a global standardised method to finance and contractualise projects. ▪ Wheeling is important to involve private off takers, although not yet proven with CSP only PV and wind. Potential for wheeling agreements to contain multiple off takers. ▪ Education & social acceptance important to increase knowledge and belief in the technology; government belief also important to ensure technology survival. ▪ Good focus on introducing RE and CSP material into school syllabus ▪ Perception important in terms of choice and support for energy technology. ▪ Promotion of CSP's clean nature and job creation potential can boost social acceptance and mobilise support amongst poor communities ▪ Good range of media platforms proposed, but also need other direct approaches, such as involvement of community/church/political leaders to educate them on CSP.	
OA	▪ Some capabilities are likely to be more important; pretty comprehensive range presented here. ▪ Probably require more R&D centres around SA, such as the one at Stellenbosch. ▪ Need to harness operational experience gained in SA; can prove a source of competitive advantage.	▪ Capabilities are important. Most of them appeared to be covered by that list.
Partnership	▪ Big challenge to have lots of people working together. But anything is possible with large groups of people working in a coordinated way. ▪ Localisation increases price; would be beneficial to suspend/reduce such requirements just to get industry going, then can bring them back. ▪ Nature of business is competition, but the framework involves businesses working together; competition could take place elsewhere.	▪ Scale of partnership necessary due to scale of CSP technology. Large investments needed. Unlikely that a single entity would be appear to commercialise a technology independently. ▪ Need board diversity; members with technical knowledge to assist decision-making process. ▪ Perhaps differentiate between different levels of government.

Framework component	Participant 3-1 Participant 3-2	Participant 3-3
	▪ Some unhappiness with SASTELA for poor support in wake of IRP draft; good that business sector drives this thing. ▪ Time frames: CSP needs to be self-sufficient in 10/20 years e.g. have reached cost parity and no longer require significant government subsidies. ▪ Possible inclusion of other metrics: amount of CO_2/GHG emissions avoided, plant lead time, percentage contribution of different energy technologies to SA electricity supply during peak periods, capital expenditure. ▪ CSP LCOE as a percentage of the average cost of electricity. ▪ Revise ROI target values set; would expect them to be high initially, then decrease over time. ▪ Differentiate between local and export where possible – keep in line with emphasis on export of CSP technologies and components. ▪ Good selection of partners and partnership; however missing media bodies.	▪ Partnership should be driven by the business sector, but needs to be accepted by government independent of external and private agendas.
Interfaces	▪ Could indicate relationship between TA and OA more clearly somehow. ▪ People appear far away from partnership.	(Not discussed due to lack of time)

Appendix F.3.4 Round four

Table F.4 presents a summary of the participants' responses during round four of the validation process. The interview with Participant 4-3 was not conducted due to an administrative email fault. Due to the relatively short turn around between iterations four and five of the validation process, it was not possible to schedule a meeting with another individual during this time. As such, the pod of Round four only consisted of two participants.

Table F.4: Round four participants' responses

Framework component	Participant 4-1	Participant 4-2
General commentary on strategic management framework approach & CSP industry in SA	▪ Good visual representation of framework. ▪ Secondary components as engine room of framework, and people and partnership responsible for speed of process and success achieved. Timing also very important. ▪ Low level of RE penetration likely to continue in short-term given SA's expertise with fossil-fuel	▪ Very good model; addresses everything needed for the commercialisation process, and a successful strategic framework: technology build-up/roadmap to implementation, organisational capabilities, and networking through partnerships. '*A 5th generation management model for technology and business development*'. ▪ Government-related CSP efforts and project development tend to be slower and more uncertain than that of the business sector. However, less desire for CSP

Framework component	Participant 4-1	Participant 4-2
	energy generation, and cheapness of coal. Seeming preference of government for nuclear technology.	with electricity oversupply. Overall, the environment for CSP is uncertain; also need to consider the wider energy sector. Lack of promotion and awareness of CSP likely to significantly limit future industry prospects. Might be better to focus on regional potential, not national-scale. Decision will be guided by the costs involved. Consider competition from Spain and abroad. South Africa's technological capabilities will also play a role.
Key challenges to commercialisation process of CSP	▪ The low level of allocation given to CSP in the REI4P. ▪ Poor perception and awareness of CSP technologies in South Africa. ▪ Low access to finance. ▪ Technology/financing valley of death – need to scale up a technology to make it commercially viable. ▪ Lack of buy-in and support from key policy decision-makers.	▪ Social acceptance and support for CSP. ▪ Poor technological capability and know-how, together with a lack of transfer of technology and associated skills. ▪ Unskilled labour force and poor education system. ▪ The slow implementation of CSP projects, strategies etc. in South Africa. ▪ The cost/price of CSP. ▪ The financial strength of CSP companies. ▪ Reliability of data regarding technology operation. ▪ Political interference.
People	▪ Good focus on people, can make or break technology. Political decision-makers can help drive supportive policy. However, very difficult to get buy-in from these decision-makers; need practical demonstrations of technology to convince them - value for money, together with champions/believers in the technology. ▪ Education and awareness will increase number of believers, while interpersonal relationships also play a role. Government role will get smaller and business larger over time.	▪ Politically very important, to put pressure on government decision-makers. Trust between people and all role players very important.
TA	▪ (not discussed – time constraints)	▪ Six broad areas cover everything you need, as well as the more detailed breakdown. However, the inclusion of technology forecasting/some planning tools for future technological development is required.
MAPPS	▪ Policy is necessary; good range of policies proposed. ▪ Education and marketing help get knowledge out there, increase awareness and understanding of CSP by the average citizen.	▪ Education and social acceptance also key to commercialisation process, to inform SA's citizens and promote. Suitable range of tools and methods proposed. Good foundation of trust as underlying factor to the social acceptance tools. ▪ Four MAPPS presented are well chosen. Might consider order of the four MAPPS, and how they are interpreted. Else state if any importance attributed to

Framework component	Participant 4-1	Participant 4-2
	▪ Public awareness and understanding drive social acceptance. Peoples' perception helps create technology reputation.	the order or not. As it stands, understood as government is the overarching thing, which is good as policy acts to synchronise the other three. ▪ Government policy mix seems fine. Very important that business sector takes the lead role over the whole lifecycle to achieve meaningful progress, in place of government. But government still has a role to play in providing (financial) guarantees to make CSP ventures profitable.
OA	▪ (not discussed – time constraints)	▪ Good selection of capabilities, no obvious omissions.
Partnership	▪ Good partnership structure presented; representative of all stakeholders. ▪ TCB need to be believers/champions of CSP technology, given voluntary nature of partnership. Buy-in from government, media, and general public very important→key stakeholders. Can influence peoples' actions and make the key decisions. ▪ Clear communication is required for each partner to understand their role and responsibility in the wider commercialisation process. ▪ Massive amount of coordination needed to make partnership structure work.	▪ Successful implementation of strategic tools has a number of criteria: (1) Need to ensure tool is well developed and you know what you want to implement, (2) acceptance of tool and its requirements by all stakeholders/role players, (3) ability of tool to deal and adapt to impact(s) of changing (external) environment on its implementation. Need to consider (technological) capabilities behind tools' implementation & management of change. Ability of capabilities to be continuously upgraded and realigned with the framework. Also consider human aspect in implementation, alignment of technology and the organisation. ▪ Partnership includes all the role players. TCB partnership core needs to be run by the business sector. ▪ To mobilise such a large number of people, you can either do it by force i.e. government forced, such as in Japan or South Korea, or in a democratic way, where everyone agrees to it i.e. a win-win situation. In SA, no single player who can enforce partnership, not even government, due to a lack of trust. Thus, it has to be the democratic way. To get buy-in from all the partners, the partnership has to provide value and benefits to each partner based on their needs and wants.
Interfaces	▪ (not discussed – time constraints)	▪ Alignment of different components is critically important. Sufficient thought and consideration of all the interfaces in framework. Integration of operational and innovation network layers, together with the capabilities to support them. People and roadmap level.

Appendix F.3.5 Round five

Table F.5 presents a summary of the participants' responses during round five of the validation process. This round demonstrated a case of snowball sampling with respect to the selection of participants, as the original three in the pod were able to secure three additional individuals for participation. Given that the participants were from the same organisation, they were all interviewed together, allowing for a robust debate on the framework presented. Following completion of the interviews, there was one individual left who had agreed to participate in the validation process. To avoid the case of a single-individual pod, the participant was added to pod five instead, and assigned the name Participant 5-7. No changes were made to the nature of the framework before presentation, with the only alterations being the inclusion of greater detail in the PowerPoint presentation to make clearer the framework being presented, and the message conveyed by the researcher,

In addition to these seven participants, an interview[122] was conducted with Dr Lloyd Hill of the Department of Sociology and Social Anthropology at the University of Stellenbosch. While he was not considered for the participation in the validation due to his ineligibility with respect to the selection criteria set, he was nonetheless able to provide some interesting views relating to the social acceptance of a new (energy) technology.

Table F.5: Round five participants' responses

Framework component	Participant 5-1 Participant 5-2 Participant 5-3 Participant 5-4 Participant 5-5 Participant 5-6	Participant 5-7
General commentary on strategic management framework approach & CSP industry in SA	▪ Need certainty and knowledge about new build CSP projects for the industry to develop properly in South Africa. ▪ Framework is very comprehensive; easy to get lost in all the information. Need to more clearly define its objectives and output, the net results, and the process by which framework will address commercialisation. These comments arguably relate more to the presentation of the framework, rather than the framework itself.	▪ Need an approach focused on cost reduction, or that targets areas where system cost of electricity is higher than that of CSP, such as Namibia. Another option is to target places where CSP is well supported (Morocco, Middle-east, China). ▪ Issue with CSP is that areas with DNI are not located nearby people or industries; the technology is very site-specific. Need to consider site location of MTRESs in approach. ▪ Greater clarity needed on different terms used throughout framework, and purpose of the tool.
Key challenges to commercialisation process of CSP	▪ Political interference. Policy itself is very good.	▪ Cost. Limited possibilities for cost reduction given standard material costs involved.
People	▪ (not asked – lack of time)	▪ (not asked – lack of time)
TA	▪ (not asked – lack of time)	▪ (not asked – lack of time)
MAPPSs	▪ Difficulty on part of many of the participants to see how social acceptance and education would benefit CSP. Many questioned whether these tools were really necessary on a CSP basis, as opposed to a higher level e.g. solar vs wind vs coal. ▪ Consider the relationship people share with information. Not only about money; jobs count for a lot in South Africa.	▪ Need to provide greater guidance on how policies are to be implemented: through central planning or on a more individual and localised basis.

[122] An audio copy of this interview is available.

Framework component	Participant 5-1 Participant 5-2 Participant 5-3	Participant 5-4 Participant 5-5 Participant 5-6	Participant 5-7
OA	▪ (not asked – lack of time)		▪ (not asked – lack of time)
Partnership	▪ Greater clarity needed on target values & assumptions used for objectives e.g. LCOE target; possibly need to revisit how these target values were set. Influence of capacity credit, time-of-day tariff etc. ▪ Need to consider implementation in greater detail; a set of steps/roadmap regarding framework implementation. Which activities are to be implemented when → link government policy and business activity mapping together with the implementation of the framework. ▪ Investigate methods of achieving buy-in from multiple stakeholders; need to provide clear evidence of realistic, transparent and achievable prospects & assumptions relating to industry growth, and the commercialisation of technology, to convince stakeholders of the likelihood of the partnership succeeding. ▪ Target values could be complemented with a probability matrix to test sensitivity matrix.		▪ Difficult to compare different energy technologies with different purposes and value propositions, and which are used in energy grids in different ways and at different times. Need to include consideration of the energy system into which the MTRES is to be introduced. ▪ Greater clarity required on LCOE metric. Average LCOE is a poor metric to use, rather consider system cost per kWh. Also need to specify how you would average the LCOE.
Interfaces	▪ (not asked – lack of time)		▪ (not asked – lack of time)

Appendix F.4 Market analysis of CSP technologies

To increase the (rate of) commercialisation of MTRESs, it is necessary to expand the consumer base that makes use of such technologies (Stapleton, 2009). Consumer segmentation is typically based on elements such as demographics, geography, and behavioural and psychological factors (Larsen, 2010). However, the need for energy transcends many of these divisions (Tse & Oluwatola, 2015). While it is acknowledged that some may argue for a CSP market segmentation based on need (thermal versus electrical energy) (Brent & Pretorius, 2011), the emphasis here is placed on consumer type.

The consumer market for CSP technologies is divided into four common segments: residential, commercial, industrial, and utility-scale. Applications for CSP technologies in each segment were investigated, together with the associated power output and temperature ranges, as well as which CSP technology[123] is suitable in terms of attributes such as performance, cost, and reliability (see Table F.6).

Table F.6: CSP market segmentation

Market segment	Application	Power Output	Temperature (ºC)	CSP technology[124]
Residential	Self-consumption	N/A	N/A	N/A
Commercial	Air conditioning	< 1 MW	-	LFC, DS
	Desalination	> 1 MW	90 - 120	PTC, LFC
	Cooling (adsorption chillers, single and double)	> 1 MW	130 - 180	PTC, LFC
Industrial	Desalination	> 1 MW	50 - 120	PTC, LFC
	Cooling (adsorption chillers, single and double)	> 1 MW	130 - 180	PTC, LFC
	Process heat	> 1 MW	< 250	PTC, LFC
	Process heat	> 1 MW	< 500	PTC, LFC
	Thermochemistry and fuels	> 1 MW	> 750	CR
Utility-scale	Mass electricity production for national consumption	> 10 MW	-	CR, PTC, LFC

(Source: adapted from DST & DoE, 2010)

The decision was made not to explore the residential sector, consisting of rural (off-grid) and urban (grid-tied) populations, in any great detail, given that the use of CSP technologies by residential consumers will likely prove to be too expensive and impractical, even in the long-term. As urban centres continue to grow, the amount of space available for such technologies will be put under pressure. Although rooftop power generation is an option for smaller CSP systems, issues of cost and practicality emerge. While rural areas typically do not have this problem in South Africa, the question of finance emerges again, as many rural communities are unable to afford such technologies without significant financial support (Karekezi, 2002).

One solution to the lack of CSP in rural areas is the construction of low cost solar technologies built on CSP principles, which use readily available recycled automobile and plumbing components (Bullis, 2006). However, the projected cost of these systems, at a couple of thousand US dollars (Bullis, 2006), may prove too expensive for many poverty-stricken communities, both urban and rural, to afford on their own (Department of Energy, 2015b). While the lack of knowledge and awareness of how to construct such systems can be

[123] There is still uncertainty as to which CSP technology may emerge as the dominant design (Grobbelaar *et al.*, 2014). From a strategic point of view, the potential use of the four existing CSP technologies in the different market segments was investigated, positioning the strategy should major R&D breakthroughs be achieved, and market dominance realised, in any of the four technologies.

[124] LCF – Linear Fresnel Collector; DS – Dish Stirling; PTC – Parabolic Trough Collector; CR – Central Receiver.

overcome through specialised training, the demand created is also unlikely to be great enough to support commercialisation efforts.

Another aspect to consider is the influence of competing energy technologies. Solar PV technology is experiencing increased use in the residential sector in South Africa (Maphelele, Stanford & Kooverji, 2013), and would pose a large threat to the deployment of CSP technologies. The improvement in solar PV technology, such as the new solar rooftop tiles recently introduced by SolarCity (Richardson, 2016), a subsidiary company of Tesla in the United States, will only strengthen the competition in this market segment. Therefore, the strategic management framework will focus instead on the commercial, industrial, and utility-scale markets.

Currently, the utility-scale market is the dominant market segment in South Africa. The sole purchaser of the electricity produced in this market segment is Eskom, the state utility (GreenCape, 2016). As a utility-scale purchaser, Eskom is forced to buy CSP-generated electricity under the policies of the South African DoE (Mpakama, 2016). However, Eskom has shown great reluctance to comply with these policies (Tsanova, 2016), slowing progress made in the CSP industry, and contributing to the uncertainty about the future of CSP technologies in South Africa's energy mix (CSP Today, 2015), and RE in general. As such, continued market prospects in this segment are uncertain, and likely limited.

However, given the strategic value offered by the utility-scale market to the CSP industry in South Africa, this market segment is too important to be ignored, with large scale power plants presently being the most feasible option due to economies of scale. As a result, and based on such uncertainty in the local market, a global export-driven strategy for this segment could prove a viable option. The choice of global market should be made with care, considering the case of the Danish wind turbine industry, where many businesses suffered bankruptcy following the collapse of their single export market in California (Grobbelaar, 2017). Moreover, commercialising a technology for a market in which you are not geographically situated is not easy.

Such uncertainty, and insufficient demand, cannot continue if the rate of commercialisation of CSP technologies is to increase. It is thus imperative that new types of consumers emerge who are willing to make use of CSP technologies to meet their electrical and thermal energy needs. Due to Eskom's monopoly in the utility-scale market, greater use needs to be made of CSP technologies in commercial and industrial applications, market segments dominated by the business sector. By exploring potential consumer groups and applications in these two market segments, greater economies of scale can be realised sooner, supporting a sustainable CSP market in South Africa and increasing the country's export potential.

The existing composition of the energy and electricity usage in South Africa was used as a starting point to identify prospective commercial and industrial consumer groups. Figures F.2 and F.3 present the 2005 energy and electricity consumption per sector, with the largest segments being the transport and industry sectors. Exploring the industry sector in greater detail, Figures F.4 and F.5 illustrate the energy and electricity consumption of the different divisions that exist. The largest energy consumer is the mining industry, followed by the chemical and petrochemical industry.

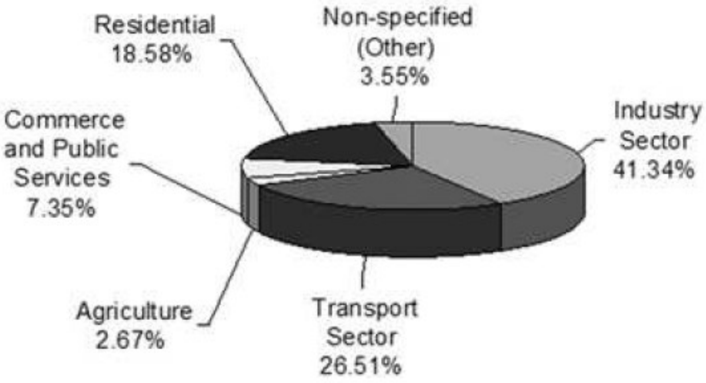


Figure F.2: Energy consumption per sector in South Africa – 2005
(Source: Department of Minerals and Energy, 2006)

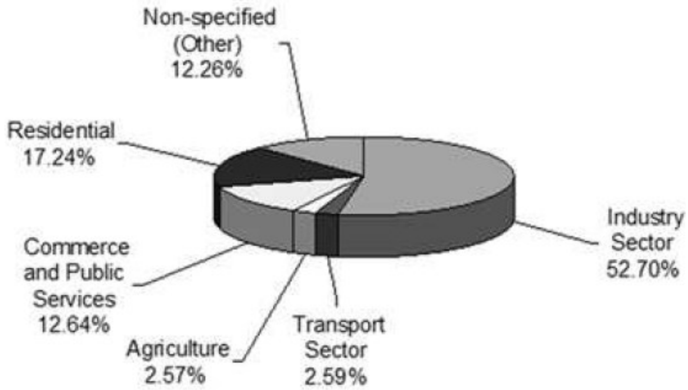


Figure F.3: Electricity consumption per sector in South Africa – 2005
(Source: Department of Minerals and Energy, 2006)

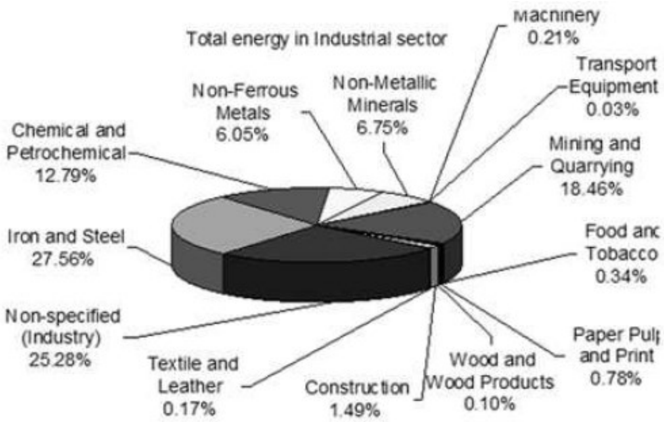


Figure F.4: Energy consumption of the industry sector of South Africa – 2005
(Source: Department of Minerals and Energy, 2006)

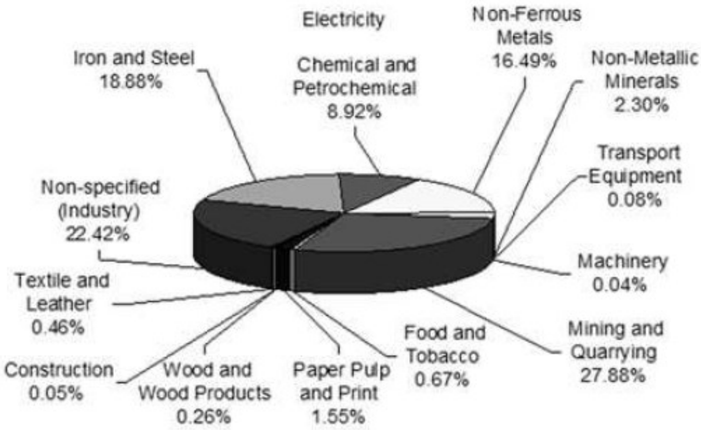


Figure F.5: Energy consumption of the industry sector of South Africa – 2005
(Source: Department of Minerals and Energy, 2006)

In addition to the CSP technology applications listed in Table F.6, the commercial and industrial market segments were examined from a thermal energy perspective, gaining a greater understanding of the various applications and processes in which CSP technologies can be deployed. Although the possibility exists to use CSP technologies in any application that requires heat, only those with a sufficient size of operations were investigated due to the large capital costs involved. Brent & Pretorius (2011) and the DST & DoE (2010) identified several solar thermal applications for CSP technologies (see Table F.7), the majority of which relate to the mining and chemical and petroleum industries. While it may not be presently feasible to utilise CSP technologies for all the applications listed, they are included for strategic purposes, highlighting potential markets in the medium- to long-term.

Table F.7: Industrial and commercial applications of CSP technologies in South Africa

Industry	Application / Process	Temperature (ºC)	CSP technology[125]
Food and Beverages	Drying	30 – 90	LFC/DS
	Washing	40 – 80	LFC/DS
	Pasteurising	80 – 110	LFC/DS
	Boiling	95 – 105	LFC/DS
	Sterilising	140 – 150	LFC/DS
	Heat treatment	40 - 60	LFC/DS
Textile Industry	Washing	40 – 80	LFC/DS
	Bleaching	60 – 100	LFC/DS
	Dyeing	100 - 160	LFC/DS
Chemical industry	Boiling	95 - 105	LFC/DS
	Distilling	110 – 300	LFC/DS
	Various chemical processes	120 - 180	PTC/LFC
	Solar thermochemical processes[126]	500+	PTC/CR
Desalination	Multi-effect[127]	< 70	PTC/LFC/DS
	Multi-stage flash[128]	90 – 120	PTC/LFC/DS

[125] See footnote 77.
[126] Solar Thermolysis, Solar Thermochemical cycles, Solar Reforming, Solar Cracking, Solar Gasification (Steinfeld, 2005). Primary purpose of these processes is the production of hydrogen as a clean liquid fuel (Brent & Pretorius, 2011). Competing processes include the electrolysis of water using electricity generated from solar technologies and fossil-fuel powered processes (Brent & Pretorius, 2011).
[127] Can be used to solve the issue of mine acid drainage, and provide fresh water to mines (Brent & Pretorius, 2011).
[128] Can be used to solve the issue of mine acid drainage, and provide fresh water to mines (Brent & Pretorius, 2011).

	Membrane Distillation	50 - 90	PTC/LFC/DS
	Reverse Osmosis	-	PTC/LFC/DS
All industries	Space heating and cooling	30 - 80	PTC[129]/LFC/DS
	Air conditioning[130]	30 - 80	PTC/LFC/DS
	Pre-heating of boiler feedwater	30 - 100	PTC/LFC/DS
Hybridisation	Natural gas	-	CR/PTC/LFC
	Diesel	-	CR/PTC/LFC
	National electricity grid	-	CR/PTC

(Sources: adapted from DST & DoE, 2010; Brent & Pretorius, 2011)

As an immediate focus for a new consumer base for CSP technologies, the mining sector holds great promise, being an energy-intensive industry with operations frequently located away from urban centres in areas with good solar resources. Currently, the sector uses on-site diesel generators and electricity sourced from the national grid as power sources, which frequently surpass 25% of total mining operational costs. Both these power sources are at risk from rising fuel prices and instability of supply. (Votteler & Brent, 2016)

CSP technologies offer mining companies the option of self-generation, through stand-alone power plants with storage, or co-generation, through the hybridisation of CSP systems and their components to complement electricity supply from other (baseload) energy technologies (diesel generators, national grid), and provide solar thermal heat for the sector's heat-intensive operations (Gauché *et al.*, 2017). Both these options have the added benefit of reducing the sector's carbon footprint, which may become more valuable should South Africa implement a carbon tax (Votteler & Brent, 2016). Presently, hybrid systems are to be favoured over stand-alone systems due to being more cost-effective (Pierce, Gauché, Von Backström, Brent & Tadros, 2013).

From a strategic perspective, it is worth investigating the competition posed to CSP technologies within South Africa's mining sector. In a review of the potential inclusion of (alternative) energy technologies into mining operations in South Africa (see Table F.8), Votteler & Brent (2016) recommended solar PV as the MTRES most suitable for use in the mining sector in South Africa, as it is close to cost-parity[131] with Eskom-provided electricity, followed by wind (onshore) and geothermal. However, their analysis did not examine the additional ability of CSP to supply solar thermal heat in any great detail, and the benefit that such energy may provide to mining operations.

[129] PTC can be used to power double effect absorption chillers used for the ventilation of mines, as well as supply process steam for use in chemical and petrochemical operations (Brent & Pretorius, 2011).
[130] Use of single-effect absorption chillers located on rooftops. Alternatively, a double effect absorption chiller could be used (Brent & Pretorius, 2011).
[131] This recommendation was made based on several factors such as LCOE, existing service infrastructure in South Africa, availability of power source and experience with the technology. (Votteler & Brent, 2016)

Table F.8: Analysis of electricity producing technologies for use in South Africa's mining sector

	Initial investment USD/kW	LCOE USD/kWh	Capacity factor in %	Annual forecast until 2020	Experience	Availability of power / fuel source	Service infrastructure	Project size 1–10 MW
Diesel generator[1,2,3,4,5]	500–800	0.35–0.4	<95	8% increase	Excellent	Good	Very good	Yes
Eskom[16, 17,18, 19]	400–450	0.07–0.075	<99	12% increase	Excellent	Good	Very good	Yes
Solar PV[1,6,7]	1 500–2 000	0.072–0.22	<30	3.4% decrease	Good	Good	Very good	Yes
CSP[1,6,7,8,9]	3 500–8 700	0.18–0.3	<80	3.5% decrease	Limited	Medium	Good	Not commercial
Wind on-shore[6,7,10]	1 300–2 200	0.06–0.12	<48	2% decrease	Good	Medium	Very good	Yes
Geothermal[7, 12,15,16]	3 000–5 500	0.08–0.14	<90	0%	No	Medium–good	Low	Yes
Biomass[2,6,13]	2 600–4 500	0.04–0.14	<80	0%	No	Medium–low	Low	Yes
Battery storage[1,15]	2 000–4 000	0.42–0.6		10.6% decrease	Limited	/	Low	Yes
Hydro power[2,6]	1 500–3 500	0.04–0.15	<60	0%	Limited	Medium–low	Medium–low	Yes

(Source: Votteler & Brent, 2016)

Should the mining sector move to adopt solar PV technology on a large scale, it would represent a great opportunity lost for the CSP industry in South Africa. To foster the rapid introduction and adoption of CSP technologies into the mining sector, it is crucial to educate (chief) mining executives on the benefits of CSP over other MTRESs, namely: the potential to act as a dispatch and/or baseload energy source, improving consistency and stability of energy supply (Votteler & Brent, 2016), as well the supply of solar thermal heat for mining operations. While it is acknowledged that increased cost reduction and greater service infrastructure may act as strong drivers behind the decision (of mining companies) to adopt CSP over solar PV and other energy technologies, these are activities that take time and financial investment. Hence, an emphasis on the education of mining executives may produce more effective results, both short- and long-term.

One potential solution to the competition posed by solar PV is to combine the two technologies in a hybrid CSP-PV energy system[132], where PV provides electricity during the day and CSP and TES at night (Platzer, 2016). In a study on the feasbility of such power plants[133] in South Africa, Platzer (2016) demonstrated that greater cost reductions can be realised as opposed to seeking lower costs through increased storage facilities, and a larger solar field (heliostats and central receiver), of a stand alone CSP plant. Thus, a hybrid CSP-PV system highlights another option aimed at providing cost-competitive, uninterrupted solar-generated electricity on a daily basis.

Hybridisation of CSP technologies is not limited to the mining sector. As listed in Table F.7, there are various applications within the chemical and petroleum industry reliant on thermal heat that could be met by CSP. Given the wide range of applications, the precise manner in which CSP could be deployed was not investigated further, with it deemed sufficient to merely highlight the market potential that exists within this sector.

Options for the hybridisation of CSP are also found within the power generation sector. Solar aided power generation (SAPG), also known also as solar augmentation[134], integrates solar technologies with fossil fuel-based power systems, which in South Africa are almost entirely coal-powered. SAPG systems combine the scale, efficiency, and low costs of existing power plants with the environmental benefits of solar technologies. The primary application of solar thermal heat in such systems is the preheating of boiler feedwater, reducing the need for

[132] Plans currently exist for the development of three CSP-PV hybrid systems in Chile (Platzer, 2016).

[133] The systems modelled were a 100MW FPV-100MW LFC, 150MW FPV-100MW LFC, 100MW CPV-100MW LFC and 150MW CPV-100MW LFC. Combining CSP-CPV yielded a capacity factor of 80%, while also generating a lower LCOE than a standalone CSP power plant. (Platzer, 2016)

[134] Other terms include solar boosting and solar assisted (Pierce *et al.*, 2013).

turbine extracted steam while allowing for greater work output or fuel consumption savings. (Pierce *et al.*, 2013)

Pierce *et al.* (2013) investigated the performance of a 600MW SAPG system (Lephale, Limpopo) compared to a similar-sized stand-alone CSP plant (Upington, Northern Cape) in South Africa, both with no storage. Analysis of the electricity output of both systems shows that the SAPG system generated 27% more than the stand-alone CSP system, while being 72% of the cost, demonstrating a cost-effectiveness of 1.8 times that of the CSP system. These results indicated that the introduction of such technologies could rapidly increase the rate of commercialistion of CSP technologies. (Pierce *et al.*, 2013)

Based on Pierce *et al.* (2013)'s study, it is clear that SAPG systems have the potential to ensure a reliable supply of affordable electricity and thermal energy, as well as providing environmental benefits through CO_2 reductions, and greater support for local industries. However, it is worth noting that although the study conducted was based on PTC technology, presently the most widely used CSP technology, issues may arise due to the high pressures reached. Compact LFC and CR technologies are also viable options, with LFC seen as the most suitable candidate for SAPG applications. (Pierce *et al.*, 2013)

A second form of hybridisation within the power generation sector is that of virtual hybridisation, the process of '*providing backup generation that is lowest cost for the system'*. This refers to the inclusion of CSP into an energy mix often during peiods of peak consumption, typically replacing more expensive diesel or OCGT power sources, which are still maintained in a lower capacity as backup for the CSP technology. (Gauché *et al.*, 2017)

For the sake of completing the argument relating to the prospective commercial and industrial applications, it is worth considering the agricultural sector. The Northern Cape province (see Figure F.6) possesses some of the best solar resources in South Africa, and as such is a favoured choice for CSP project sites (Fluri, 2009). The area is home to few urban centres, with most of the land being used for agricultural purposes (Brand South Africa, 2011). From a proximity perspective, the agricultural sector offers a strong consumer base, one located near to the project sites where CSP plants are to be constructed, thus limiting the amount of costly transmission and distribution grid infrastructure lines needed. Having such a close power source would also reduce the risk of interruptions in the electricity supply faced by local farmers, disruptions that could prove disastrous in cold winters.

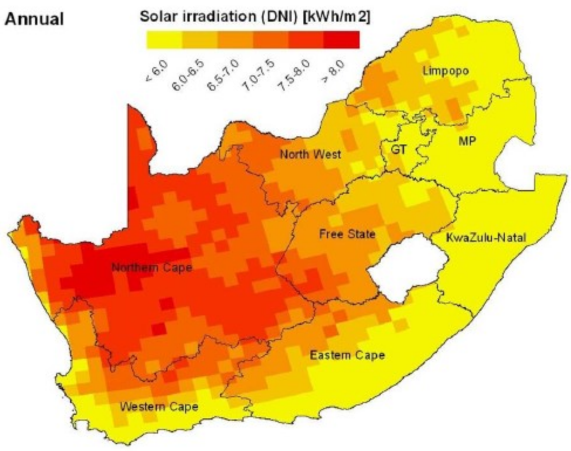


Figure F.6: Solar resources of South Africa's provinces
(Source: Fluri, 2009)

However, despite the greatly reduced grid infrastructure costs, and consistency of electricity supply, such an option is unfeasible from a cost perspective. Even were economies of scale to be utilised through the development of a large CSP plant, meeting the energy needs of a large number of farms, the initial capital costs would likely still prove too great to finance. Furthermore, farmers would be unwilling to pay a higher price for CSP-generated electricity as opposed to the price charged by Eskom. Innovative financial mechanisms could be deployed to reduce the cost, but it is unlikely that cost-parity would be achieved once the additional grid infrastructure costs have been factored in. Furthermore, concerns would also arise regarding the visual aesthetics, and other environmental impacts, of any potential power plant's.

To summarise, CSP technologies hold great potential for use in South Africa's mining and chemical and petrochemical sectors, while opportunities also exist within the power generation sector. Hybridisation of CSP systems and their components with other (baseload) energy technologies, such as diesel generators, coal power stations and solar PV, should be favoured in the short- to medium-term, being the most cost-effective option presently available from a CSP technology point of view. Stand-alone CSP systems may be more feasible in the medium- to long-term once costs have fallen sufficiently. In addition, opportunities exist for the application of CSP components in other industries, as summarised in Figure F.7.

As a result of the present uncertainty surrounding the future of CSP in South Africa, it can be argued that foreign markets should currently be targeted, where a global export strategy may prove most effective. A case in point is the recent Helio100 Project, which involved the design of low cost and easy to install heliostats as a means of reducing the overall cost associated with CSP systems (ESI Africa, 2015). This project received interest from abroad in terms of commercialisation prospects (Helio100, 2017). Finally, despite the close proximity of agricultural land to many CSP plant sites, the costs involved prohibit the industry from being the sole customers of the energy output from such projects.

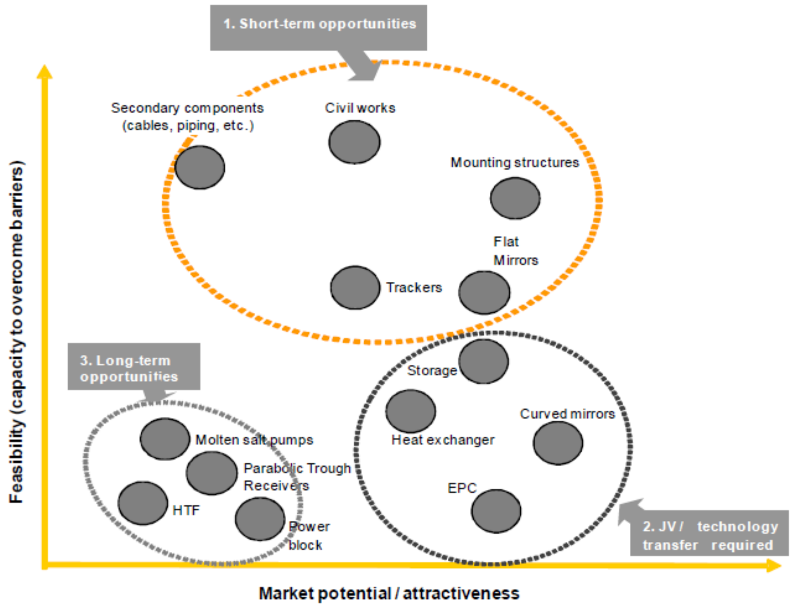


Figure F.7: Opportunities for CSP components
(Source: SASTELA, Dti & GIZ, 2013)

Appendix F.5 Grid expansion and integration plan

During round one of the validation process, Participant 1-1 highlighted the relative lack of attention given to accessing, strengthening, and expanding the national electricity grid, with the framework only touching on the subject primarily through wheeling tariffs as a business sector activity. Given that the researcher is not an expert on grid infrastructure and related systems, existing literature on the subject was investigated, together with discussions held with other participants, most notably Participants 3-2 and 3-2, to form the basis for a grid expansion and integration plan for the refined strategic management framework. Studies on the existing South African national grid were used as a benchmark, and adapted accordingly for use with the framework.

The plan proposed in this section outlines the potential expansion and integration of the national grid with CSP technologies, with consideration given to the existing grid, areas of high DNI, availability of water resources, and grid code requirements. However, devising such a plan is complicated by the fact that the rollout of the national grid is dependent on energy policy, as the optimal location for different energy technologies are located in different geographic areas around South Africa. As such, this plan does not make specific recommendations. Instead, it merely highlights aspects that decision-makers need to consider in the expansion and integration of the national grid, with a focus on CSP technologies, while also indicating the direction that grid development needs to take to support a growing CSP industry in South Africa. The finer details regarding implementation and/or refinement of the plan, following the emergence of new data or (clarified) government policy, is left to the discretion of the partnership, and other experts, involved in the commercialisation of CSP technologies.

The expansion of the national grid is divided into three-time frames: short-term (0-5 years), medium-term (5-15 years), and long-term (15+ years). The focus for each time frame is discussed below, followed by the integration of the grid with CSP technologies through the South African grid code. The plan presented pertains predominantly to stand-alone CSP systems only; the hybridisation of CSP with other energy technologies is not expected to face significant issues of grid expansion or connectivity.

Appendix F.5.1 Grid expansion: short-term focus

In the short-term, the view is held that no new large-scale infrastructure is possible, due to the great costs and lengthy construction time involved, a view shared by Gauché *et al.* (2014), as well as the support required from Eskom to first construct a transmission backbone in order to serve future power plants[135]. The result is that the development of any new CSP plants would need to be located near existing grid infrastructure. Figure F.8 illustrates potential locations for the introduction of CSP plants into the national grid in the near future. The small black circles indicate ideal locations, while the larger black circles indicate more feasible sites located next to grid transmission lines. The partnership, and other CSP plant developers, constructors, and suppliers, should look to develop CSP plants along this central transmission line, offering a cost-effective approach to the short-term rollout of CSP technologies in areas with relatively high DNI.

Connecting any power plant, be it CSP or other, to the national grid requires permission from Eskom, given that they own the national grid. Thus, engagement with Eskom is key in this regard, despite the fact that they may not form part of the partnership (initially). A second important consideration is the different voltage levels of this high capacity line (400 kV), and transmission lines connected to a CSP plant (132-275 kV). There are several options available to safely connect such power plants to the national line. The cheapest and easiest is a simple loop-in loop-out approach, where the line is brought to the individual power plant, then looped back to the national grid. A second possibility is the construction of a separate substation and separate parallel line to the power plant, an approach favoured by Eskom as it is then able to serve future plants developed in the region. One also needs to consider the length of downtime experienced by the high capacity line due to construction or maintenance, as the Western Cape relies on it for its electricity, and Eskom will not allow the line to be non-operational for any lengthy period of time.

[135] This is unlikely given Eskom's apparent reluctance for CSP-generated electricity.

While these factors do raise the costs involved, it is predicted that even if the Eskom approach is adopted, it will likely still be a cheaper and faster option than the construction of entirely new grid infrastructure in the Northern Cape, the area with the highest DNI in South Africa. This remains true even if circumstances in South Africa's energy sector change dramatically and CSP is afforded a much larger allocation in new bid rounds of the REIP4P. However, once again, this plan does not presume to make any specific recommendations to decision-makers, it merely highlights the factors that need to be considered.

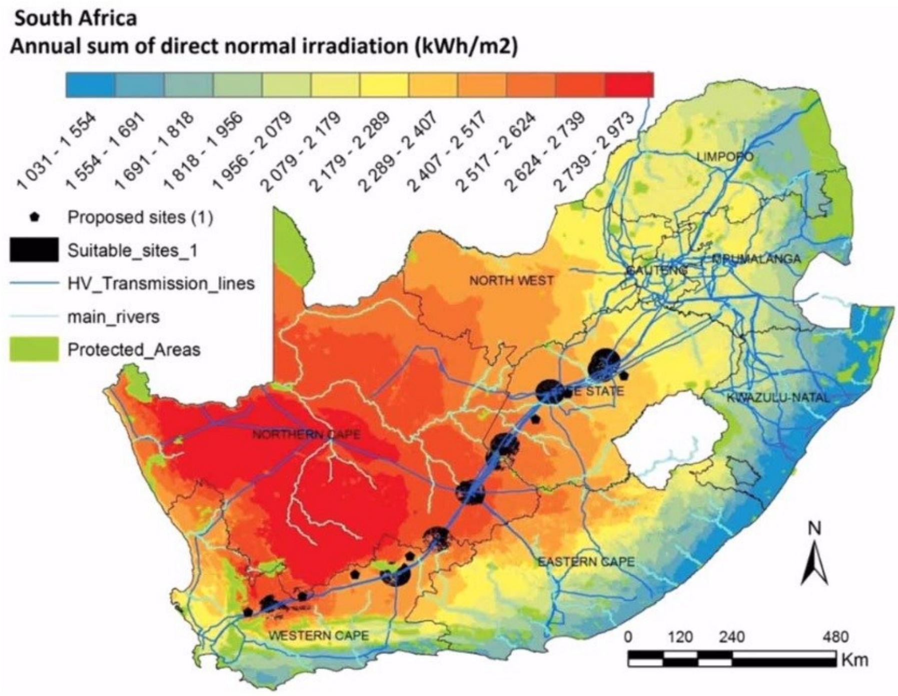


Figure F.8: South Africa grid expansion and integration – short-term focus
(Source: Gauché *et al.*, 2014)

Appendix F.5.2 Grid expansion: medium-term focus

In the medium-term, it is likely that the availability of connection points (connection capacity) on the existing grid will begin to decrease rapidly due to the connection of CSP power plants and those of other technologies. Hence, the focus of the grid expansion and integration plan should be on expanding the existing grid infrastructure into geographic areas with high DNI, in order to accommodate new CSP power stations, and support the rollout of a CSP fleet in South Africa. This will require support from Eskom, and certainty from policy-makers regarding the future of the CSP industry in South Africa. This goal is aided by the fact that Eskom has already initiated efforts to improve the national grid countrywide, in areas such as the Northern Cape (see Figure F.9) (Meyer & van Niekerk, 2011). However, once again, the continuation of these efforts is dependent on national energy policy, and whether CSP is granted a greater percentage of the country's energy mix in the future.

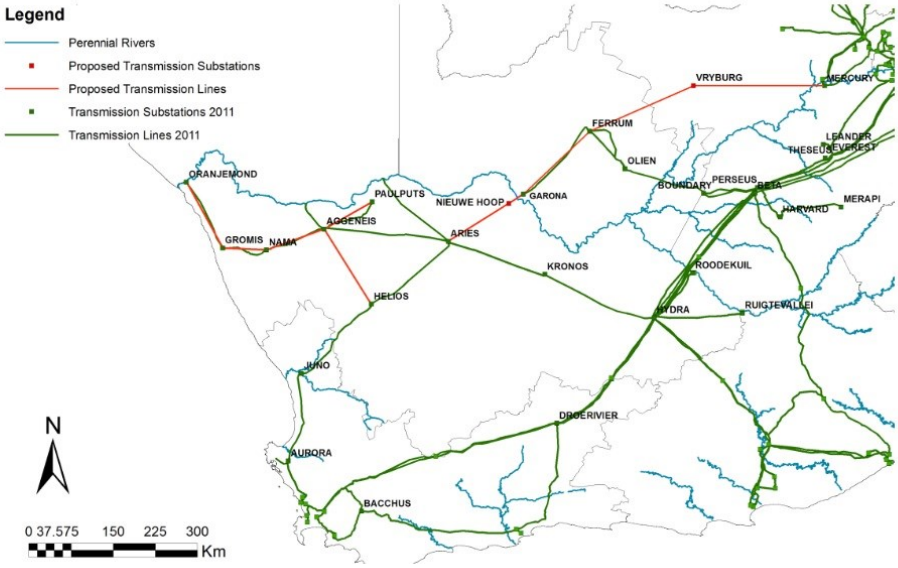


Figure F.9: South Africa national electricity grid expansion plans - Northern Cape
(Source: Meyer & van Niekerk, 2011)

South Africa's expansion plans are outlined in the latest transmission development plan (TDP), laying out Eskom's vision for the future of the national grid. One challenge encountered is the uncertainty faced by Eskom regarding future load and generation sites. This uncertainty has highlighted the need to identify so-called 'corridors' of high electricity consumption that are likely to grow with increasing demand, along with the recognition of the national grid's existing pressure points. Five power transmission corridors (see Figure F.10) have been marked for development, each 100 km long. These corridors will allow for the rapid construction of additional transmission infrastructure within each of South Africa's geographic regions due to pre-established rights and approvals that are valid for extended time periods. This will reduce the time it takes to develop the transmission infrastructure required to support the construction of new build power plants based on generation scenarios and energy policy. (Eskom, 2016)

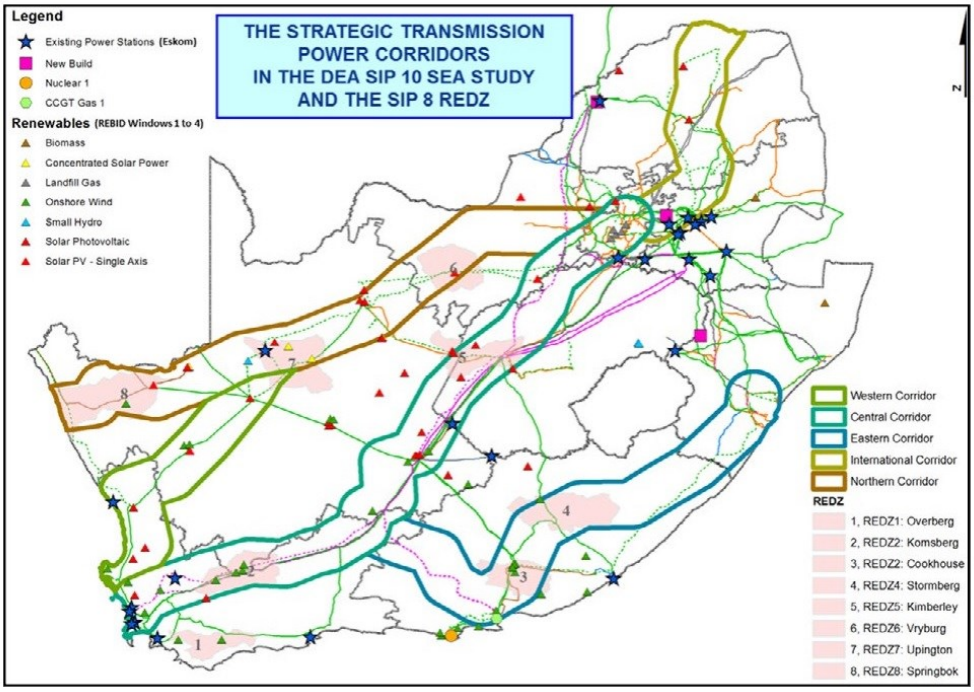


Figure F.10: South Africa's planned power transmission corridors 2016 - 2025
(Source: Eskom, 2016)

The role envisaged for the partnership involves assisting Eskom, NERSA, and the national DoE with the development of new grid infrastructure that is completed on schedule and within budget. This assistance will take the form of ensuring that new transmission lines and substations are constructed in areas optimal for CSP technologies, while also taking into consideration constraints such as land slope, water availability, local wildlife, and distance from human settlements. Furthermore, the partnership could assist with the financing of some of the costs[136], increasing the partnership's stake and influence in the South African energy industry, as well as strengthening relationships with Eskom, NERSA, and the national DoE.

Appendix F.5.3 Grid expansion: long-term focus

In the long-term, it is expected that the grid will continue to be strengthened, completing the infrastructure plans described in the TDP while highlighting new areas that require upgrades, on the basis of more up-to-date information relating to the country's energy needs. It is likely that increased construction of new grid infrastructure will take place on both a regional and local basis, as sites for new power plants are approved by the South African government. The partnership's role will be the same as for the medium-term focus, namely: assisting Eskom, NERSA, and the national DoE with the development of new grid infrastructure that is completed on schedule and within budget, particularly in those areas of high DNI, to further support the rollout of a CSP fleet in South Africa.

An additional factor, one which will become more prevalent in the long-term, is the availability of water resources for CSP power plants. This issue is especially important given the water scarce nature of the Northern Cape, together with the drought faced by many regions in South Africa. Concerns over water resources may be alleviated somewhat by the use of dry cooling technology with CSP systems, reducing the water consumption of each plant by approximately 10%, while also greatly increasing the number of feasible sites for CSP plant development (see Figure F.11). (Meyer & van Niekerk, 2011)

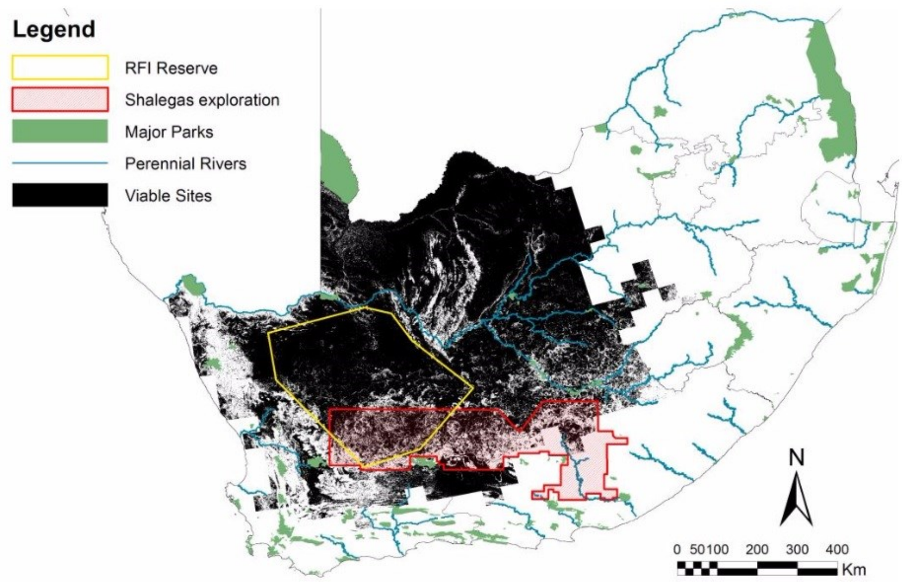


Figure F.11: Feasible future locations for waterless CSP power plants
(Source: Meyer & van Niekerk, 2011)

However, these systems decrease the annual efficiency of CSP plants by 5%. One solution to this problem is the deployment of hybrid cooling systems. These systems are based largely on dry-cooling technology, but include the option to use water during the day. Other

[136] The total costs of the grid expansion plans outlined in the TDP are R206,8 billion (Eskom, 2016).

alternatives to limit water consumption involve the use of robots to clean the heliostat mirrors with a brush, as well as the potential integration of gas turbines instead of steam turbines to generate electricity. These efforts highlight progress towards a 'waterless' CSP power plant. (Meyer & van Niekerk, 2011)

Appendix F.5.4 Grid integration: grid code

The final component of the grid expansion and integration plan is that of grid legislation, namely: The South African grid code, which details requirements for the introduction of new energy power plants into the national grid. The existing grid code relating to RE power plants was published by NERSA in 2012, amid concerns that the connection of such technologies could cause grid instability. The code addressed issues such as frequency and voltage deviations, operating conditions, and power quality, necessitating a change in CSP power plant designs from developers, contractors, and suppliers. However, it failed to take into consideration the various components of CSP technologies which had already been procured under Round One and Two of the REI4P, and which did not meet the new requirements. (Relancio *et al.*, 2016)

In response to the noncompliance of CSP systems under the first two bid windows of the REI4P, grid code working groups were established, consisting of members of Eskom, NERSA, developers, and other relevant stakeholders involved in the construction of CSP plants. The aim of these working groups was to discuss clauses of the new grid code which the CSP plants were unable to meet, resulting in certain exceptions being granted on a temporary and permanent basis to these specific CSP projects. The grid code was updated in 2014, amending some of the clauses which CSP systems were unable to meet. However, a number of clauses are still contentious, such as the tolerance allowed for sudden voltage peaks and drops, power frequency response, and active power. (Relancio *et al.*, 2016)

In light of the issues posed by the existing South African grid code, the role of the partnership will be to facilitate continued discussion by the various parties involved in the grid code working group, seeking to address the challenges faced by CSP power plants, as well as strengthen the existing planning and permit process. This interaction between various stakeholders will not only allow for the improved integration of CSP technologies with the national grid, but also strengthen the relationships and channels of communication between such parties, allow for an inclusive process where multiple stakeholders are able to provide input, and foster greater certainty and positive sentiment towards the inclusion of CSP in South Africa's energy mix, and the future prospects for the country's energy industry as a whole.

Appendix F.6 Organisational capabilities

Following round two of the validation process, it became apparent that there was a need to conduct a more thorough process into those organisational capabilities required by the commercialisation process. This process is documented in Table F.9, where a new range of organisational capabilities was identified from literature and the supply and value chains of the CSP industry, and incorporated into the strategic management framework from round three of the validation process onwards. The sources used were as follows:

1. Cetindamar *et al.* (2010)
2. Pearce II & Robinson Jr. (2009)
3. Montalvo (2008)
4. Value and supply chains: Gazzo *et al.* (2010), Gereffi, Dubay, Robinson & Romero (2010), SASTELA *et al.* (2013)
5. Yumkella & Vinanchiarachi (2003)
6. Fang, Wang, Wu & Chen (2014)
7. Löfsten (2016)
8. Harryson (2008)
9. Chen (2009)
10. Amui, Jabbour, de Sousa Jabbour & Kannan (2017)

Table F.9: Identification of organisational capabilities

	Reference source									
Organisational capability	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Marketing	X			X	X	X	X	X	X	
After-sales support / end-user involvement	X		X	X				X		X
Learning / knowledge management / skills training	X		X		X	X	X	X		X
R&D	X	X	X			X		X	X	
Technology management	X		X	X	X				X	X
Organisational structure (organisational & business models)		X	X			X		X		X
Leadership		X	X					X		X
Risk management		X	X			X				X
Communication		X	X				X	X		
Asset Management		X		X						
Manufacturing	X	X	X	X	X	X				X
Services (technology-related)		X				X	X	X	X	X
Strategic Positioning/thinking	X	X						X		X
Data collection		X							X	
Project management				X						
O&M			X	X						
Human resource management		X	X		X		X	X	X	X
Industry/supply-chain relations			X	X	X	X		X		X
Entrepreneurship		X						X		X
Innovation capability	X	X			X	X	X	X	X	X
Sensing capability: predict opportunities & respond to threats						X		X		X
Reconfiguration capability: apply technology to products/ markets/ applications in different geographical regions.						X	X		X	X
Business management & experience		X			X		X	X		X

Appendix F.7 Partnership balanced scorecard

This section documents the revised approach used to select the objectives and metrics of the balanced scorecard for the partnership, with consideration given to their relevance to the commercialisation process. The (new) objectives and metrics were derived from literature, the value and supply chains of the CSP industry, and feedback received during the validation process. However, it is acknowledged that the list of those presented here is not absolute, and that other objectives and metrics may be equally valid for use in the framework.

Appendix F.7.1 Objectives

A range of objectives were identified (see Table F.10) in an attempt to address the multiple aspects of the commercialisation process. The following sources were used:

1. Haas, Panzer, *et al.* (2011)
2. Assefa & Frostell (2007)
3. Coombs & Bierly III (2006)

4. Edkins *et al.* (2009)
5. Sager *et al.* (2015)
6. Gallego Carrera & Mack (2010)
7. Székely & Knirsch (2005)
8. Lichtenthaler (2008)
9. Dale, Efroymson, Kline, Langholtz, Leiby, *et al.* (2013)
10. Archibugi & Coco (2005)

Table F.10: Partnership objectives

	Reference source									
Objective	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Economic Efficiency	X				X					
Effectiveness	X			X	X					
Cost reduction	X									
Investment credibility	X									
Industry growth				X	X					
Education & social acceptance (of technology)		X				X			X	
Technological capability			X							X
Organisational performance										
▪ Market			X				X			
▪ Accounting			X				X			
▪ Environmental							X			
▪ Social							X			
Reliability of energy supply						X			X	
Political stability and legitimacy						X				
Risk – social components						X				
Quality of life / social well-being						X			X	
Monetary / Revenue generation								X		
Strategic										
▪ Product-orientated								X		
▪ Technology-orientated								X		
▪ Mixed								X		
Compulsory[137]								X		
External trade									X	
Profitability									X	
Resource conservation									X	

From the list of objectives of Table F.10, those deemed most relevant to the commercialisation process were selected for the strategic management framework. This process was made easier by the fact that many of the objectives are closely related, and thus can be combined to a certain extent. The objectives to be used in the framework are as follows:

1. Cost reduction
2. Effectiveness / industry growth
3. Education and social acceptance
4. Legal and regulatory compliance

[137] Legal and regulatory compliance.

5. Technological capability
6. Organisational performance
    6.1. Economic[138]
    6.2. Environmental
    6.3. Social

Appendix F.7.2 Metrics

Having established the objectives for the partnership with respect to the implementation of the framework, attention is now given to the respective metrics or indicators used to track the progress achieved in pursuit of each objective, with consideration given once again to the potential role in the commercialisation process. Numerous metrics were ascertained from literature, and are displayed in Table F.11. To make it easier for the reader, a consistent numbering pattern is used linking each objective with its associated metric(s) and target value(s). The following sources were used to identify the metrics:

1. Haas, Panzer, *et al.* (2011)
2. Assefa & Frostell (2007)
3. Coombs & Bierly III (2006)
4. Edkins *et al.* (2009)
5. Sager *et al.* (2015)
6. Griffith (2016)
7. Rollauer (2013)
8. Gallego Carrera & Mack (2010)
9. Székely & Knirsch (2005)
10. Dale *et al.* (2013)
11. Archibugi & Coco (2005)
12. Lichtenthaler (2008)
13. Silinga, Gauché, Rudman & Cebecauer (2015)
14. de Zúñiga, Jung & Valenzuela (2012)
15. Pfenninger & Keirstead (2015)
16. Evans *et al.* (2009)
17. Edkins *et al.* (2010)

Table F.11: Partnership metrics

	Reference source																
Metrics	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1.1 LCOE (R/kWh)	X			X	X											X	
2.1 Additional annual installed capacity (MW/year)	X			X													
2.2 Annual electricity production (TWh)	X			X	X												
2.3 Number of CSP plants under construction				X													
2.4 Plant lead time																	X
2.4 Number of plant licenses				X													
2.5 % contribution to electricity supply	X				X			X									
2.6 % contribution to energy supply	X				X			X									
2.7 Job creation (construction, manufacturing, O&M)					X			X		X							

[138] Includes market, financial, and accounting related metrics.

	Reference source																
Metrics	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
2.8 Annual level of financial investment (millions ZAR)	X			X	X												
2.9 Trade (import & export)										X	X						
2.10 Entry into foreign markets – number of licensing agreements												X					
2.12 Entry into foreign markets – number of strategic alliances/ partners												X					
2.13 Number of public technology institutions											X						
2.14 Number of firms				X													
2.15 Local content					X												
3.1 Knowledge[139]		X									X						
3.2 Perception[140]		X						X									
3.3 Fear[141]		X						X									
3.4 Social media views & action buttons (like, subscribes)														X			
3.5 Website views & visits														X			
3.6 Search engine keywords														X			
3.7 Land use								X								X	
3.7 Water consumption								X								X	
3.8 Aesthetic impact on landscape								X									
3.9 Noise pollution								X									
3.10 GHG emissions									X							X	
3.10 Contribution to traffic congestion in (local) area (during construction)								X									
3.11 Effective stakeholder participation in decision-making process								X		X							
3.12 Reserve capacity / storage time span								X									
3.13 Public opinion										X							
3.14 Transparency										X							
3.15 Risk of (harm due to) catastrophe								X		X							

[139] What does the public know? (Assefa & Frostell, 2007). Percentage targets set refer to percentage of public who demonstrate some degree of knowledge about the technology and its basic operation.

[140] What does the public think? Based on overall attitude, emotional feeling, and rational feeling. Range of five levels: Very negative, negative, neutral, positive, very positive. (Assefa & Frostell, 2007)

[141] What does the public feel? Use of the word fear interchangeable with worry and concern in this context. Applicable in a general sense to physical health, safety, and well-being. Range of six levels: very high, high, medium, low, very low, no fear. (Assefa & Frostell, 2007)

Metrics	Reference source																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
3.16 Avian deaths															X		
4.1 Internal audit						X	X										
4.2 External audit						X	X										
4.3 Training completion rate						X	X										
4.4 Self-assessment						X	X										
4.5 Peer review						X	X										
4.6 Ethics and consumer complaint							X										
4.7 Employee ethic surveys							X										
5.1 Technology strength			X														
5.2 Science linkage / number of scientific publications			X								X						
5.3 Science strength			X														
5.4 System efficiency[142]																X	
5.4 Technology cycle time			X														
5.5 Current impact index			X														
5.6 R&D intensity / expenditure			X		X						X						
5.7 Patent & patent citations			X		X						X						
5.8 Royalties & license											X						
5.9 GHG emission									X							X	
5.10 Land use								X								X	
5.11 Water consumption								X								X	
5.11 Reserve capacity / storage time span								X									
5.12 Flexibility to market changes								X									
5.13 Hybridisation / flexibility to incorporate new technological development								X									
5.14 Infrastructure											X						
5.15 Trade (technology import and export)											X						
5.16 Technology export per capita											X						
5.17 Number of tertiary level science students											X						
5.18 Number of scientists and engineers											X						
5.19 Technology literacy rate											X						
5.20 LPOE (millions ZAR, R/kWh)	X												X				

[142] Efficiency of (net) energy transformation: solar energy to electricity.

	Reference source																
Metrics	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
5.21 Avian deaths															X		
6.1.1 Market value			X														
6.1.2 Market value added (MVA)			X														
6.1.3 Return on sales (ROS)			X														
6.1.4 Return on assets (ROA)			X						X								
6.1.5 Return on equity (ROE)			X						X								
6.1.6 Economic value added (EVA)			X														
6.1.7 LPOE	X												X				
6.1.8 Income (total and by country)									X								
6.1.9 Net income									X								
6.1.10 Earnings per share									X								
6.1.11 Sales									X								
6.1.12 Cash flow									X								
6.1.13 Investment R&D									X								
6.1.14 Capital expenditure									X								
6.1.15 Personnel costs									X								
6.1.16 Net profit margin									X								
6.1.17 Gross profit margin									X								
6.1.18 ROI										X							
6.1.19 NPV										X							
6.2.1 Energy consumption									X								
6.2.2 Water consumption									X								
6.2.3 GHG emissions									X								
6.2.4 GHG emission reduction									X								
6.2.5 Waste									X								
6.2.6 Environmental protection/ conservation spending									X								
6.3.1 Total number of employees (fulltime, part-time)									X								
6.3.2 Number of employees in training									X								
6.3.3 Employee turnover rate									X								
6.3.4 Average hours of (further) training per employee									X								
6.3.5 Workforce composition (gender, racial mix)									X								

From the list of metrics in Table F.11, the following were chosen for use in the strategic framework, measuring the objectives established in Appendix F.7.1:

▪ Cost reduction	▪ LCOE (R/kWh)
▪ Effectiveness / Industry growth	▪ Additional annual installed capacity (MW/year) ▪ Annual electricity production (TWh) ▪ Number of CSP plants under construction ▪ Plant lead time (years) ▪ % contribution to South Africa electricity supply ▪ % contribution to South Africa energy supply ▪ Job creation (construction, manufacturing, O&M): local and export ▪ Local content (%) ▪ Annual level of financial investment (billions ZAR) ▪ Trade (billions ZAR / volume): import & export ▪ Number of international licensing agreements ▪ Number of international strategic alliances / partners
▪ Education & social acceptance	▪ Knowledge (%) ▪ Perception ▪ Fear ▪ Effective stakeholder participation in decision-making process (%) ▪ Social media views, action buttons (likes, subscribes) (%) ▪ Website views & visits ▪ Search engine keywords (%)
▪ Legal and regulatory compliance	▪ Audits (internal, external) (%) ▪ Employee training completion rate (%)
▪ Technological capability	▪ Patents & patent citations ▪ Number of scientific publications ▪ Land use ▪ Water consumption ▪ GHG emission reduction ▪ System efficiency ▪ R&D expenditure ▪ Reduction in avian deaths (per GWh
▪ Organisational performance	▪ ROI (%) ▪ Levelised profit of electricity (LPOE) (millions ZAR)

Appendix F.8 Final strategic management framework

This section presents the final version of the strategic management framework (see Figure F.12), post five iteration rounds of the validation process, having been refined based on the feedback received from the participants in the validation process.

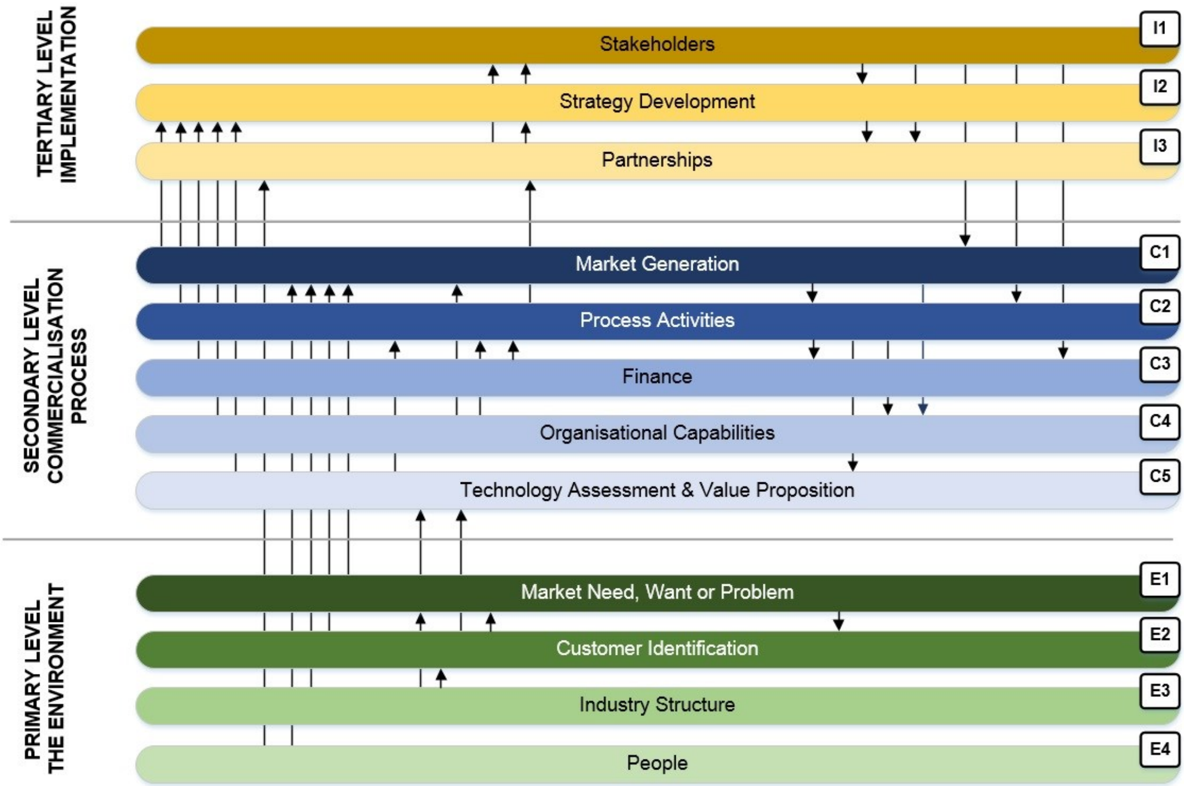


Figure F.12: Final strategic management framework

The framework is divided into three different levels: (1) the environment, (2) the commercialisation process itself, and (3) the implementation stage. Each level is explained in further detail in the following text. It should be noted that the framework is designed to be a macro-level tool to support the development of strategies aimed at increasing the rate of commercialisation of CSP technologies in South Africa. As such, it concerns itself predominantly with how the commercialisation process concerning the entire class of CSP technologies may be sped up. In addition, while efforts are made to provide commercialisation practitioners with a comprehensive list of tools for practical application, it is acknowledged that discrepancies may exist in the amount of detail covered between the different components of the framework.

Appendix F.8.1 Primary level – the environment

The primary level, or foundation, of the framework is the environment in which the commercialisation process takes place. The development of any strategy to increase the rate of commercialisation of a given MTRES needs to take into account the relevant environment and context in which the process occurs. These factors act to shape the nature and implementation of any required strategy. Four key components were identified as contributing to the environment (see Figure F.12). A breakdown of the industry structure and people components is displayed in Figure F.13. A description of all the components comprising the primary level is presented in Table F.12. Further information concerning the role of people in the commercialisation process, viewed as arguably the most important influence on the environment of those four components listed, is provided after Table F.12.

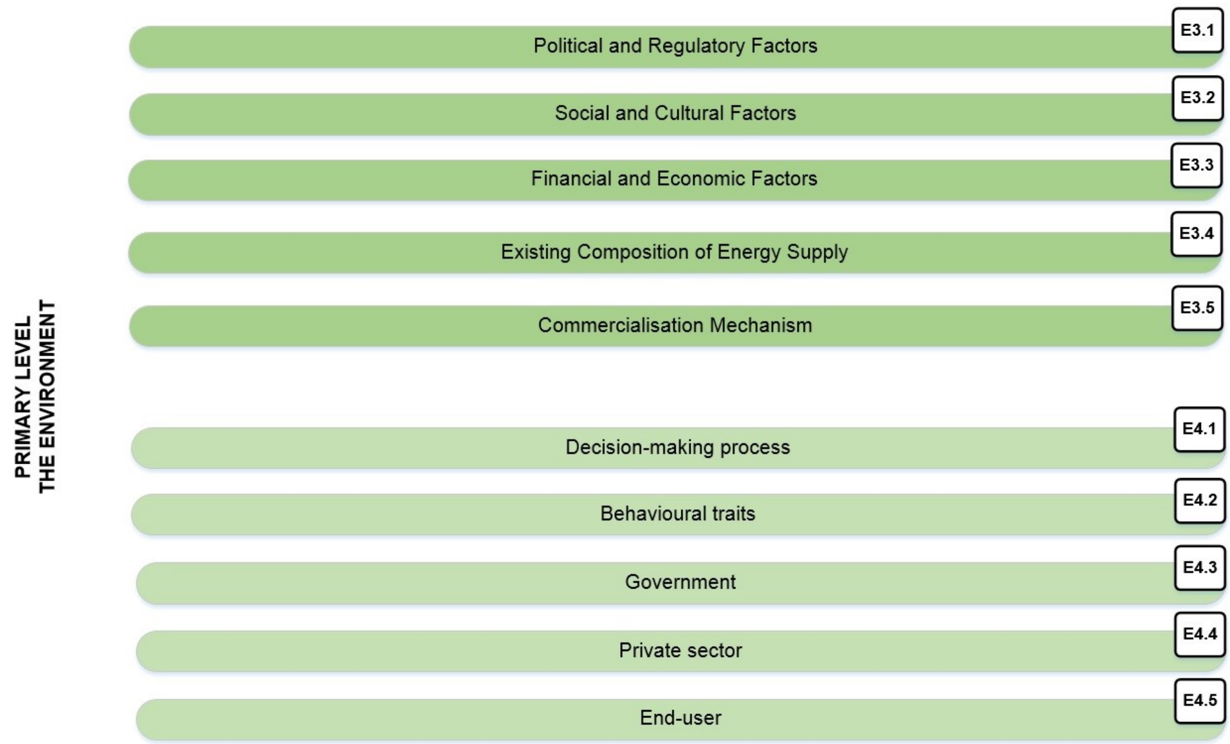


Figure F.13: Framework primary level – the environment

Table F.12: Primary level components

Factor	Reference number	Description
Market need, want or problem	E1	In the context of CSP technologies in South Africa, the market need, want, or problem, which a technology is commonly designed to address, is typically determined by government in response to the country’s energy needs. Although the identification of the market need, want, or problem happens prior to the commencement of the defined commercialisation process, it forms part of the environment by influencing whether the commercialisation of a given technology remains relevant throughout the entire process, namely: does the market need or want persist until commercial status is reached. Other aspects to be considered are whether the technology would be better used for some other purpose, or whether commercialisation efforts should be stopped in the face of stiff competition, or a change in the market. Therefore, it is important to keep the market need, want, or problem in mind throughout the entire commercialisation process, continually re-evaluating whether it exists or whether corrective action needs to be taken. A case in point is the recent 100 MW Redstone project, which, despite winning a bid under South Africa’s REIPPP Programme in bid window 3.5 (Relancio *et al.*, 2016), has failed to reach financial close, and looks to be doomed as far as projects go (Van Rensburg, 2017b), with the net result that none of the specific technologies associated with the project are likely to reach a commercialised state.
Customer identification	E2	The identification of customers for energy technologies such as CSP is not a straightforward task. Although energy technologies have traditionally been purchased by state utilities, the good generated, a unit of energy/electricity, is consumed by the nation’s citizens, be it for residential use, or to meet the energy needs of a commercial or industrial firm. However, in the

Factor	Reference number	Description
		context of this research study, the consumer was identified as the entity who purchases an entire CSP system, or associated subcomponent, and thus is likely to be government or an energy-intensive user from the private sector.
Industry structure	E3	The industry structure plays a significant role in the commercialisation of any technology. Given the wide range of factors that influence how energy sectors are structured globally, this component is elaborated on further in the associated sub-components.
Political & regulatory factors	E3.1	The energy sector is largely dictated by a country's policies and regulations, which set the rules of the market. These rules are not always conducive to the commercialisation of new energy technologies such as CSP, and are often used by incumbent actors to maintain the status quo of fossil-fuel based energy technologies.
Social & cultural factors	E3.2	Many MTRESs represent a departure from established means of energy generation, which have come to be associated with various social and cultural factors. For example, South Africa's heavy reliance on coal provides a lot of low level skilled jobs to the nation's citizens. In addition, many citizens distrust MTRESs of an intermittent and embedded generation nature, preferring a more consistent grid connection. However, MTRESs do offer health and environmental benefits due to their clean nature.
Financial & economic factors	E3.3	Unless an energy technology is able to present a sound financial and economic case, it is unlikely to reach market status without direct government intervention. Such a case is clearly evident in South Africa, where cost has been cited by many entities as a dominant reason to resist the rollout of CSP, which has a higher cost than other energy technologies, despite its unique dispatchability value proposition.
Existing composition of energy supply	E3.4	The commercialisation of energy technologies does not happen in isolation; the existing composition of the energy supply strongly influences the environment in which commercialisation takes place. Energy infrastructure is typically developed to favour the incumbent energy technology, which is coal in South Africa. Existing grid constraints may limit the uptake of CSP technologies. In addition, it takes time to build the necessary expertise to develop and operate a novel technology.
Commercialisation mechanism	E3.5	The dominant commercialisation mechanism currently used for CSP technologies in South Africa is integrated resource planning (IRP), embodied by the country's REI4P. Hence, any commercialisation effort needs to be directed through, and governed by, this mechanism. Given that this mechanism forms such a core element of the environment, it needs to be leveraged by relevant actors in order to increase the rate of commercialisation of CSP technologies in South Africa.
People	E4	Arguably one of the most important elements of any process in the modern era, people play a critical role in the commercialisation process. However, not all people share the same position in society, with some possessing greater influence than others with respect to the commercialisation process, such as government, the business sector, and the end-user. Furthermore, it is also necessary to understand the effect that peoples' decision-making and behaviour may have on the commercialisation process.
Decision-making	E4.1	The decisions made by people play a key role in determining the environment in which commercialisation takes place. These decisions affect the various policy and regulatory, social and

Factor	Reference number	Description
		cultural, and financial and economic factors mentioned. The ability to influence such decisions to the benefit of CSP is of great importance towards increasing the rate of commercialisation achieved.
Behavioural traits	E4.2	Peoples' behaviour, and the actions they take based on their agendas and self-interests in different sets of circumstances, contribute towards the environment faced by the commercialisation of CSP technologies. Understanding these behavioural traits can assist management practitioners in leveraging support, and making appropriate decisions towards increasing the rate of commercialisation of CSP technologies in South Africa.
Government	E4.3	Arguably the most important group of people is government, responsible for setting the energy policies that determine the future energy mix of a country's energy sector, and which energy technologies are to be favoured above others, sometimes at the expense of logical argument and rational debate. If government officials are opposed to certain energy technologies for whatever reason, there is a tendency to display bias against said technology with respect to future ministerial determinations. Such a case has proven evident in South Africa in the past 2 years, especially with respect to CSP, based on the actions of Eskom and the national DoE.
Private sector	E4.4	Under South Africa's REI4P, the private sector has been tasked with constructing and operating the country's CSP plants. The role played by the private sector in the environment is thus an important one to ensure the survival of South Africa's CSP industry, lobbying the government to ensure a future allocation to CSP in the country's energy mix, and allowing for the commercialisation process to take place.
End-user	E4.5	Although the end-user has little say in the commercialisation of CSP technologies in South Africa, being a predominantly utility-scale technology, they still have the ability to influence the environment and commercialisation process. Whether the end-user is interpreted as the final consumer of energy/electricity, or the entity who purchases a CSP system (government/energy-intensive user), the ability of the end-user to exert influence on the commercialisation process is growing together with greater awareness of environmental and socio-economic issues. Furthermore, should more users choose to go off grid, this will put pressure on state utilities, such as Eskom.

The relationship between the three most important groups of decision-makers identified in the commercialisation process, government, the business sector and the end-user, is illustrated in Figure F.14. The solid lines represent their existing ability to impact the commercialisation process, and the dotted lines the potential change in this influence over time as a result of the framework's implementation, and as progress is made towards a commercialised state. The size of each bubble demonstrates their relative importance to the other two decision-making groups.

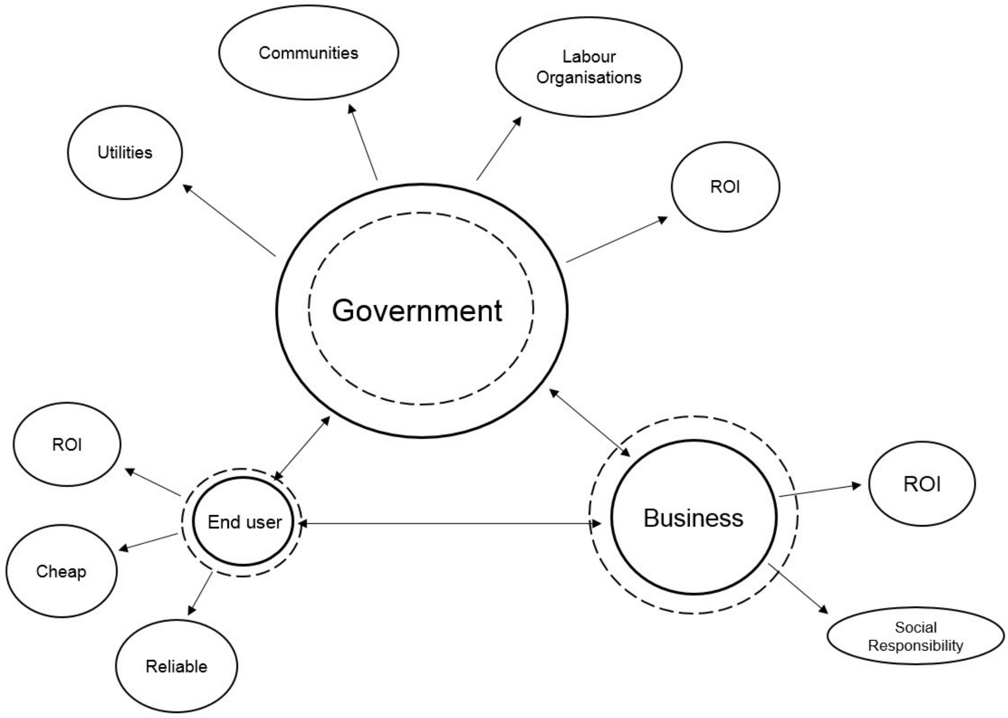


Figure F.14: Decision-makers in the commercialisation process

Each of these three groups of decision-makers have certain factors which influence their thoughts and behaviour, the dominant of which are included in Figure F.14. Government's actions are based on the potential reaction of communities, who represent the voters responsible for keeping politicians in power. Labour organisations present a strong lobbying force, placing workers' rights and job creation at the top of their agenda. Utilities, whose roles consist of transmission, distribution, and generation, also wield considerable power to affect government's decision-making.

The business sector is primarily concerned with achieving profitability, although some firms do express a sense of responsibility to society. Finally, there is the end-user of energy, which, while arguably having the least amount of influence, is also worth considering. In the past, consumers have had little choice about where their electricity comes from, being forced to buy directly from state utilities through the national grid. However, liberalised energy markets, such as those implemented in Scandinavia, the United States and the United Kingdom, are beginning to change the energy landscape, presenting a challenge for state utilities and local municipalities faced with declining electricity sales and loss of revenue. As such, the motivation behind the decision-making of end-users can now be said to be dominated by factors of technology cost and reliability

It is also worth analysing the factors which influence the standard decision to adopt MTRESs. While a large body of literature exists on this subject, Figure F.15 provides an overview of various social and technical factors that influence the decision to use a MTRES, while also incorporating elements of the Theory of Planned Behaviour.

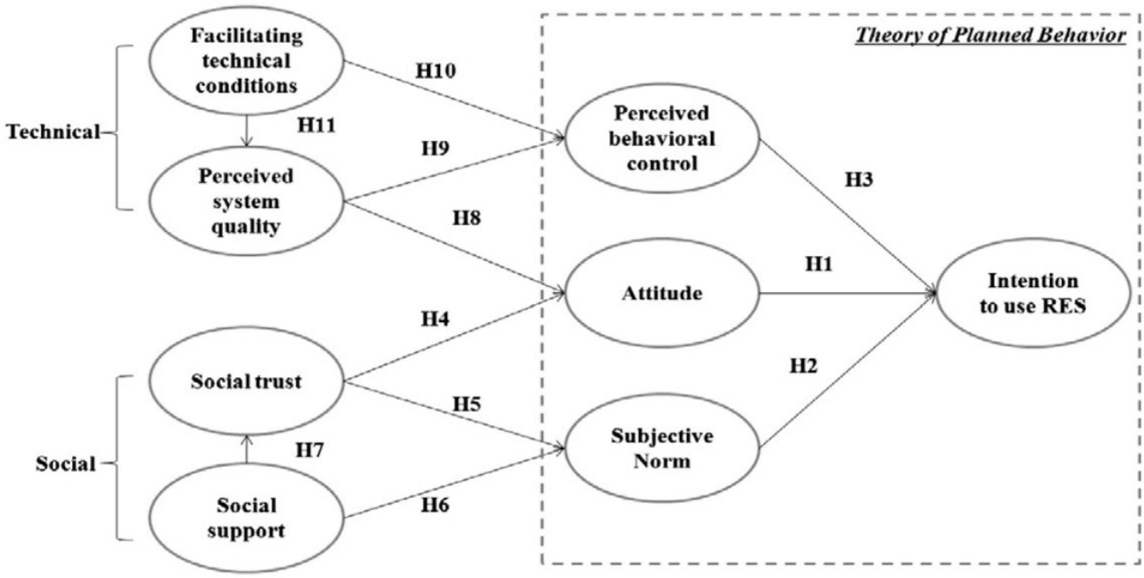


Figure F.15: Theory of planned behaviour
(Source: Yun & Lee, 2015)

Appendix F.8.2 Secondary level - commercialisation process

The secondary level of the framework concerns the commercialisation process itself. Five principal components were identified as being relevant to the process (see Figure F.12), with a further breakdown of several of these components provided in Figures F.16 - F.18. A description of all the components comprising the secondary level is provided in Table F.13. Additional information in the way of practical tools and methods concerning certain components is provided after Figure F.18.

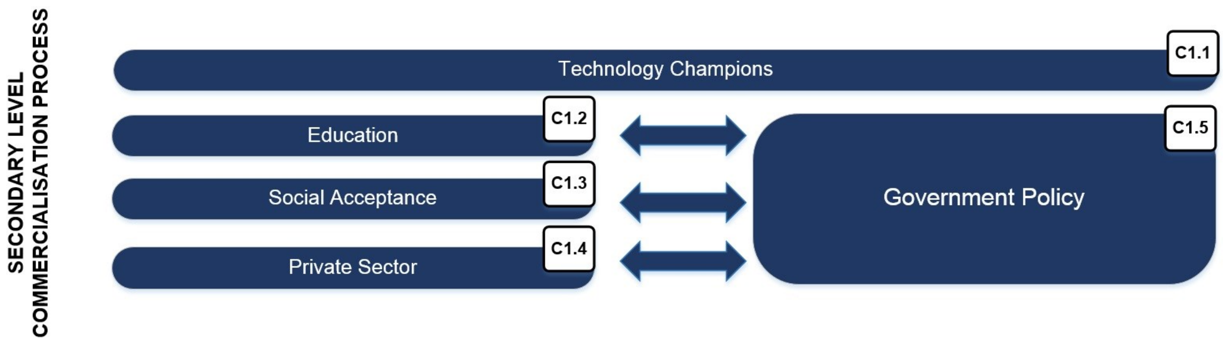


Figure F.16: Framework secondary level - commercialisation process - market generation

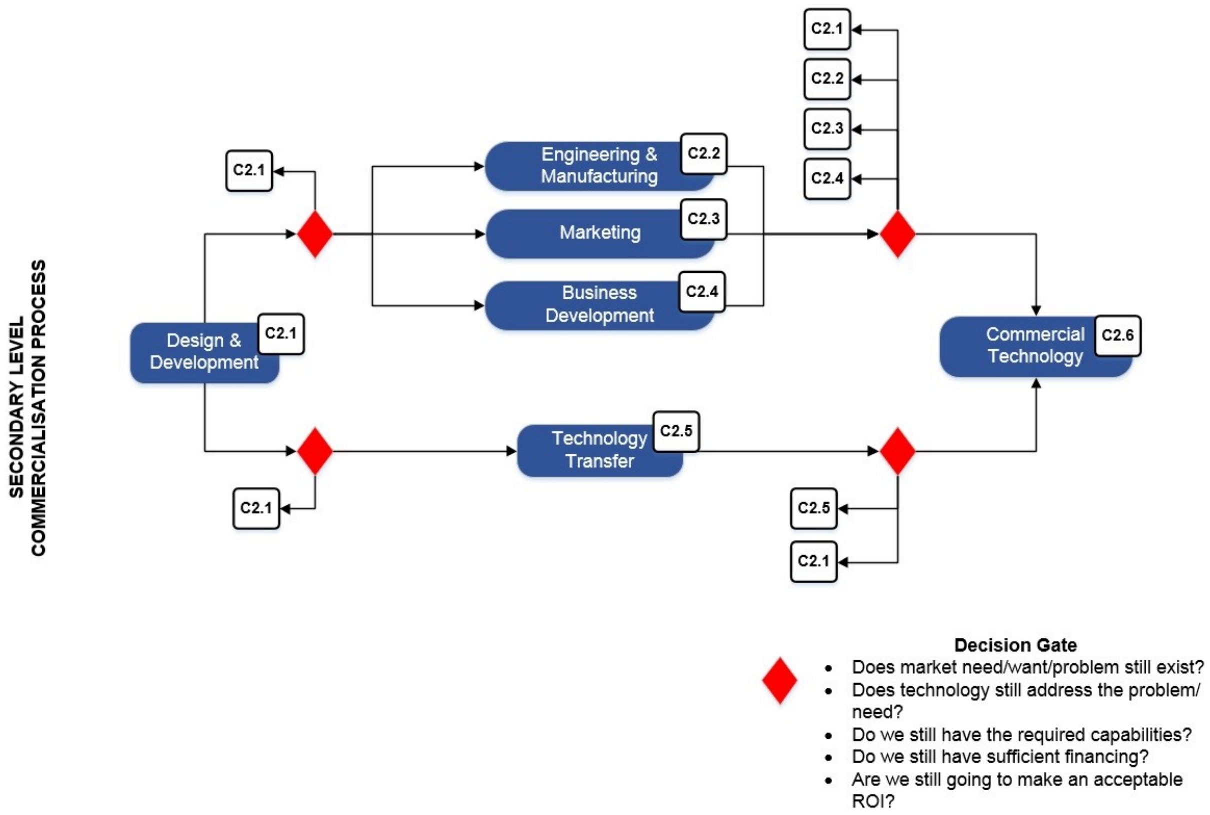


Figure F.17: Framework secondary level - commercialisation process - process activities

Figure F.18: Framework secondary level - commercialisation process - technology assessment and value proposition

Table F.13: Secondary level components

Factor	Reference number	Description
Market generation	C1	Market generation refers to the tools and initiatives available to promote a market for CSP technologies in South Africa, as elaborated on in the following subcomponents. The market for energy technologies is strongly influenced by policy-makers in government, with respect to the (future) energy mix of a country, as well as the policies and regulations that govern the energy sector. Their decision-making is guided by planning processes such as integrated resource planning, and software such as Plexos.

Factor	Reference number	Description
Technology champions	C1.1	Technology champions are individuals typically classified as early-adopters, being individuals (or entities) who believe strongly in a new technology, and who actively champion its use. These individuals are crucial towards efforts to increase the use of CSP technologies in South Africa, promoting its benefits to the country's citizens, and growing the number of individuals who believe in CSP and its place in South Africa's energy mix. Such champions, depending on their position and status in society, can have a large impact on efforts to increase the rate of commercialisation of CSP technologies in South Africa.
Education	C1.2	In the case of CSP technologies in South Africa, it is ultimately government policy which will have the biggest impact on the commercialisation of such technologies. One means of influencing government policy to the benefit of CSP in the country is to educate both government and the nation's citizens about the technology. The education initiatives proposed focus on primary and secondary levels of education, together with the general public. This focus is in line with the fact that CSP is frequently viewed as a long-term prospect, yet to reach maturity. In addition, future politicians, businessmen, and other leaders and key decision makers, will come from the people, in particular the nation's youth.
Social acceptance	C1.3	In the case of CSP technologies in South Africa, it is ultimately government policy which will have the biggest impact on the commercialisation of such technologies. One means of influencing government policy is through improving the social acceptance of CSP technologies in South Africa. Several tools and mechanisms are proposed to foster trust in the respective technology, leading to the establishment of credibility and legitimacy in the technology. This may lead to lower levels of active opposition from local communities during the development and construction of such technologies. Furthermore, such initiatives may also improve the acceptance of CSP technologies by government officials, leading to a greater share of the technology in South Africa's future energy mix. Lastly, such mechanisms may improve the view of CSP technologies from South African society as a whole.
Private sector	C1.4	In the case of CSP technologies in South Africa, it is ultimately government policy which will have the biggest impact on the commercialisation of such technologies. One means of influencing government policy is through lobbying from the private sector to ensure a greater percentage of the future energy mix is allocated to CSP, thus creating a market for the technology. This will result in greater business opportunities for them, as well as employment and monetary benefits. The private sector also needs to take a more proactive role in the CSP industry's development, and wider commercialisation process.
Government policy	C1.5	It is ultimately government policy which will have the biggest impact on the commercialisation of CSP technologies in South Africa, being the dominant factor responsible for market generation through the policies set

Factor	Reference number	Description
		and decisions made. As such, it is vital to influence such policy in order to create the market necessary for the commercialisation process to take place. Ideally, lobbying of key government officials with the power to set energy policy, and make related decisions, will result in a stable pipeline of projects, thereby creating greater surety in the technology and associated industry. However, greater policy certainty is also required, along with improved policy implementation, especially from a technology management perspective.
Process activities	C2	A firm knowledge of the activities constituting the commercialisation process is crucial before any strategy can be implementing towards increasing the rate at which commercialisation takes place. While different interpretations of the process and its activities exist in literature, those presented in the framework serve to highlight the more important tasks required. The engineering & manufacturing, marketing, and business development activities tend to happen simultaneously, hence their respective positioning in Figure F.17.
Design & development	C2.1	The design and development of a technology is in response to a market need, want or problem. The commercialisation process is understood to begin once this stage has been completed. However, the design and development of a technology may need to be revisited due to changes in the market, as well as changes in government policy and regulation, economic factors, and so forth.
Engineering & manufacturing	C2.2	The large-scale engineering and manufacturing of a technology in preparation for market entry.
Marketing	C2.3	Promotes a given technology in order to generate a market for it. Increases consumer awareness, and ensures that there is a large-enough customer base willing to purchase the given technology. With respect to CSP technologies, marketing efforts should be directed at influencing government policy, along with the aforementioned education and social initiatives. Should small-scale CSP technologies become cost-competitive for the industrial and commercial market segments, marketing efforts can be increased to include customers in these segments.
Business development	C2.4	In order to conduct the activities required during technology commercialisation, and increase the rate at which the process takes place, businesses along the supply chain may need to develop and establish new competencies, depending on the needs of CSP technologies as they progress towards maturity.
Technology transfer	C2.5	Commercialisation of a technology can also take place through the licensing or transfer of IP rights.
Commercial technology	C2.6	The stage where a technology is considered commercially mature. Not always clear when such a stage has been reached.
Finance	C3	A set of innovative financial mechanisms to provide the financial capital required for the different commercialisation activities.
Organisational capabilities	C4	A set of organisational capabilities to ensure sufficient strength in operations for each of the activities of the commercialisation process. The term ‘organisation’ is

Factor	Reference number	Description
		used here to refer to any entity, be it private or public sector based, that wishes to increase the rate of commercialisation of CSP technologies.
Technology assessment and value proposition	C5	A set of assessment tools and methods to analyse and monitor different technology aspects relating to the lifecycle, social and political impacts, market-related factors, and so forth. These tools also serve to allow practitioners to periodically review the value proposition of the respective technology, and whether it still meets the identified market need, want or problem, as well the relevant customer.

Appendix F.8.2.1 Education initiatives

To assist the diffusion of knowledge concerning CSP technologies, additional educational initiatives are required beyond those currently implemented. The view is held that the number of programmes offered on a tertiary level by technical institutions, learning centres, and universities is sufficient; educational programmes need to focus on broadening the pipeline of talented individuals wishing to pursue a career in the CSP industry, as well as improving public knowledge and awareness of CSP. Therefore, the focus of this component is on creating awareness and knowledge of CSP technologies, through primary and secondary education, as well as public-based, initiatives.

Table F.14 presents several educational initiatives to be explored and implemented through the strategic management framework. It is not presumed to be an exhaustive list, and education practitioners are welcome, and encouraged, to devise their own initiatives to achieve the same goal.

Table F.14: Categorisation of educational initiatives

Primary	Secondary	Public
Basic CSP operation	In depth CSP operation Comparison with other energy technologies	Demonstration projects
Site visits (location dependent)	Site visits (location dependent)	Cell phone applications
Nationwide science and technology challenges/competitions		Virtual reality
School presentations and small-scale practical demonstrations		
Open Days (universities, research councils & institutions)		

Appendix F.8.2.2 Social acceptance

Table 5.9 outlines several tools available to improve the social acceptance of CSP technologies. The list of tools is not presumed to be definite, and management practitioners implementing the strategic management framework are welcome, and encouraged, to explore additional avenues and tools. Any social acceptance strategy is to be driven by an NGO, considered the most trustworthy in the eyes of the public. It should be built on solid facts, logical assumptions, and rational debate. Fostering trust should form a core aspect, aiming to strengthen ties and improve communication channels between stakeholders. This will create favourable public awareness and opinion of CSP, establishing credibility and legitimacy in such technologies.

Table F.15: Tools for promoting social acceptance of CSP in South Africa

Tool	Relevance to CSP
Cell phone applications	Cell phone applications can communicate large amounts of information to a large number of people in a short period of time. Globally, a large percentage of

		the population uses cell phones to access the internet than traditional personal computers, making them arguably the best avenue to access the broader population.
Media	Mass	Use of mass media (TV, radio, newspapers, magazines, public demonstrations & exhibitions, community centre posters) in media campaigns to present information on the numerous benefits associated with CSP. The emphasis should be on providing trustworthy, accurate, and reliable information in an easy-to-interpret medium.
	Social	Use of social media platforms, such as Facebook, Twitter and Instagram, together with public personality and celebrity endorsements, and local political, church and community leaders to inform and educate society about CSP.
Labelling and (technical) standards		Present the public with a reference point to promote trust in CSP through specific technical support and system reliability. This includes harnessing brand power that may begin to emerge due to competition between RE companies.
Decision-making process		While not a specific tool as such, all stakeholders, be they members of a local community, government officials or external experts and investors, need to feel that they are able to participate in a fair, transparent, credible, and collaborative decision-making process. The process should involve significant sharing of all relevant information between stakeholders, and involve institutions perceived as trustworthy by society with respect to CSP.

By carefully crafting the public image of CSP technologies, positive societal sentiment for such technologies can be realised. Moreover, exerting influence over the national energy discourse can benefit CSP technologies, and MTRESs in general, ensuring they are strategically positioned to become a major energy technology, one well supported by the nation's citizens. While the exact message to be delivered is left to the discretion of those implementing the tools, the recommendation is made to focus on the clean nature of CSP, and their great potential for job creation and localisation.

Appendix F.8.2.3 Private sector

Despite the implementation of government policies, adoption of MTRESs such as CSP technologies has been slow. Hence, a change in mind-set is required, one in which the business sector assumes a more pro-active role towards increasing the rate of commercialisation of CSP technologies in South Africa. The (new) role for the business sector may include one or more of the following activities, which are mapped in Figure F.19:

1. Increase demand for CSP technologies in South Africa.
2. Finance and conduct R&D into CSP technologies in South Africa.
3. Finance and develop CSP technologies in South Africa
4. Operate and maintain CSP technologies in South Africa
5. Assist the expansion and strengthening of the national grid with respect to CSP technologies in South Africa
6. Establish and strengthen skills training initiatives towards CSP technologies in South Africa
7. Establish a local manufacturing hub(s) to supply the components necessary for CSP technologies in South Africa
8. Explore opportunities for the exportation of CSP technologies developed and manufactured in South Africa.

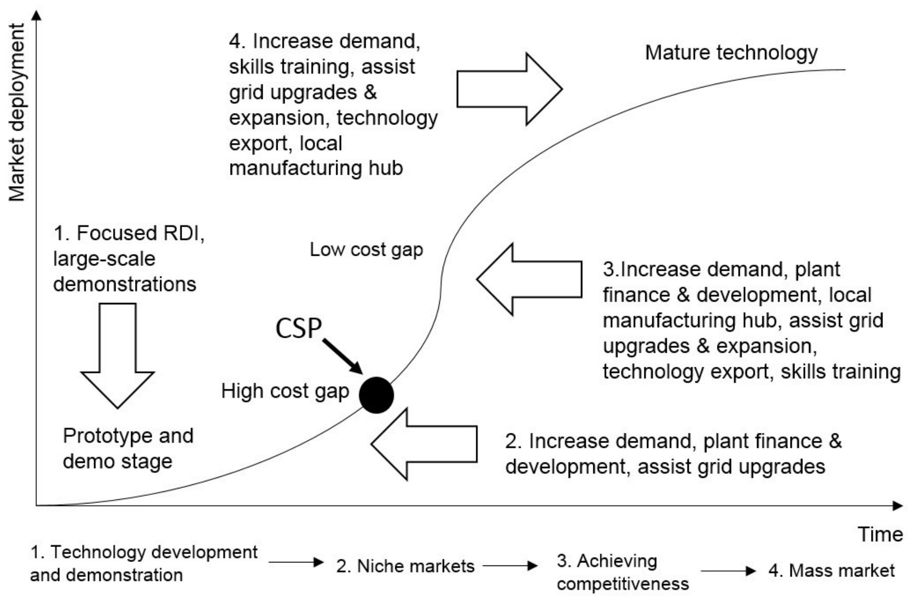


Figure F.19: Mapping of business sector activities
(Source: adapted from Grobbelaar, 2017)

Appendix F.8.2.4 Government policy

Following an investigation of literature concerning government policies, a policy mix was developed for the strategic management framework comprising a wide range of technology-push, market-pull, and interface improvement policies (see Table F.16). Consideration was also given to several policy design principles advocated by Grobbelaar *et al.* (2014). The purpose behind such a wide range of policies is to present policy-makers with a choice of policy depending on the policy environment that they operate in, which differs from country to country, and the changing needs of CSP as the technology progresses through the commercialisation process.

Table F.16: Strategic management framework policy mix

Market-pull	Technology-push	Interface Improvement
FIT	RDI subsidies and grants	Certification and technical standards.
Tender bid programme	RDI loans	Regulations
Tax incentives	National RDI centre	Consultancy services
Carbon tax	Demonstration projects	Training and certification programmes
Carbon credits	Equity	Project assessment centre
Loans and bonds		
TGCs / quota		
Renewable portfolio standards / quotas		
Voluntary green pricing scheme		
Wheeling agreements		
(Installation) rebate		
Grid access legislation		

Given the wide range of policies proposed for the policy mix, it is highly unlikely that any government will possess the time or resources to implement all of them simultaneously. Furthermore, each policy has a different impact on a technology depending on its current life cycle stage, namely: its current position on the s-curve, and are likely to be implemented at different stages of the commercialisation process for greatest impact. Thus, the actual policy mix selected and implemented will likely change over time, and should be reviewed at regular intervals to ensure it is kept aligned with the needs of CSP technologies as they progress through the different stages of the commercialisation process. To provide guidance to those implementing the policy mix, Figure F.20 maps the policies proposed for the framework, while Figure F.21 presents a decision matrix to further support the policy implementation process.

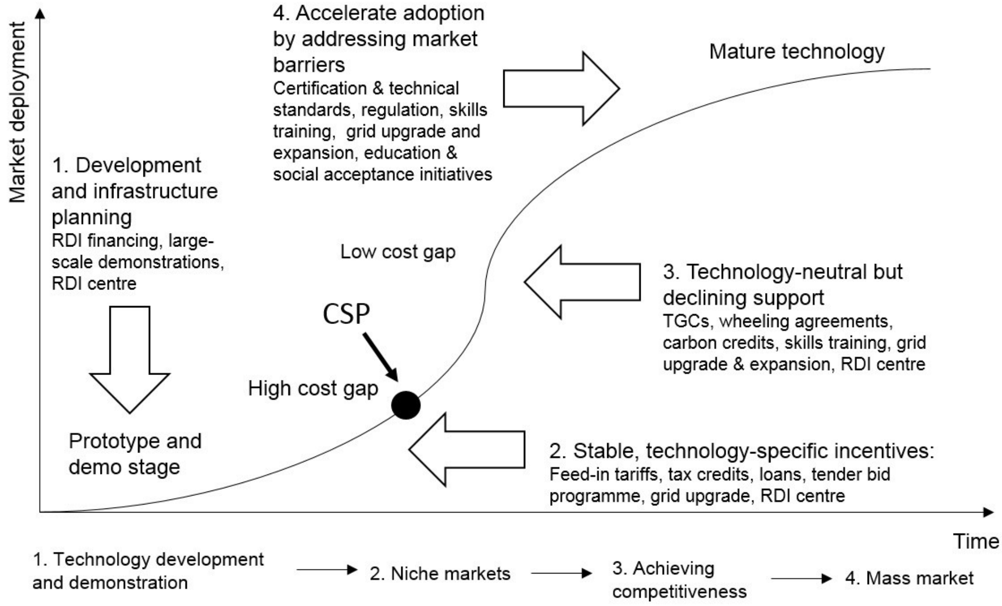


Figure F.20: Mapping of government policy mix
(Source: adapted from Grobbelaar, 2017)

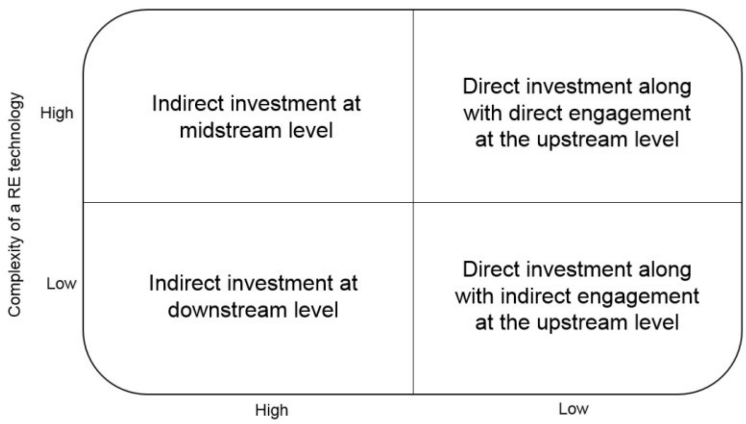


Figure F.21: Decision matrix to guide implementation of government policy
(Source: Aslani, 2015)

The implementation of policies depends, to a large extent, on the specific country context. Many countries favour centralised planning, with provincial and local government implementing the policies determined on a national basis. However, depending on the existing legislation, there may be scope for lower levels of government to implement their own RE-related policies, if desired. It is important to keep in mind that policies often require (financial) backing from National Treasury Departments. This is particularly relevant with respect to any energy-related projects or initiatives. Hence, on a local government level, it may only be wealthy municipalities who are able to enact such policies.

A further comment regarding policy implementation is the need to ensure that policies are able to stand up to scrutiny, and that consistency in implementation is observed. In the case of South Africa, a common view held by experts is that the actual energy policy itself is sound.

Instead, it is the implementation of the policy, and political interference, that has prevented the country from reaching many of its objectives, and harming industry confidence in the process.

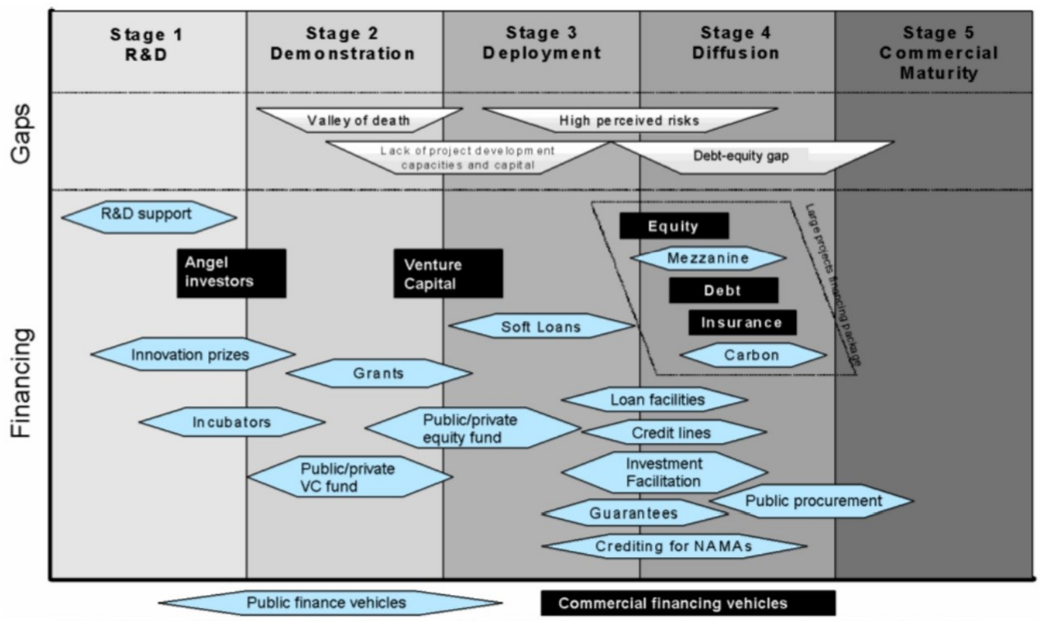
Appendix F.8.2.5 Financial mechanisms

Presently, a significant funding gap exists between CSP and other energy technologies (Department of Energy *et al.*, 2016). Despite the (potential) success efforts to improve awareness of, and demand for, CSP and other MTRESs may achieve, firms in the business sector are reluctant to invest in technologies that are not deemed cost-effective (Herzlinger, 2006). Thus, it is assumed that once MTRESs achieve cost-parity with other energy technologies in the same demand category, they will be adopted on a larger scale, due to their environmental benefits, and security of energy supply.

While cost reduction is often attributed to R&D efforts (Gazzo *et al.*, 2010), such activities take time and capital, both of which are in short supply. In order to bridge the existing funding gap, attention was placed on several (innovative) financial mechanisms (see Table 5.7), some of which have already been mentioned under the market-pull government policies. Further guidance is provided in Figure F.22 regarding the time of implementation of the various financial mechanisms mentioned.

Table F.17: Financial mechanisms for bridging the funding gap

Financial mechanism	Source
Favourable loans (low interest rates, long payback periods)	Development banks, national government, institutional RE investors
Crowdfunding	General population
Leasing/renting	Business sector
Structural funds	Banks, venture capital, private equity
TGCs	General population, local government, business sector
FITs	Local government, business sector
CERs	Business sector
Hybrid-wheeling agreements	PowerX, local government, business sector
Equity	Investors (venture capital, private equity, institutions)



Abbreviations: NAMA = nationally appropriate mitigation action, R&D = research and development, VC = venture capital.

Figure F.22: Implementation of different green financial mechanisms
(Source: Edkins, Winkler, & Marquard, 2009)

Appendix F.8.2.6 Organisational capabilities

The organisational capabilities component highlights key capabilities (see Table F.18) required for the commercialisation process. However, it is important to note that the relative importance of each capability is likely to change over time. For example, R&D, together with O&M experience, are currently two of the more important capabilities to reduce costs. This can be achieved through the use of improved materials, and the optimisation of current CSP designs and system operation. The decision of how to incorporate each capability, and to what extent, is left to the discretion of those implementing the strategic management framework. Furthermore, it is acknowledged that the capabilities will need to be reviewed as the needs of CSP technologies change in response to internal progress and the external environment.

Table F.18: Strategic management framework organisational capabilities

Organisational Capability		
Marketing	Communication	Entrepreneurship
After-sale support / end-user involvement	Asset management	Industry / supply-chain relations
Learning / knowledge management / skills training	Manufacturing	Business management & experience
R&D	Services (technology-related)	Human resource management
Technology management	Strategic positioning / thinking	Innovation capability
Organisational structure	Data collection	Sensing capability[143]
Leadership	Project management	Reconfiguration capability[144]
Risk management	O&M experience	Production management
Lobbying of policy-makers	Exploitation of public policy	Fostering/strengthening stakeholder relationships

Appendix F.8.2.7 Technology assessment & value proposition

Six broad areas of TA were identified as being most appropriate for the strategic management framework (see Figure F.18). A specific list of methods and tools under each area to be used in the framework is presented in Figure F.23. These tools and methods are aimed at ensuring a systematic view of a technology is reached, not limiting the focus to the technology itself, but considering the broader implications, in particular the potential for unplanned and unanticipated effects that may limit the rate of commercialisation realised.

[143] Predict opportunities & respond to threats.

[144] Apply technology to products/ markets/ applications in different geographical regions.

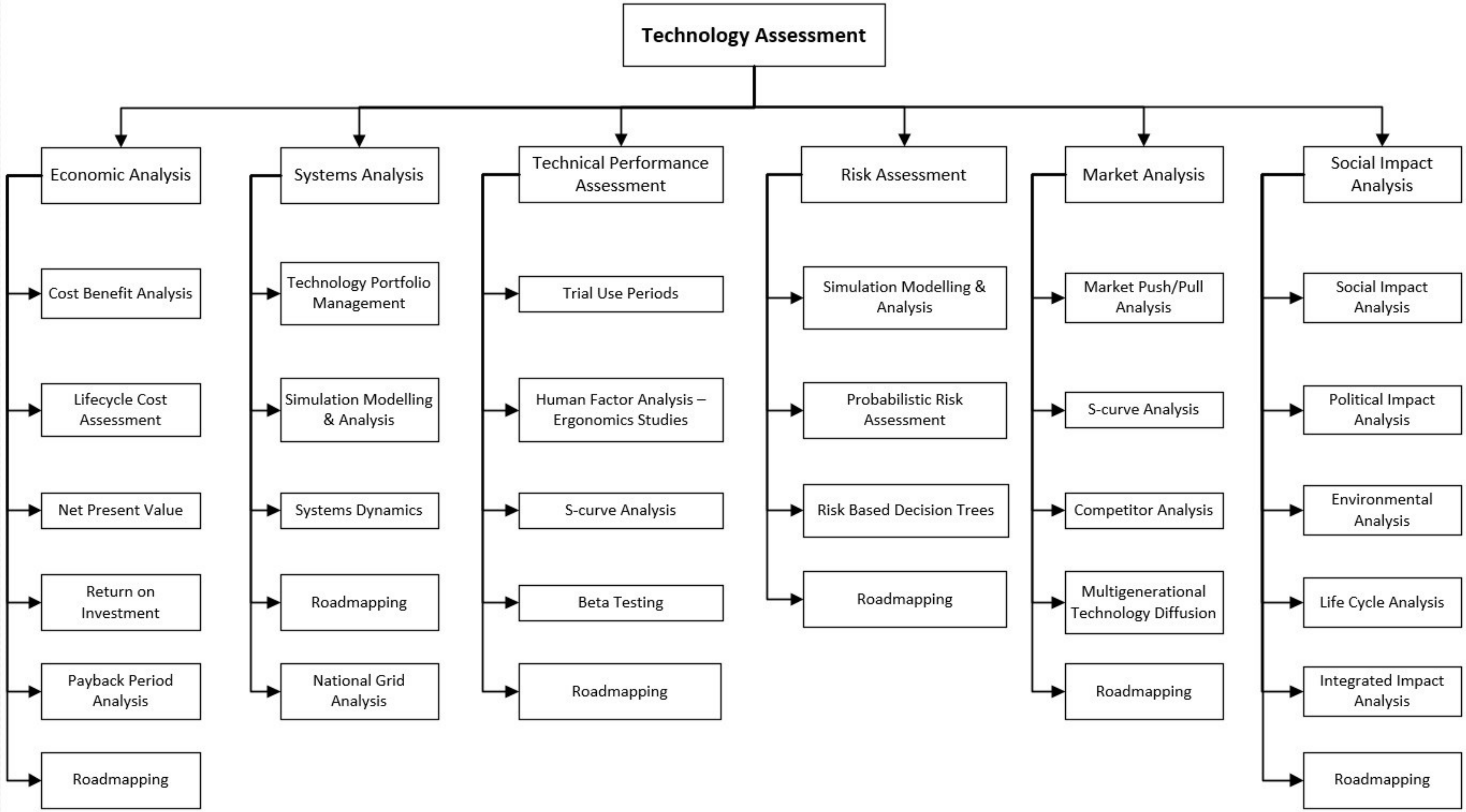


Figure F.23: Technology assessment component breakdown

Appendix F.8.3 Tertiary level - implementation

The tertiary level of the framework (see Figure F.12) concerns the implementation of the framework, assisting the development of strategies to increase the rate of commercialisation of CSP technologies. A breakdown of several of the components comprising the tertiary level is illustrated in Figure F.24, with a complete description of all the components of the tertiary level outlined in Table F.19. Additional information on some of these components is presented post-Table F.19.

Figure F.24: Framework tertiary level - implementation

Table F.19: Tertiary level components

Factor	Reference number	Description
Stakeholders	I1	The implementation of the framework will require a wide range of stakeholders to support the development of the different types of strategies required for increasing the rate of commercialisation of CSP technologies in South Africa. Although the people component (E4) focuses on the influence of key groups such as government, the private sector, and the end-user, the tools, mechanisms, and activities of the framework's secondary level require extensive expertise for successful application. As such, there is a need for a diverse range of stakeholders able to provide the relevant skills and knowledge necessary for implementation.
Strategy development	I2	To inject a degree of flexibility into the framework, the exact manner in which strategies are to be developed is left to the discretion of those who make use of the tool. While the framework may be used by anyone who possesses an interest in increasing the rate of commercialisation of CSP technologies in South Africa, it is important to recognise that different stakeholders will have different levels of involvement in the commercialisation process. Energy associations, the private sector, and government are viewed as those stakeholders most likely to make use of the framework, and with the potential to have the greatest impact on the commercialisation process.
Energy association	I2.1	As the custodians of a respective energy technology, an energy association will likely have the most interest in using the framework to support commercialisation efforts. Indeed, an energy association can be viewed as merely being a partnership of different stakeholders in the supply chain of a technology. Energy associations are often able to speak with a stronger and more coherent voice than

Factor	Reference number	Description
		single entities to represent the interests of its different members. However, to achieve success, an energy association should take care to ensure that the interests of its members are represented, or risk the possibility of losing its membership base.
Private sector	I2.2	The private sector will possess the greatest interest in conducting the commercialisation activities for their own financial gain. The case also exists for RDI institutions to be involved with soft technological development through licenses and IP rights
Government	I2.3	In order to utilise the tools and methods outlined in the framework, there will be a need for government involvement in terms of creating market demand (through capacity allocations to CSP), improving the policy and regulatory environment, and deployment of the social and education mechanisms provided.
Partnerships	I3	Given the wide range of tools, mechanisms, activities, and capabilities listed within the framework, it is highly unlikely that a single individual or entity will be able to implement all of them without assistance of some kind (Fang *et al.*, 2014). Indeed, such a case would prove highly unusual, given the multifaceted nature of the commercialisation process. Hence, it is proposed that partnerships be formed between the relevant stakeholders, to ensure that all components of the framework are addressed and implemented successfully. A partnership structure is included (see Figure F.25) to provide guidance regarding which stakeholders need to be mobilised in order to address the different components of the framework.
Partnership development	I3.1	A ladder of partnership development is presented (see Figure F.27) to provide support on how such partnerships may be developed successfully within the RE industry.
Balanced scorecard	I3.2	A set of objectives, metrics/KPIs, short-, medium- and long-term targets, and respective data sources, to measure the progress made by the strategies developed (see Table F.23). It is left to the practitioners using the framework to establish their own target values per time period, keeping in mind that these values will need to be updated periodically, due to internal and external changes and events. The listing of relevant data sources is intended to provide practitioners with supportive sources in the setting of target values, as well as monitoring progress achieved towards these targets.

Appendix F.8.3.1 Stakeholders

Table 5.12 presents a list of stakeholders to be considered in the implementation of the framework, with respect to the many tools and acitivities listed in the secondary level. The focus on the different roles required for the commercialisation of CSP technologies in South Africa, instead of existing players in the energy sector, limits the possibility of bias on the part of the researcher. In addition, Table 5.12 covers the anticipated role of each stakeholder in the commercialisation process.

Table F.20: Stakeholders and actors

Stakeholder/Actor	Role in commercialisation process
(Wealthy) Municipalities	Medium- to high-income municipalities can implement supportive financial mechanisms (FITs, TGCs, wheeling agreements), establish a local carbon credit market, and institute policies aimed at greater business involvement.

Stakeholder/Actor	Role in commercialisation process
	However, they need to consider the applicable legislation concerning any actions that they may take.
Government departments	Set policy and legislation relating to future energy planning and associated projects.
Political allies	Provide institutional support to the development of the CSP industry.
State Utility	Often the sole purchaser of CSP-generated electricity in the utility-scale market due to energy monopoly and support from government.
Energy regulator	Determines the electricity price the state entity is allowed to charge consumers, affecting the cost-competitiveness of electricity generated from CSP power plants.
Media	Media can assist educational programmes and social acceptance initiatives to increase knowledge and awareness of CSP technologies.
RE institutions	RE institutions possess the necessary knowledge and expertise to advise and assist CSP project developers and conduct continual R&D into CSP.
NGOs	Lead efforts to increase social awareness and understanding of CSP technologies, fostering greater societal acceptance.
Donor funding agencies	Contribute to the financing of CSP R&D and project finance.
Development banks	Contribute to the financing of CSP R&D and project finance.
Institutional investors	The long-term nature of CSP projects is well suited to the long term financial needs of institutional investors, such as green funds, insurance companies, and pension funds.
Business sector • Suppliers • Construction	Adopt the role as the primary driver of the RE industry, assuming control of all value and supply chain activities.
Technology & service providers	Assist CSP project developers during development and operation of CSP power plants.
Universities	Conduct R&D into CSP, resulting in cost reductions, increased energy output and potential for technology export.
Research Councils	Assist with R&D into CSP. Promote education and social awareness of CSP technologies.
Technical skills development centres	Develop the skills necessary in the population to expand the existing workforce.
Labour organisations	Mobilise support for CSP and influence government policy. Assist the rapid increase of CSP technologies into the energy mix, creating jobs in the process.

Appendix F.8.3.2 Strategy development

To support strategy development, a structure of the various stakeholders is presented in Figure F.25, based on models found in literature, and those used to develop CSP technologies in South Africa’s REI4P. The purpose of this structure is to provide insight into the relationships and interactions between the different stakeholders, which are likely to be needed with respect to the commercialisation process. At the centre is a *technology commercialisation board* (TCB), a board of high level individuals, preferably with extensive technology management experience. Their role is to engage with, and facilitating interaction between, the various partners. Furthermore, they are to coordinate efforts aimed at advancing the commercialisation process. The board members will each have different roles and responsibilities, and possess differing relationships with each of the partners, based on the board member’s respective background, be it in finance, government relations, R&D, and so forth. While the TCB may in practice be represented largely by the respective CSP associations (SASTELA and STASA), it is advised that the board also include high ranking members of government and the business sector, who may also be members of any respective energy association. Finally, the outer circle of people is positioned to further emphasise the role of people in the commercialisation of CSP technologies, and that their interests, agendas, and beliefs need to be considered if CSP technologies are to reach a commercial state faster in South Africa.

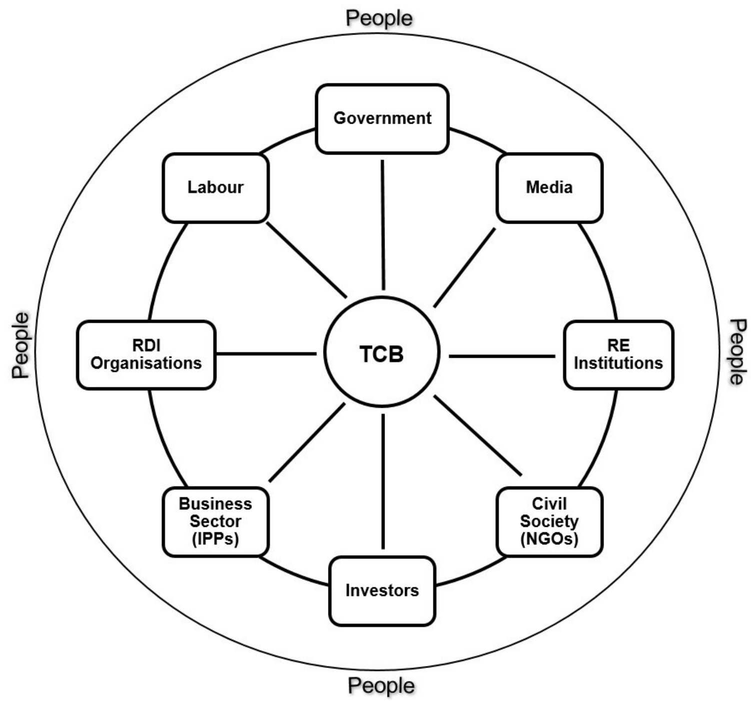


Figure F.25: Stakeholder structure

On the subject of strategy development, it is important to realise that the choice of strategy is dependent on both internal and external factors (Lund, 2009). Rather than specify exactly how the strategies are to be chosen or developed, the framework affords the user a degree of flexibility, merely providing a list of tools, techniques and other mechanisms from which strategies may be developed.

It is also necessary that for users of the framework take note of the need for different strategies depending on what level the respective CSP technology, which the user is attempting to commercialise, forms part of a wider energy system. To assist commercialisation practitioners with this decision, Figure F.26 provides a supportive decision-making tool, highlighting the focus points of different areas of the commercialisation process with the corresponding level of focus within a standard MTRES,

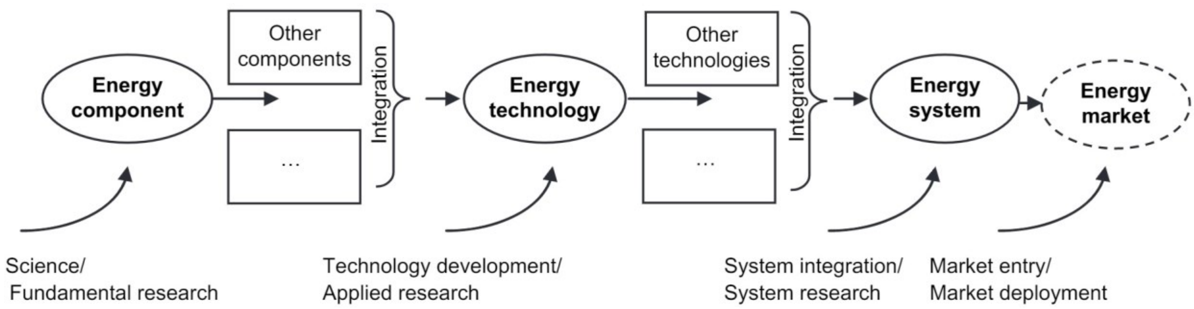


Figure F.26: MTRES system level supportive decision-making tool
(Source: Lund, 2009)

To further assist the development and choice of strategies for commercialising MTRESs, Table F.21 highlights several factors to be considered. However, this is not necessarily a complete list, providing more of an example as to what should be considered with respect to efforts to increase the rate of commercialisation. Table F.22 provides further support with respect to the type of broad commercialisation strategy to be implemented, and when to do so. One of the key decisions with any strategy is what part of the commercialisation process, and technology supply/value chain, to target. Typically, efforts are targeted either at upstream activities, or downstream activities.

Table F.21: Factors influencing development and choice of strategies for commercialising MTRESs

Factor	Extreme limits	
Technology status	Mature	Embryonic
Technology know-how	Low	High
Industrial basis	Weak	Strong
Raw materials	Scarce	Abundant
Production location	Foreign	Domestic
Manufacturing units	Small	Large
Business consolidation	Horizontal	Vertical
Industry structure	SME	Centralized
Innovation system	Fragmented	Networked
Innovation type	Incremental	Radical
Market		
– Geography	Domestic	Global
– Size	Small	Large
– Status	Mature	Embryonic
Timing	Late	Early
Policy measures	RTD	Market deployment
Public funding	Small	Large
Value positioning	Component	System

(Source: Lund, 2009)

Table F.22: Commercialisation strategy development support tool

Commercialisation method		Company's relative standing	Technology categories	Urgency of commercialisation	Need for support technology	Commitment/ investment	TLC	Potential application
Internal	Employ in own products/ processes/ marketing	All levels	Distinctive/ basic	Lowest	Lowest	Highest	Earliest	Narrowest
External	Contract out manufacture or marketing to others	Product technology high Process/ marketing technology low	Distinctive product technology	High	High	High	Early	Narrow
	Contract in manufacture, marketing or product design for others	High	Distinctive	High	High	High	Later	Wider
	Joint venture	High or low	Distinctive/ basic	Higher	Higher	Low	Early	Wide
	Licensing out	High	Distinctive	Low	Low	Lowest	Later	Widest

(Source: Cetindamar, Phaal, & Probert, 2010:60)

Appendix F.8.3.3 Partnership development

Glasbergen (2010) presents a ladder of partnership development (see Figure F.27), with a focus on those activities required to enact real change within an energy sector, change which can be of benefit to the commercialisation of CSP technologies. These activities allow for objectives to be reached faster and more effectively, thereby improving the chances of long-term success and sustainability in the modern era. To proceed up the ladder, partnerships need the support of strong companies or industry leaders, those with considerable market power and influence, and who are able to change the nature of a market if necessary. NGOs can provide professional knowledge and expertise, while it is often useful to have personnel available to attend to the administration, and other internal matters, of the partnership. Furthermore, it is important to gain rapid trust and legitimacy in the eyes of the respective industry, as well as ensure sufficient confrontational power is held as a means of driving the process of partnership development towards its goals. (Glasbergen, 2010)

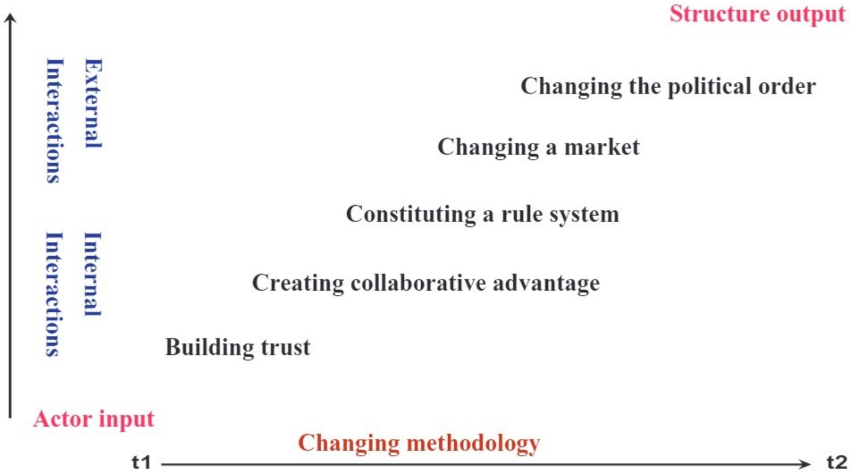


Figure F.27: Ladder of partnership activity
(Source: Glasbergen, 2010)

Another aspect worth considering is that the structure proposed in Figure F.25 will require the mobilisation of a large number of people. This is typically achieved in one of two ways. One, the direct or force approach, is where a single role player forces buy-in from other stakeholders into the implementation of a technology or idea. This is the case in countries like Japan and South Korea, where the government is the dominant decision maker. The second approach is that of democracy, one where there is agreement and acceptance from all partners. For this approach to be implemented in South Africa, a win-win situation needs to be advocated, whereby partnerships are able to offer value and benefits to prospective partners in order to ensure buy-in from all stakeholders.

Appendix F.8.3.3.1 Balanced scorecard

This section presents a choice of objectives (see Table F.23) to measure the progress made by any strategy developed in an adapted balanced scorecard[145] format, together with a set of quantitative and qualitative metrics, or key performance indicators (KPIs). While the list is extensive, it is not presumed to be an exhaustive one, and practitioners are welcome, and encouraged, to use other objectives and metrics not listed here. In addition, it highlights the need to set short- (0-5 years), medium- (5-15[146] years), and long-term (15+ years) targets

[145] The balanced scorecard approach is a strategic execution model based on four primary aspects: (1) the customer, (2) finances, (3) internal business process, and (4) knowledge, education and growth. The choice of the balanced scorecard over other strategic implementation tools, for example the Ansoff Matrix, is based on the nature of the components of the strategic management framework developed here.

[146] Although medium-term is often set at 5-10 years, the researcher felt that 15 years was a more appropriate time

(where applicable), as well as the relevant data source(s) that can inform these targets, and provide figures on the actual progress being made. Achieving short-term success is especially important with respect to overcoming initial scepticism, establishing credibility, and fuelling progress towards achieving medium- and long-term targets.

One example of how this scorecard may be used is as follows: should a strategy be developed that focuses on the education of CSP technologies by a particular demographic group in South Africa, then a set of education-based objectives and metrics will be selected. It is recommended that only a small number of metrics is used per objective in order to maintain focus on the task at hand, lest it try to be measured by too many different elements. The choice of metrics should be guided through consultation with relevant experts, in this case educational practitioners, as well as any other notable stakeholders based on the given strategy.

frame to allow sufficient time for progress to be made towards reaching any targets set. However, it is acknowledged that a more conservative set of targets could result in 10 years also being a suitable choice as a time period boundary.

Table F.23: Partnership balanced scorecard

Objective	Metric/KPI		Short-term: industry formation (0-5 years)	Medium-term: industry growth (5-15 years)	Long-term: industry maturity (15 years+)	Data source
Cost reduction	LCOE (R/kWh)	CSP[147]				Annual RE reports
		National electricity system[148]				Annual RE reports
		Average of competitive energy technologies [149]on time-of-day basis				Annual RE reports
		% Average of competitive energy technologies[150]				Annual RE reports
Effectiveness / industry growth	Additional annual[151] installed capacity (MW/year)	Local				Annual RE reports
		Export				Annual RE reports
	Annual[152] local electricity production (TWh)	Local				Annual RE reports
		Export				Annual RE reports

[147] This LCOE applies to utility scale CSP power plants. Target values should be presented as a range to account for the effect of different assumptions and CSP technologies on the LCOE value.

[148] The average cost of electricity generated by South Africa's national electricity grid.

[149] This metric is designed to measure the average LCOE of all energy technologies which are able to supply electricity for the same time-of-day period on an annual basis and type of application (e.g. peaking, baseload). For example, if we take the case of CSP, which is a dispatchable technology and often used for peaking purposes during early mornings and evenings, the comparison would be made with other energy technologies which compete with it for the same purpose.

[150] Designed to track percentage changes in cost of competitive energy technologies.

[151] This metric can also be expressed in annual or cumulative terms.

[152] See footnote 18.

	Number of CSP power plants under construction (at any one time)					Annual RE reports; IPP office
	Plant lead time (years)					Annual RE reports
	% contribution to electricity supply					Annual RE reports
	% contribution to energy supply					Annual RE reports
	Job creation (construction, manufacturing, O&M)	Local				Annual RE reports
		Export				Annual RE reports
	Local content[153] (%)					Annual RE reports
	Number of companies operating in respective MTRES industry					Annual RE reports
	Annual[154] level of financial investment (billions)					Annual RE reports
	Trade	Net trade balance[155] (billions)				Annual RE reports
		Contribution to GDP (billions / %)				Annual RE reports

[153] Local content is typically defined by the relevant national government department, usually the Department of Energy.
[154] See footnote 18.
[155] Includes services and components.

	Number of international licensing agreements					Partnership data
	Number of international strategic alliances / partners					Partnership data
Education and social acceptance	Knowledge (%)[156]					Surveys & questionnaires
	Perception[157]					Surveys & questionnaires
	Fear[158]					Surveys & questionnaires
	Stakeholder participation in decision-making process (%)					Surveys & questionnaires
	Social media views, action buttons (likes, subscribes) (%)[159]					Analytics[160]
	Website views & visits (%)					Google analytics

[156] What does the public know? (Assefa & Frostell, 2007). Percentage targets set refer to percentage of public who demonstrate some degree of knowledge about the technology and its basic operation.

[157] What does the public think? Based on overall attitude, emotional feeling, and rational feeling. Range of five levels: Very negative, negative, neutral, positive, very positive. (Assefa & Frostell, 2007)

[158] What does the public feel? Use of the word fear interchangeable with worry and concern in this context. Applicable in a general sense to physical health, safety, and well-being. Range of six levels: very high fear, high fear, medium fear, low fear, very low fear, no fear. (Assefa & Frostell, 2007)

[159] Percentage increase above existing levels.

[160] Refers to the analytics of the respective social media platform. For example, Facebook will make use of Facebook's embedded analytics tools.

	Search engine keywords (%)[161]					Google Trends
Legal and regulatory compliance	Audits	Internal (%)				Internal to organisation
		External (%)				3rd party organisation
	Employee training completion rate (%)					Internal to organisation
Technological capability	Patents & patent citations					Relevant IPP or IP office
	Annual number of scientific publications worldwide					(Bibliometric) Analysis of journal articles
	Water consumption (l/kWh)					Annual RE reports
	Life cycle GHG emissions (g/kWh)					Annual RE reports
	System efficiency[162] (%)					Annual RE reports
	Annual percentage reduction in avian deaths					Surveys & questionnaires; Annual RE reports
Organisational performance	ROI (%)[163]					Organisational data
	Levelised profit of electricity (LPOE) (millions)					Annual RE reports; Organisational data

[161] See footnote 26.
[162] Energy source to electricity efficiency.
[163] Nominal returns.

Appendix F.8.4 Interfaces

Various interfaces exist within the framework, as illustrated by the black arrows in Figure F.12, and described in Table F.24. These arrows serve to indicate the relationships and feedback loops between the different components. In addition, several decision gates exist within the commercialisation process, as indicated by red diamonds. These gates highlight that progress needs to be monitored at all time to ensure resources are allocated in a cost-effective manner, while drawing attention to important decisions such as time of market entry, as well as financing and (organisational) capability considerations. Although interfaces also exist in the breakdown of the components of the primary, secondary, and tertiary levels, this discussion only concerns itself with the relationships shown in Figure F.12.

Table F.24: Framework interfaces

From	To	Description
Market Need, Want or Problem	Market Generation	The market need, want or problem indicates the type of market to be generated, or fostered, in order to ensure sufficient demand for the respective technology.
Market Need, Want or Problem	Technology Assessment & Value Proposition	The market need, want, or problem acts as a reference point against which a technology may be assessed, and allows for comparison with the value proposition of the technology developed.
Market Need, Want or Problem	Customer Identification	The market need, want, or problem shares a close relationship with the identification of the customer, as the market need will typically emerge to fulfil the need of a certain customer group. However, should the needs or preference of the customer group change, a new market need or problem may emerge to be addressed. In addition, an alternative customer group may also emerge during a technology's life cycle.
Customer Identification	Market Generation	Customer identification plays a key role in market generation, as ultimately customers are the ones who purchase a technology. Thus, customer identification serves to guide the direction of market generation efforts.
Customer Identification	Market Need, Want or Problem	Customer identification shares a close relationship with the market need, want, or problem, as the market need will typically emerge to fulfil the need of a certain customer group. However, should the needs of the customer change, or an entirely new consumer group emerge, the respective market need, want, or problem may have to be changed accordingly.
Industry Structure	Market Generation	The existing industry structure has a significant influence on the nature and success of market generation efforts, and can act either as a constraint or enabler towards future market generation.
Industry Structure	Market Need, Want or Problem	The existing industry structure in South Africa currently has a large impact on the identification of any CSP-related market needs, wants, or problems. At the moment, these are likely to refer to the construction and operation of CSP plants presently under development, or in operation.
Industry Structure	Customer Identification	The current state of South Africa's energy sector positions Eskom as the sole purchase of CSP-generated electricity. However, this may change in the future if a more policy-friendly approach to the technology is adopted by the national government. An increase in electricity prices may also result in the private sector seeking alternative means of addressing their energy needs.
People	Partnerships	People have a direct impact on any partnerships developed, as it is individual interests, agendas, beliefs, and cultures that will influence whether they enter into a partnership or not. These factors also influence the process by which a partnership is formed, and the length of time which it lasts.
People	Market Generation	People play a vital role in market generation, as it is ultimately the decisions of individuals in government that are able to create sizeable markets for different energy technologies.
Market Generation	Strategy Development	The nature of the market for CSP technologies in the energy sector will affect which strategies are needed for market generation and expansion, as well as the means by which they are developed.
Market Generation	Process Activities	Before the commercialisation process can begin, there needs to be a sufficient market for the technology in order to make the process feasible and attractive to the private sector. A larger market will also encourage greater competition in the business sector, and is likely to ensure that greater efforts towards increasing the rate of commercialisation are implemented.

Market Generation	Organisational Capabilities	The activities conducted as part of market generation efforts will indicate which organisational capabilities should be prioritised over time, based on the needs of the respective CSP technology.
Process Activities	Strategy Development	The process activities provide an indication of what strategies are needed to order to improve the rate at which commercialisation takes place, based on the respective stage of the process.
Process Activities	Partnerships	The process activities serve as a guide regarding which partnerships are needed to increase the rate of commercialisation of the process as a whole, as well as which partnerships are needed on a more granular level, namely: on a task-by-task basis.
Process Activities	Finance	The process activities dictate which financial mechanisms, together with their respective sources, are suitable to provide the capital required, based on the different commercialisation activities. A selection of financial mechanisms is provided to assist users of the framework.
Process Activities	Organisational Capabilities	Conducting the different activities of the commercialisation process will require a range of different capabilities, which will depend on the given process activity at any point in time.
Process Activities	Technology Assessment & Value Proposition	Each process activity will require a different set of TA tools to monitor the progress achieved, while ensuring that the value proposition of the technology continues to address the respective market need.
Finance	Process Activities	The availability of finance, at an acceptable cost, often determines the possibility of success for each activity in the commercialisation process, and whether the activity commences at all.
Finance	Strategy Development	The financial mechanisms and sources presented provide an indication of what strategies are needed to order to secure the capital required.
Organisational Capabilities	Strategy Development	The strength of organisational capabilities will affect strategy development, as the development and implementation of any strategy needs to take into account the knowledge, experience and skillset of those entities involved in the process. For example, despite having knowledge of what needs to be done to increase the rate of commercialisation, if the capabilities do not exist, or are of a poor standard, it is unlikely that such activities may be conducted successfully.
Organisational Capabilities	Process Activities	The strength of organisational capabilities impact on the prospects of success for the activities of the commercialisation process, as poor implementation of an activity may not result in any real level of success.
Organisational Capabilities	Market Generation	The success of any market generation efforts is dependent on whether sufficient strength in the relevant organisational capabilities is possessed. Neglect of these capabilities, and their alignment with the relevant organisational and commercialisation goals, will likely hinder potential progress in the commercialisation process.
Technology Assessment & Value Proposition	Strategy Development	The list of TA tools and methods presented provides guidance to which strategies to develop in order to monitor the technological progress made.
Technology Assessment & Value Proposition	Process Activities	Assessment of the technology at hand will guide the process activities conducted, and indicate when each activity should be conducted, and whether any significant success is realised.
Stakeholders	Market Generation	Generating a market for a technology requires engagement with several different stakeholders in order to ensure that the correct decisions are made to achieve this goal.
Stakeholders	Process Activities	Unless the entire commercialisation process is conducted in house, the expertise of different stakeholders positioned along the supply chain will be needed to bring a technology to market.

Stakeholder	Finance	Securing the necessary capital will involve engagement with stakeholders in the financial sector, primarily different types of investors.
Stakeholder	Strategy Development	The influence of different stakeholders, with their various roles, interests, and agendas, needs to be considered prior to the development of any strategies.
Stakeholder	Partnerships	The influence of different stakeholders, with their various roles, interests, and agendas, needs to be considered prior to the formation of any partnerships.
Strategy Development	Stakeholders	The impact that the development and implementation of any strategies may have on different stakeholders should be considered, in an attempt to mitigate any unanticipated or undesirable consequences which may occur.
Strategy Development	Partnerships	The impact that the development and implementation of any strategies may have on the formation of any partnerships should be considered, in an attempt to mitigate any unanticipated or undesirable consequences which may occur.
Partnerships	Strategy Development	The influence and ability of partnerships to develop strong strategies is of great importance, particularly with respect to increasing the rate of commercialisation.
Partnerships	Stakeholders	The influence of partnerships on the individual stakeholders should be considered, as such partnerships may have unforeseen impacts on the stakeholders in terms of their interests, assets and so forth.