Evaluating the economic viability of concentrated solar power systems as renewable energy source

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DECLARATION

I, **VB NGOMANE**, declare that **Evaluating the economic viability of Concentrated Solar Power systems as renewable energy source** is my own work and that all the sources used or quoted have been indicated and acknowledged through complete references. This mini-dissertation has not previously been submitted by me or any other author to any other university.

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ABSTRACT

Title: Evaluating the economic viability of concentrated solar power systems as renewable energy source

Keywords: Concentrated Solar Power, Independent Power Producer, Integrated Resource Plan, Renewable Energy, Direct Normal Irradiation, Cost-Benefit Analysis, Economic Viability

Access to electricity is one of the key drivers of economic activity, and sustaining a reliable electricity supply is essential for South Africa to grow its economy, reduce the unemployment rate, and alleviate poverty. Since 2007, the country has grappled with electricity shortages, resulting in continuous power cuts in the form of load shedding. This predicament is mainly attributed to an aging power generation fleet, with much of the infrastructure reaching the end of its operational lifespan. The aging fleet's reliance on coal, a non-renewable fossil fuel, contributes to excessive emissions of greenhouse gases (GHG) into the atmosphere. These emissions cause environmental challenges such as global warming, manifesting in increased temperatures, intensified storm events, and rising sea levels. To address the electricity challenges without harming the environment, South Africa is transitioning from fossil fuel power generation technologies to Renewable Energy Technologies (RET) such as Concentrated Solar Power (CSP) technology.

The research question driving this study was whether CSP could be economically viable as a renewable energy (RE) source in South Africa. Thus, the primary objective was to evaluate the economic viability of CSP as an RE source using a cost-benefit analysis. The study further applied a PESTLE analysis and a SWOT analysis to evaluate the economic viability of CSP as an RE source.

The research followed a qualitative methodology. Data were collected through semi-structured interviews with eight participants who were selected using purposive sampling. The sampling was performed based on the individuals' knowledge of CSP plants from a strategic and operational point of view. The sample comprised two CEOs, two CFOs, two plant managers and two operations managers from two CSP plants in the Northern Cape Province, South Africa.

The findings from the literature review and empirical study indicate that CSP systems equipped with thermal energy storage (TES) not only generate electricity during sunlight hours, but can continue to generate electricity after sunset. This capability stems from TES's ability to store energy or heat acquired during the day, allowing the technology to use the stored heat after sunset for sustained electricity generating. The ability to generate electricity after sunset enables CSP technology to provide baseload power to the grid as requested by grid operators. In contrast, other

RETs, such as wind and photovoltaic (PV), can only generate electricity when there is adequate wind and sunlight respectively, leading to grid instability.

The results from the cost-benefit analysis, the PESTLE analysis and the SWOT analysis showed that, for the South African context, CSP technology is indeed economically viable as an RE source. The study recommends that the South African government maintain its support for CSP technology and consider increasing the allocated electricity generation capacity by CSP beyond the 600 MWh currently designated in the Integrated Resource Plan. It is advised that the country's infrastructure be upgraded to accommodate further CSP developments in the Northern Cape. These recommendations are based on the fact that the Northern Cape has some of the world's highest levels of direct normal irradiance, which is crucial for the optimal functioning of CSP technologies.

OPSOMMING

TITEL: ’n Evaluering van die ekonomiese lewensvatbaarheid van gekonsentreerde sonkragstelsels as hernubare energiebron

Sleutelwoorde: Gekonsentreerde Sonkrag, Onafhanklike Kragprodusent, Geïntegreerde Hulpbronplan, Hernubare Energie, Direkte Uitstraling, Koste-Voordeel-Analise, Ekonomiese Lewensvatbaarheid

Toegang tot elektrisiteit is een van die sleutelfaktore van ekonomiese aktiwiteit. Daarom is dit noodsaaklik dat Suid-Afrika se elektrisiteitstoevoer betrou is om ekonomiese groei, ’n daling in die werkloosheidsyfer en verligting van armoede te bewerkstellig. Sedert 2007 gaan die land gebuk onder elektrisiteitstekorte, met die huidige situasie van deurlopende kragonderbrekings in die vorm van beurtkrag tot gevolg. Hierdie krisis word hoofsaaklik toegeskryf aan die land se verouderde kragopwekkingsvloot, waarvan groot dele van die infrastruktuur binnekort nie meer operasioneel gaan wees nie. Die verouderde vloot se gebruik van steenkool, ’n niehernubare fossielbrandstof, dra by tot uitermatige vrystellings van kweekhuisgasse in die atmosfeer. Hierdie vrystellings veroorsaak omgewingskwessies soos aardverwarming, wat in verhoogde temperature, uiterste stormtoestande en stygende seevlakke manifesteer. Om die elektrisiteitsprobleme te bekamp – sonder om skade aan die omgewing te rig – is Suid-Afrika tans in ’n oorgangstydperk vanaf kragopwekkingstegnologie wat van fossielbrandstowwe gebruik maak na tegnologie wat van hernubare energie gebruik maak. Gekonsentreerde sonkrag (GSK) ressorteer onder laasgenoemde.

Die navorsingsvraag wat deur hierdie studie beantwoord is, is of GSK ekonomies lewensvatbaar is as ’n hernubare energiebron in Suid-Afrika. Dus was die hoofdoelwit van die studie om die ekonomiese lewensvatbaarheid van GSK as ’n hernubare energiebron te evalueer aan die hand van ’n koste-voordeel-analise. Die studie het ook ’n PESTLE-analise en ’n SWOT-analise gebruik om die ekonomiese lewensvatbaarheid van GSK as ’n hernubare energiebron te evalueer.

Die navorsing het ’n kwalitatiewe metodologie gevolg. Data is ingesamel deur middel van semigestruktureerde onderhoude met agt deelnemers. Die steekproef is gekies met behulp van doelbewuste steekproefneming. Die deelnemers is uitgesoek op grond van hulle kennis van GSK-aanlegte vanuit ’n strategiese en operasionele oogpunt. Die steekproef het bestaan uit twee HUB’s, twee HFB’s, twee aanlegbestuurders en twee operasionele bestuurders by twee GSK-aanlegte in die Noord-Kaapprovinsie, Suid-Afrika.

Bevindings uit die literatuuroorsig en empiriese studie toon dat GSK-stelsels wat met termiese energiestoring (TES) toegerus is, nie slegs elektrisiteit gedurende die dag kan opwek nie, maar daarmee kan volhou ná sonsondergang. Dit word moontlik gemaak deur TES se vermoë om die

energie of hitte wat gedurende die dag opgewek is, te stoor. Op hierdie wyse kan die tegnologie die gestoorde hitte ná sonsondergang gebruik om elektrisiteitsopwekking voort te sit. Die vermoë om elektrisiteit ná sonsondergang op te wek, stel GSK-tegnologie in staat om basisladingkrag aan die netwerk te verskaf na gelang van netwerkoperateurs se versoeke. Hierteenoor kan ander hernubare energie-tegnologieë, soos wind- en fotovoltaïse tegnologie, slegs elektrisiteit opwek wanneer daar genoegsame wind en sonlig onderskeidelik is – wat tot netwerkonstabiliteit lei.

Die resultate van die koste-voordeel-analise, die PESTLE-analise en die SWOT-analise toon dat GSK-tegnologie wel ekonomies lewensvatbaar is as hernubare energiebron in die Suid-Afrikaanse konteks. Die studie beveel aan dat die Suid-Afrikaanse regering sy ondersteuning vir GSK-tegnologie voortsit. Die studie stel ook voor dat die regering dit oorweeg om die huidige GSK-elektrisiteitsopwekkingskapasiteit van 600 MWh wat in die geïntegreerde hulpbronplan aangedui is, te verhoog. Nog ’n aanbeveling is dat die land se infrastruktuur opgegradeer word om verdere GSK-ontwikkeling in die Noord-Kaap moontlik te maak. Hierdie aanbevelings is gegrond op die feit dat die Noord-Kaap van die hoogste vlakke van direkte uitstraling ter wêreld het, wat noodsaaklik is vir die optimale funksionering van GSK-tegnologie.

LIST OF ABBREVIATIONS

CBA	Cost-Benefit Analysis
CEO	Chief Executive Officer
CFO	Chief Financial Officer
CIPD	The Chartered Institute of Personnel and Development
Covid-19	Coronavirus disease
CSP	Concentrated Solar Power (systems/technologies); also known as Concentrated Solar Thermal (systems/technology)
DE	Department of Energy
DNI	Direct Normal Irradiation
DNT	Department of National Treasury
DPE	Department of Public Enterprise
DPME	Department of Planning, Monitoring and Evaluation
EPC	Engineering, procurement and construction
ERA	Electricity Regulation Act
FIT	Feed-in tariff
GDP	Gross domestic product
GHG	Greenhouse gas/(es)
GWh	Gigawatt hour
HTF	Heat transfer fluid
IEP	Integrated Energy Plan
IETA	International Emissions Trading Association
IPP	Independent power producer
IRP	Integrated Resource Plan

IRR	Internal Rate of Return
JET	Just energy transition
kWh	Kilowatt hour
LBPL	Lower bound poverty level
LCOE	Levelised Cost of Electricity/Energy
LFR	Linear Fresnel Reflector
MSCA	Minerals Council South Africa
MTBPS	Medium-term Budget Policy Statement
MWh	Megawatt hour
NDP	National Development Plan
NERSA	National Energy Regulator of South Africa
NPC	National Planning Commission
NPV	Net Present Value
NWU	North-West University
OCGT	Open-cycle gas turbine
PBP	Payback Period
PDS	Parabolic Dish Systems
PESTLE	Political, Economic, Social, Technological, Legal and Environmental
PPA	Power Purchase Agreement
PPP	Public–private partnership
PSA	Public Servants Association
PTC	Parabolic Trough Collector
PV	Photovoltaic Solar panels/systems/technology

R&D	Research and development
RE	Renewable energy
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
RET	Renewable energy technology
ROI	Return on Investment
SA	South Africa(n)
SoE	State-owned enterprise
SONA	State of the Nation Address
SPT	Solar Power Tower
STERG	Solar Thermal Energy Research Group
SWOT	Strength, weaknesses, opportunities and threats
TES	Thermal energy storage
TWh	Terawatt hour
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
WWF	Worldwide Fund for Nature

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1. CHAPTER 1: BACKGROUND AND INTRODUCTION

1.1 Background and introduction

Access to energy lies at the heart of development but, if not implemented effectively, it can have a detrimental impact on people's health, education, food security, gender equality, livelihoods, and overall economic wellbeing (World Bank, 2018). Energy is also the lifeblood of modern living and an enabler of economic growth and stability (DE, 2019a:2). As alluded to by Van der Nest (2015), for effective and efficient development, South Africa (SA) needs a reliable and accessible infrastructure providing utility services.

The SA electricity infrastructure comprises three divisions: generation, transmission, and distribution. With regard to generation, Eskom, which is a state-owned enterprise (SoE), dominates the production of electricity. Eskom generates, transmits, and distributes electricity to industrial, mining, commercial, agricultural, and residential customers in SA, as well as to municipalities, who, in turn, redistribute electricity to businesses and households within their areas. The utility also purchases electricity from Independent Power Producers (IPPs) in terms of various agreement schemes, as well as from electricity generating facilities beyond the country's borders (DE, 2019a:16).

Since the end of 2007 and the beginning of 2008, the generating capacity of the SA energy system could not keep up with the electricity demands of its customers; consequently, load shedding had to be implemented across the country (Pretorius *et al*., 2015:257). Load shedding, as defined by Dewa *et al*. (2020:111), involves planned rolling blackouts on a rotating schedule throughout the country to avoid total system failure. A high load demand that exceeds the generated power negatively affects the energy system's frequency and overall capacity. In such cases, load shedding becomes the best option to restore the frequency (Raghu & Manjunatha, 2017:3236).

Most of SA's energy production comes from coal, although there is substantial evidence that coal power is no longer required for energy security (Merven *et al*., 2021:2). Merven *et al*. (2021:2) argue that coal is more costly when compared to other alternatives and will increase greenhouse gas (GHG) emissions in a sector where there are cost-competitive and commercially viable alternatives. Eskom, as an SoE, supplies 95% of SA's electricity, with the remainder coming from IPPs and imports (Mokveld & Von Eije, 2018:3).

Merven *et al.* (2021:2) indicate that the current state of energy in SA stands in contradiction with the government's commitment to the goals of the Paris Agreement and its objective of achieving net zero carbon emissions by 2050, reducing global temperatures to below two degrees Celsius. SA's ratification of the Paris Agreement and the recent long-term energy planning iterations have reinforced the country's commitment to renewable energy (RE) (DE, 2018:2). The latter also

emphasises the need for the implementation of greener RE sources, minimising (or at least lowering) carbon emissions.

1.1.1 South Africa's existing energy crisis

As mentioned above, load shedding was first introduced in SA towards the end of 2007 and, since then, the country has been faced with continuous electricity challenges (Deloitte, 2021:2). This, in spite of the fact that a white paper on the energy policy of the country, published in 1998, had forecasted that the electricity demand would exceed generation capacity by 2007 (Marta & Agnieszka, 2015:103). The white paper's recommendation was that capacity expansion should be considered to meet the needs of the growing economy at that time (Marta & Agnieszka, 2015:103).

South Africa's electricity infrastructure has been degrading in the past decade, with both scheduled and unscheduled power outages on the increase, despite slowed economic activity due to the Covid-19 pandemic the past two years. For example, the country experienced about 1 130 hours of planned power cuts in 2021, the highest ever (Winkler, 2022). In his 2022 State of the Nation Address (SONA), President Cyril Ramaphosa outlined five areas to be prioritised by the government, one of which was expanding the electricity generation capacity (Ramaphosa, 2022). Today, more than 20 years since the white paper was published, it is clear that the energy capacity expansion has not been paid the attention it deserves (Marta & Agnieszka, 2015:103).

Pretorius *et al*. (2015:256) identify three main contributing factors to the energy crisis. The first is the dramatic increase in demand after 1994 when the economic sanctions of the apartheid era were lifted. The second is the government's delayed decision in 2004 to fund the building of new power stations when it had become apparent that new capacity was needed. The third factor is the delayed maintenance of the current generation fleet. According to Ndlovu and Lotz (2019:16), the energy crisis has been caused by deficiencies in the strategic management and policy implementation of the SA energy supply system.

Hedden (2015) contends that resolving SA's energy crisis is not sufficient on its own: greater emphasis is needed on the transitioning and distribution of electricity. This suggests that SA is not at a stage where other technologies within RE projects can be isolated since the demand for electricity continues to rise. This is the main reason why energy experts have raised concerns regarding the exclusion of Concentrated Solar Power (CSP) systems/technologies beyond 2030 in the projections by the Department of Energy (DE, 2019b:71). Tan (2021) adds that the total number of RE projects will still not be enough to resolve the escalating energy demand, meaning SA might still need to rely on fossil fuel for some time.

According to Golberg (2015:1), future load shedding remains a possibility as much of the nation's electricity generation infrastructure is approaching an age at which replacement will be required. Winkler (2021) predicts that the country will continue to experience load shedding for the next five years due to aging power plants. Eskom's average plant age, as indicated by Booysen and Rix (2021), is about 40 years, and breakdowns and maintenance have amounted to as much as 20 Gigawatt hour (GWh) loss in generating capacity. Furthermore, SA's track record of building new generation capacity since the crisis in 2007 has been dubious (Golberg, 2015:1). The Public Servants Association (PSA, 2015:1) states that the root of the crisis lies in inadequate investment in new generation capacity due to the energy monopoly by Eskom, which does not generate enough revenue to cover capital costs.

1.1.2 Consequences of South Africa's existing energy crisis and challenges

The SA economy is extremely energy intensive, and, on average, the industrial energy efficiency is significantly lower when compared to other countries (Mokveld & Von Eije, 2018:3). As explained by Mokveld and Von Eije (2018:3), industrial and mining sectors consume over 60% of electricity generated. With the inclusion of commerce, this figure increases to about 75%.

The longer the crisis, the more severe the impact will be on economic growth and unemployment, which will further put a damper on the country's efforts to alleviate poverty (PSA, 2015:1). The reliance on coal for Sa's energy production further challenges the crisis: while struggling to keep the lights on, the country has to honour its commitment to the Paris Agreement (PwC, 2021:15). Deloitte (2021:2) claims that about 120 000 jobs could be lost in the coal sector because of the transition to lower-carbon technology in the electricity sector; hence this transition has to be just and consider the potential socio-economic impacts. Moreover, the drastic increase in electricity prices and unreliable electricity supply for over more than a decade have caused irreparable harm to SA's economic and development performance and aspirations (MCSA, 2021).

Access to electricity is one of the key drivers of economic activity and any shortage of supply has an impact on the country's economic growth, international competitiveness, and production (Van der Nest, 2015). Energy experts have indicated that, since its inception in late 2007 until the end of 2018, load shedding has cost SA around R1.4 trillion, which is almost half of SA's gross domestic product (GDP) (Head, 2019).

South Africa's domestic electricity generation capacity can be broken down into 38 GWh which comes from coal; 1.8 GWh from nuclear; 2.7 GWh from pumped storage; 1.7 GWh from hydro; 3.8 GWh from diesel; and 3.7 GWh from RE (DE, 2019b:11). The SA government has given Eskom a mandate to be a single buyer of electricity within the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) over and above its main function to generate, transmit, distribute, and sell electricity. Eskom's customer base includes industrial,

mining, commercial, agricultural, international, municipal, residential customers, as well as redistributors (DE, 2019a).

The fact that load shedding has been persisting since 2007 clearly indicates that Eskom cannot provide sustainable energy to the grid without a mix of robust energy mix strategies (DPE, 2019:4). More recently, alleged financial irregularities and governance concerns at several SoEs have surfaced, which includes Eskom (DPME, 2018:19).

Eskom is the only utility that can procure electricity generated by IPP's. In order to generate electricity, the IPP's requires a generation licence from NERSA. Before August 2021, IPP's were only allowed to generate electricity up to 1 MWh without a generation licence. With effect from August 2021, the generation license threshold was increased from 1 MWh to 100 MWh (IEA, 2023). A watt hour (Wh) is a unit of energy, indicating the energy that an item consumes within one hour (usually measured in kilowatt hours, kWh) (Karssing, 2019). Thus, kWh indicates a consumption of 1 000 watts per hour; MWh, a consumption of one million watts per hour; GWh, a consumption of one billion watts per hour; and a Terawatt hour (TWh), a consumption of one trillion watts per hour.

South Africa signed the Paris Agreement on 22 April 2016 and ratified it on 1 November 2016 to set out long term climate strategies with a goal to become a net zero carbon emission economy by 2050 hence the commitment to RE (Mills *et al*., 2021:11). Ndlovu and Lotz (2019:15) also emphasises the importance of optimisation and diversification of the South African energy mix to meet developmental goals and enhancing the security of supply looking at the growing demand and aging power plant fleet.

Owing to electricity shortages, SA is facing global challenges when it comes to competitiveness in manufacturing; hence the need to grow the RE industry which includes CSP technology (WWF, 2015:6). Economic growth will play a pivotal role in improving SA’s unemployment rate. Already in 2009, prior to the establishment of CSP plants in SA, research had identified more than 104 billion square metres of suitable areas, with a total theoretical potential of more than 11 000 TWh electricity generation capacity (Duvenhage *et al.*, 2020:1). The Integrated Resource Plan (IRP) only indicates CSP projects of up to 0.6 GWh until 2030, and no CSP projects between 2030 and 2050 are forecasted.

There has been a huge public outcry about the cost of renewable energy technologies (RETs) to Eskom and it has been very difficult to convince the public regarding the value-adding prospects of RETs (Groenendaal, cited by Bungane, 2019) despite the fact that the cost of RE continued to decline in 2020 (IRENA, 2021:3). According to Groenendaal (cited by Bungane, 2019), the SA government has lost credibility on the RE programme due to not only politics, corruption, mismanagement, and policy uncertainty, but also the increase in primary energy costs depicted

in Eskom's published annual financial statements (Eskom, 2020:3). State capture has further contributed to Eskom's problems in meeting the country's electricity needs (DPE, 2019:2).

The above clearly indicates that there is a need for SA to explore different energy technologies to serve its electricity needs and remain competitive globally with regard to electricity pricing. This can be achieved by using the abundance of RE resources available without causing more harm to the environment.

1.1.3 Alternative and available electricity generation solutions

South Africa has a wide range of energy technology available, as indicated in the IRP document, namely coal, nuclear, hydro, pumped storage, photovoltaic solar panels or photovoltaic systems (PV), wind, CSP, gas/diesel, biomass, landfill, and others (DE, 2019b:42). The main current source of electricity generation is coal-fired power plants and SA's plan is to reduce coal dominance by 2030 (DE, 2019b:32). Koeberg Power Station, which produces about 1 860 MWh, is the only nuclear power station in the country, and there are no further plans for any other nuclear power stations in the latest IRP documents until 2030 (DE, 2019b:23).

The most prominent RETs in the IRP document is PV, wind and CSP, with wind accounting for the largest share among the three. As indicated by Winkler (2021), by 2030, SA will be generating electricity using 64% coal, 13% wind, 8% solar, 4% nuclear, 3% hydropower and 1% gas, while programmes are in place to reduce coal usage from 64% to 42%. It should also be noted that, although these three RETs (PV, wind, and CSP) have potential to assist the SA government to move from fossil fuel power generation to RET technologies CSP is the only maintainable and dispatchable RET that can supply a significant portion of the country's electricity needs (Gauché *et al.*, 2012:1).

Shinn (2018) refers to RE as clean energy, coming from natural resources or processes that are often replenished. Ellabban *et al.* (2014:749) define RE as energy sources that are continually replenished by nature and are either derived (i) directly from the sun (such as thermal, photochemical, and photoelectric); (ii) indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass); and/or (iii) other natural movements and mechanisms of the environment (such as geothermal and tidal energy). These definitions clearly indicate that all sources of RE are used to generate electric power and have the benefit of being available and virtually inexhaustible while causing little damage to climate and the environment (REN21, 2019).

On the other hand, fossil fuels such as oil, coal, and natural gas are available only in finite quantities and, as we keep extracting them, they will run out sooner or later. Even though they are produced via natural processes, they do not replenish as quickly as human consumption depletes them (REN21, 2019). Investment in RE, which displaces coal assets, is also likely to

bring significant health benefits through reduced air pollution, enhance social wellbeing, and reduce electricity cost in the long term (O'Callaghan *et al*., 2021:9).

In brief, RETs (which include CSP) (i) emit low GHGs and air pollutants, which is beneficial to the climate and our health; and (ii) come at a lower cost, keeping the energy prices at affordable levels. As discussed in detail in paragraph 1.5 below, various factors make CSP distinct and advantageous in comparison to other RETs. CSP can not only make a unique contribution to the RE solution to SA's energy crisis, but can also be part of a balanced approach in transitioning to sustainable RE sources and, thus, adhere to the Paris Agreement.

1.1.4 Government's Integrated Resource Plan (IRP)

South African energy decision making is the responsibility of the government. The National Energy Regulator of South Africa (NERSA) is a regulatory authority established by the National Energy Regulator Act 40 of 2004. In terms of the Electricity Regulation Act 4 of 2006 (ERA), supported by government policies as well as regulations issued by the Minister of Energy, NERSA is tasked with regulating the electricity, piped gas, and petroleum pipeline industries. In turn, the ERA, with accompanying regulations, enables the Minister of Energy to, in consultation with NERSA, determine the new capacity that is required. Through ministerial determinations, electricity capacity is procured from Eskom and IPPs and added to the national grid, which is operated by Eskom.

Electricity pricing is also regulated by NERSA and they are responsible for issuing electricity generation licences to interested organisations (NERSA, 2021). NERSA (2021), through the ERA 34 of 2006 has appointed Eskom to be the single buyer of electricity generated by IPPs.

The government's IRP refers to the coordinated schedule for generation expansion and demand-side intervention programmes, taking into consideration multiple criteria to meet the nation's electricity demand. RETs, which include CSP (only up to 2030), form part of these intervention programmes (NPC, 2011:ii). The IRP was published in 2019 to support the National Development Plan (NDP). This plan envisions a reduction in inequality and unemployment and the elimination of poverty so that all South Africans can attain a decent standard of living – of which electricity is one of the core elements (DE, 2019b:8).

The IRP is the leading policy framework for addressing the short- to long-term challenges that the country faces with regard to energy security. The IRP formulates specific interventions to address electricity infrastructure development based on the least-cost electricity supply and demand balance, all while taking into account security of supply and the environment (minimising negative emissions and water usage) (DE, 2019b). The IRP also identifies the preferred generation

technology required to meet the expected demand growth up to 2030 and provides a forecast for 2030 to 2050 (DE, 2019b).

It is crucial that the IRP provide a more balanced approach with regard to choosing electricity generation technology. The existing electricity crisis in SA raises the question as to whether this plan really addresses the challenges. Therefore, this study focused on the economic viability of CSPs since insufficient attention has been paid to this type of technology in the IRP document. CSP technology is included in the IRP only as an alternative RE source up to 2030 but is excluded from the IRP beyond 2030. This raises another question, namely why CSP technology is excluded from the IRP beyond 2030. This indicates the need for further research on the economic viability of CSP as an RE source for possible inclusion in a revised IRP.

1.1.5 Concentrated Solar Power projects

The main technologies used under solar energy are PV and CSP. The focus of this study was on CSP. Since PV and CSP are closely related and easily confused, it is necessary to clearly define each and distinguish between them.

According to Suarez (2021a) and Ho (2016:6), CSP generates electric power by converting the sun's energy into high temperature heat, using various mirror/reflector configurations to concentrate the sun's energy onto a receiver. From there, the concentrated light energy is converted into heat, powering a heat engine which, in turn, drives an electric generator. Therefore, a CSP system consists of two parts: one that collects solar energy and converts it into heat, and the other that converts the heat energy into electricity.

Suarez (2021a) defines PV as the direct conversion of light into electricity whereby solar PV cells absorb light which knocks electrons loose. Once the loose electrons flow, a current is created, captured, and transferred into wires, thus generating a direct electric current which is converted into alternative current and distributed to the power network. In contrast, conventional power plants burn fossil fuels, like coal, to generate heat for the power generation cycle.

Brunel (2021) indicates that the CSP process can be repeated continuously because CSP can store the heat it has generated. The stored heat energy can then be used on days where there is no sun, or before sunrise and after sunset. This is one among many factors which distinguish CSP from PV and other technologies. Other factors include the following:

- As mentioned, CSP can provide thermal storage capabilities to generate electricity after sunset and before sunrise. CSP can be built with thermal energy storage (TES) which can be used to shift generation to periods without solar resource and to provide backup energy during periods with reduced sunlight caused by cloud cover (Zhou *et al.*, 2019). The

storage medium normally used is molten salt, known for its exceptionally high storage efficiency. Molten salt is salt that tends to be solid under standard temperatures and pressure conditions but becomes liquid at elevated and extremely high temperatures (Ladkany *et al.*, 2018).

- CSP enhances grid reliability. TES in CSP also provides capacity to the power system, replacing conventional power plants – as opposed to just supplementing their output like other RETs – and can provide high ancillary services (Sioshansi & Denholm, 2010:1). With ancillary services, electricity operators can guarantee a reliable electricity system such as voltage support and balancing of reserves (Renner & Van Herten, 2015:1179).
- CSP reduces overall electricity costs. CSP is considered an attractive technology in many parts of the world because it can be equipped with low-cost TES to provide dispatchable RE and offer flexibility to the national grid (Zhou *et al*., 2019:1).
- CSP can produce significant amounts of varying temperature heat for industrial processes. It can also be used for water purification in dry countries with abundant solar resources (Zhou *et al.,* 2019:1).

As stated by the World Bank (2021), the TES capability of CSP can store energy in the form of heat at a utility scale for days with minimal losses. In turn, the stored heat can be converted into electricity and dispatched as required to meet demand, even during nighttime or overcast periods of the day. CSP plants can be designed to work as baseload power generating assets, providing renewable power continuously throughout the year. CSP is also flexible, allowing it to quickly adjust its output as required by the grid. Even when ramping down, the output is not wasted; instead, it can be stored as heat in molten salt tanks and utilised hours or even days later. Although it currently presents some technical risks and high electricity prices, with the continuous advancement of technology and gradual localisation of core equipment, CSP will surely occupy an important position in the future RE power generation market and become the future of energy solution (Ruidong & Jun, 2021).

1.2 Problem statement

South Africa's existing energy crisis: due to Eskom's inability to provide sustainable and sufficient electricity to the grid, results in regular disruptive (usually unplanned and/or short at notice) load shedding. This has already led, since load shedding commenced in late 2007, to numerous dire consequences, e.g.: hampered economic growth, negative impact on the outlook of the country as an investment destination, decreasing international competitiveness, a rise in unemployment figures and the resultant alleviation of poverty due to deteriorating economic productivity. These are intensified by the fact that current electricity generating infrastructure is aging to such extent that, keeping up with maintenance is difficult (Winkler, 2021), (which will probably become more

difficult in the future), and the fact that the addition of new generating infrastructure is not in line with the escalating energy demands (Marta & Agnieszka, 2015:103).

Therefore, South Africa needs to urgently consider accelerating the expansion of electricity generation capacity to overcome the devastating consequences of the current energy crisis. The international pressure for green energy solutions, utilising RE sources in line with the Paris Agreement. Eskom is currently supplying 95% of the electricity in South Africa (DPME, 2018:19) of which the majority is generated from non-renewable sources (89%) (including coal, crude oil, gas and nuclear) and only 11% by renewable sources and waste (DE, 2019a:8).

To be able to be in line with the signed Paris Agreement, the South African government should pay attention on sustainable RE sources. Not only focussing on RE sources; but focussing on a balanced approach in transitioning to sustainable RE sources. All the RE sources are dependent upon unpredictable environmental and climate conditions – a major disadvantage. CSP is unique in comparison to PV and other RE sources, in the sense that CSP eliminates this unpredictability – CSP can store the heat produced for use during periods when there is no or limited sunshine (Brunel, 2021). CSP can therefore uniquely contribute to the RE solution to SA's energy crisis, with the advantage of independence from environmental and climate conditions like other RE sources.

Based on the background to the study provided above, the research question this study aimed to answer is whether CSP could be economically viable as an RE source in SA.

1.3 Study objectives

1.3.1 Primary objective

The primary objective of this study was to evaluate the economic viability of CSP as an RE source, using a Cost-benefit Analysis (CBA).

1.3.2 Secondary objectives

The primary objective of this study was supported by the following secondary objectives:

- The first secondary objective was to conduct a literature review to obtain a comprehensive understanding of the economic viability and suitability (especially in an SA context) of CSP. To achieve this, all relevant available material (from textbooks, journals, previous research and publications from the SA government) were consulted to identify, analyse, and evaluate all relevant quantitative and qualitative factors/information (chapter 2).
- The second secondary objective was to design an empirical study to enable the collection of sufficient, relevant, and trustworthy data to determine whether CSP (in an SA context)

could be considered a viable RE source of energy, considering all relevant factors (chapter 3).

- The third secondary objective was to describe, explain, and analyse the research findings to achieve the second secondary objective (chapter 4).
- The fourth secondary objective was to evaluate the economic viability of CSP as an RE source, draw conclusions, and make recommendations, all based on the literature review and the empirical findings (chapter 5).

1.4 Research design and methodology

1.4.1 Literature review

For the first secondary objective, a literature review was conducted to obtain a comprehensive understanding of the economic viability and suitability (especially in an SA context) of CSP. All relevant available material (from textbooks, journals, previous research and publications from the SA government) was consulted to identify, analyse, and evaluate all relevant quantitative and qualitative factors/information.

1.4.2 Research design and methodology

Qualitative research is an approach to the study of the social world which seeks to describe and analyse the culture and behaviour of humans and their groups from the point of view of those being studied (Nieuwenhuis, 2015:51; Shareia, 2016:3839). Nieuwenhuis (2015:51) adds that qualitative research is mostly concerned with the "why" research questions, while the focus is on the depth and quality of the data.

On the other hand, quantitative research focuses on extensive data collection and is concerned with measuring a phenomenon in terms of the quantity (scope and breadth) of the data (Nieuwenhuis, 2015:51; Patel & Patel, 2019:48-55). Quantitative research involves the objective and systematic process of generalising the findings from a specific sample to the broader target population (Maree & Pietersen, 2015:145).

Al-Saadi (2014:1) defines ontology as the assumptions we make about the nature of reality and what exists. It is the philosophical framework that deals with the science or study of being; hence, it is a belief system that mirrors an individual's interpretation of what constitutes a fact (Don-Solomon & Juliet, 2018:2). Epistemology, on the other hand, refers to the assumptions we make about the nature of knowledge and how we acquire such knowledge (Al-Saadi, 2014:1). It is concerned with what we know and how we come to know it (Don-Solomon & Juliet, 2018:2).

Researchers can take different views in their research, among them a positivist or an interpretive approach. A positivist approach is typically the philosophical stance of a natural scientist who

works with observable reality, leading to findings that can be generalised. This approach focuses on pure data and facts without being influenced by human interpretation or bias (Alharahsheh & Pius, 2020:41). In contrast, an interpretive approach is concerned with in-depth variables and factors related to context. It considers humans as different from physical phenomena as they create further depth in meaning, the assumption being that humans cannot be explored in a similar way than physical phenomena (Alharahsheh & Pius, 2020:40).

The process of evaluating the economic viability of CSP as an RE source is mostly based on the decisions and behaviour of stakeholders, and these are based on government policies, plans, and strategies in line with research on national and global levels. The process of CSP's economic evaluation mostly related to culture and behaviour of humans (Van Niekerk, 2019). Therefore, this study followed a qualitative research design in its attempt to explain why CSP could be economically viable as an RE source. To achieve this, several factors that may influence the economic viability of CSP were investigated. Hence, this study leaned towards an interpretive rather than a positivist stance.

1.4.3 Empirical study

1.4.3.1 Target population

A target population is the well-defined group of potential participants to whom the researcher may have access and who represent the characteristics of the population of interest (Casteel & Bridier, 2021:344). The Northern Cape Province is the only province in the country that has CSP plants. Currently, there are seven CSP plants in this province, including one that is under construction and planned to be commissioned in 2023. Therefore, the target population for this research was senior managers of two CSP plants in the Northern Cape with strategic information about and experience with CSP technology. Senior managers would be able to provide both quantitative (financial) and qualitative information on CSP, enabling the researcher to obtain a balanced view in addressing the research objectives.

1.4.3.2 Sampling and sampling size

Etikan and Bala (2017) define non-probability sampling as a sampling procedure that does not serve as a basis for any opinion of probability that elements in the universe will have a chance to be included in the study sample. This type of sampling is often associated with a case study research design of a qualitative nature (Taherdoost, 2016). In contrast, with probability sampling, every item in the population has an equal chance of being included in the sample (Taherdoost, 2016). While different non-probability sampling methods exist, this research focused on purposive sampling. This method applies non-random sampling techniques to select participants, relying on the researcher's judgement and the accessibility of participants (Showkat & Parveen, 2017:7).

With purposive sampling, the researcher decides what information needs to be gathered and consequently identifies people who are able and willing to provide the information by virtue of their knowledge and experience.

In this study, the researcher aimed to conduct eight interviews at two CSP plants in the Northern Cape Province. These included interviews with the Chief Executive Officer (CEO), the Chief Financial Officer (CFO), a plant manager, and an operations manager at each of the two identified plants. This gave a sample of four senior managers (two CEOs and two CFOs) and four middle managers (two plant managers and two operations managers).

These senior and middle managers would be able to provide both quantitative (financial) and qualitative information on CSP, enabling the researcher to obtain a balanced view in determining the viability of CSP as an RE source within a South African context while addressing the research objectives.

1.4.3.3 Data collection and interviews

This study used primary data collected by means of semi-structured interviews, and secondary data collected through a literature review. Semi-structured interviews are designed to elicit subjective responses from participants regarding a situation or phenomenon they have experienced (McIntosh & Morse, 2015). Semi-structured interviews also give the researcher the opportunity to pose follow-up questions according to the interviewees' responses.

The semi-structured interviews in this study were conducted with the sampled interviewees (see paragraph 4.3.2) using a pre-prepared questionnaire consisting of open-ended questions. The interviews took about one hour each and were conducted individually and face-to-face. If a face-to-face interview/(s) would be impossible or impractical for some unforeseen reason, it was conducted by means of any other effective electronic communication suitable and convenient to both the interviewee and the interviewer.

The purpose of an interview is to obtain descriptive data, allowing the researcher to understand the actuality (or reality) of the phenomenon (Maree, 2012:30) and to generate meaning from the opinions and experiences as expressed by the interviewees (Asenahabi, 2019). Therefore, the purpose of the interviews in the current study was to gather data about the economic viability of CSP to achieve the research objectives. The CEOs and CFOs were selected because the researcher considered them able to provide strategic information with regard to CSP plants. Plant managers and operations managers, on the other hand, are involved with the day-to-day operation of these plants and would therefore be able to provide an understanding of the viability of CSP from an operations point of view. Thus, two questionnaires were prepared: the first questionnaire is Interview questionnaire: Plant managers and operations managers (appendix 5)

and the second is Interview questionnaire: Chief Executive Officers and Chief Financial Officers (appendix 4).

1.4.3.4 Data analysis

As mentioned in paragraph 4.2, this study followed a qualitative approach; therefore, qualitative data analysis techniques were applied to analyse the data that were collected. Flick (2013) defines qualitative data analysis as the classification and interpretation of linguistic or visual material to make statements about implicit and explicit dimensions and structures of meaning-making within the material and what is represented in it. Qualitative data analysis is based on (i) identifying common themes and patterns in the data, subdividing the data, and (ii) subdividing the data by assigning categories or codes to the data (Archer, 2018; Basit, 2003:145).

There are different qualitative data analysis methods of which the most common are thematic analysis, grounded theory, and narrative analysis (Floersch *et al.,* 2016). Thematic analysis identifies, reports, and analyses data with regard to the meanings produced by people, situations, and events (Floersch *et al*., 2016). Braun and Clarke (2006) emphasise that, with thematic analysis, the researcher can identify patterns or themes within the data.

Regarding the other two methods, Khan (2014) defines grounded theory as a theory that is derived from data which have been systematically gathered and analysed. Narrative research is a family of approaches that centre on the stories people tell to understand and describe aspects of their lives (Ntinda, 2018).

The study at hand followed a thematic analysis approach since data were identified, reported, and analysed through interviews, as explained in paragraph 4.3.3. It should be noted that there are similarities between grounded theory and thematic analysis, but the aim with thematic analysis is not to engage in data interpretation and transformation to the point of developing theory, which is the central goal of grounded theory (Kiger & Varpio, 2020).

To address the research objectives, the researcher opted to use thematic analysis since it is a more suitable and powerful method for seeking to understand a set of experiences, thoughts, or behaviours across a set of data (Kiger & Varpio, 2020). One of the benefits of thematic analysis, as alluded to by Braun and Clarke (2006), is its flexibility and usefulness in providing a rich, detailed, and yet complex account of data.

Several researchers have published descriptions and guidelines of how to apply thematic analysis, but the current study followed the six-phase guide by Braun and Clarke (2006). The six phases are: familiarising yourself with the data, generating initial codes, searching for themes,

reviewing themes, defining and naming themes, and producing the report. This will be explained in detailed in chapter 3, which is the research methodology chapter.

1.4.3.5 Trustworthiness of data

Data used in this research were collected from accredited, reliable, and well-known sources and were verifiable with a degree of confidence coupled with adherence to the guidelines and minimum requirements of the North-West University (NWU).

To ensure trustworthiness of data, it is usually recommended to adhere to the following four criteria (Shenton, 2004):

- **Credibility:** In this research, proper engagements were conducted with highly professional participants with vast knowledge of the energy sector. The information gathered was verified with them by conducting follow-up interviews considering their availability. The researcher familiarised himself with the participants before formal engagement to prevent unexpected outcomes. The researcher also addressed any specific patterns in responses to ensure data accuracy. Previous research findings were examined to assess whether they were in line with those of the current study.
- **Transferability:** This is the extent to which the findings of one study can be applied to other situations. This study was not conducted in isolation but attempted to be in line with SA's IPP programme and energy mix, and previous research conducted. Major differences in data between this study and previous research were not identified.
- **Dependability:** This criterion refers to the researched ensuring that research results can be repeated or achieved with the same methods that were applied in a particular study.
- **Confirmability:** The researcher ensured that the findings were the result of the experiences and ideas of the participants rather than those of the researcher.

1.4.4 Ethical considerations

This study was conducted under the ethical guidelines of the NWU and approval was obtained from the university's Ethical Committee to conduct the empirical study. Ethical considerations relate to the awareness of proper ways of conducting research, protecting the research from being compromised (Akaranga & Makau, 2016:6).

In addition to the university's ethical guidelines, the ethical considerations described below were applied to this study.

1.4.4.1 Permission and consent

Written permission to conduct the research and interviews was obtained from both the identified CSP plants (see appendix 1 for the approval letter). Written consent was also obtained from the sampled interviewees (see appendix 3 for the letter of consent). In seeking permission and consent, the research title, the purpose of the study and interviews, and the intended use of the information were communicated clearly (Fleming & Zegwaard, 2018:210). It was also emphasised that participation was completely voluntary (Fleming & Zegwaard, 2018:210). As indicated by Arifin (2018), consent should be given freely (voluntary), and participants should understand what is being asked of them and be competent to consent.

1.4.4.2 Confidentiality

The second ethical consideration was the confidentiality of the information obtained for the purposes of the study. Information gathered during interviews and obtained by reviewing documents were treated as confidential and used solely for the purposes of this research. Interviewees were assured that their identity would remain confidential, and that participation was anonymous since it is unethical to share individual interview responses and reveal interviewees' personal information or identity (Kumar, 2011:221).

1.4.4.3 Integrity

The researcher's integrity is another important ethical consideration, relating to the promotion of honesty, truthfulness, and the accurate representation of facts, information, and findings. There should be no deliberate misinterpretation or deceptive conduct by the researcher which may lead to mistrust among the interview population towards the researcher (Maree, 2012). The researcher will maintain integrity by being honest, truthful, and accurately representing interpreting facts and data, considering the NWU's ethical guidelines.

1.5 Significance of the study

South Africa has an abundance of RE sources, with various available technologies to explore, especially CSP. The economic viability of CSP within an SA context has not yet been fully explored, while little research has been done on CSP from an SA perspective. Craig *et al*. (2017a) assert that the impact of CSP technology on the research, development, and innovation in the country has not been investigated to date. This can be attributed to the fact that CSP is new to the country and only a few CSP plants have been completed worldwide compared to other RE (SEA, 2017). Duvenhage *et al.* (2020:1) also acknowledge that, although SA has a high solar irradiation resource by global standards, few studies have been carried out to determine the potential for CSP. Global energy demand is expected to increase by one-third from 2011 to 2035

and a study and application of renewable and sustainable energy becomes urgent (Xu *et al*., 2016).

This study thus aims to contribute to the body of research on CSP as RE source – especially the economic viability thereof. The research findings of this study will be of interest to investors, the government, financial institutions, the solar industry (CSP particularly), and Eskom. Investors will be interested in how CSP compares to alternative RETs, whereas the government should be interested since energy planning forms part of its IRP. Financial institutions have been funding more PV projects than CSP, with a focus on cost and ignoring the ancillary services that CSP provides. This study gives a detailed overview, taking not only costs, but both qualitative and quantitative data, into consideration by means of a CBA. In addition, the study will provide the solar industry with valuable insights to enhance their solar energy options and make well-informed decisions.

1.6 Chapter classification

The study is set out over five chapters:

Chapter 1: Introduction and background

This chapter provided an overview and context of the study, detailed background, the problem statement, and how the research was conducted.

Chapter 2: Literature review

This chapter addresses the first secondary objective, focusing on a comprehensive understanding of the economic viability and suitability of within a South African context. Economic viability and financial viability are defined and distinguished. Attention is given to the following aspects to indicate its use and applicability to evaluating the economic viability of CSP as RE source: (i) economic viability and PESTLE analysis, and (ii) a PESTLE analysis and the determinants of economic viability. General perspectives on the suitability of renewable technologies in a South African context whereafter Cost-benefit analysis and SWOT analysis are outlined and its suitability for and role in determining the economic viability of CSP as RE source is discussed.

Chapter 3: Research methodology

Chapter 3 addresses the second secondary objective: outlining the research methodology and design. This entails a description of the characteristics of the research, as well as the procedures and techniques used to identify, select, process, and analyse the data.

Chapter 4: Empirical study: Research results, analysis, and discussions

Chapter 4 addresses the third secondary objective, which is to describe, explain, analyse, and interpret the information and data gathered.

Chapter 5: Conclusion and recommendation

The final chapter addresses the last secondary objective and summarises the main points of the research. This chapter also states the findings and conclusions, as well as the recommendations.

2. CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Chapter 2 aims to address the first secondary objective of the study, which is to conduct a literature review to obtain a comprehensive understanding of the economic viability of CSP in an SA context. This objective was achieved by doing a literature review of all relevant available material (from textbooks, journals, previous research, and publications from the government) with the aim to identify, analyse, and evaluate all relevant quantitative and qualitative factors/information.

In paragraphs 2.2 to 2.4, attention is given to the following: (i) defining and distinguishing economic viability and financial viability, (ii) outlining and discussing a PESTLE analysis's factors as determinants of economic viability. In paragraph 2.5 a brief overview of the suitability of RE technologies for electricity generation is given, while paragraph 2.6. discussion focuses on CSP technologies' characteristics, nature, requirements, etc. to provide a thorough understanding thereof facilitate and provide knowledge to do a Cost-benefit analysis. Paragraph 2.7's discussion focuses on identifying and discussing the determinants of economic viability in a PESTLE analysis. Paragraphs 2.8 and 2.9 discuss the applicability and use of Cost-benefit and SWOT analyses in evaluating the economic viability of CSP as RE source.

2.2 Economic viability vs financial viability

The primary objective of the study was to evaluate the economic viability of CSP technology as an RE source, using a CBA. Although sharing many similarities, economic viability and financial viability differ in significant ways. Therefore, the two concepts are distinguished below.

To determine financial viability, a financial analysis needs to be conducted, and to determine economic viability, an economic analysis needs to be conducted. A financial analysis involves an investor's perspective, which is based on market prices including taxes, tariffs, and subsidies, but excludes non-financial factors. In contrast, an economic analysis includes society's economic perspective and applies economic prices, excluding taxes, tariffs, and subsidies, to reflect the value of the project to society (Nielsen *et al*., 2016). Economic value measures both monetary and non-monetary benefits and costs to society as a whole, while market value measures the amounts that the investing market assigns to a project (Saini, 2022).

2.2.1 Financial viability

Financial viability assesses the ability of a project to generate adequate incremental cash flows to recover the financial costs without external support (Mar'ashi, 2018, Asian Development Bank, 2017:6). Financial viability is confined to individual organisations or their units. It involves a fairly

quantitative, fund-based approach and directly compares expenses and revenues to determine whether a project is profitable or not (Crespo, 2017:18). Financial viability compares benefits and costs to the enterprise or the company (Villarete, 2022).

2.2.2 Economic viability

Economic viability is achieved when the economic benefits of a project's implementation exceed the economic costs when analysed from the perspective of society as a whole. "Society" in this study refers to all the people or groups of people living in a specific country (Chakma, 2022). The term also refers to what Cole (2022) defines as a grouping of people with some active relationship with one another, often with shared characteristics, within a state or country. Pratap (2017) adds that society can be seen as a group of people involved in a persistent social interaction, or a large social grouping sharing the same geographical or social territory subject to the same political authority.

Economic viability also implies that the total costs of a project should be less than the total benefits generated by the project (Munthali, 2016). The project should be designed in such a way that the net economic benefits are sustained during the project's economic life (Asian Development Bank, 2017). An economic viable project is able to provide an overall positive net economic contribution to society after all the costs and benefits (including all social, environmental, and financial costs and benefits to society) have been accounted for (Sustainability, 2022). Thus, economic viability is achieved when a project proves to be economically feasible, innovative, and sustainable in terms of investments of financial resources in the project (Munthali, 2016). Economic viability entails more than financial considerations; it extends to a larger geographic scale, examining the national or regional implications of a project, including social and environmental factors (Sustainability, 2022).

This study evaluated the economic viability of investments (i.e., CSP projects) from a government perspective, which is different from the financial viability of investments (or projects) in the private sector. The private sector focuses on financial gains when investing in projects, while governments focus on economic gains (Villarete, 2022). This simply means that governments will evaluate projects not only in monetary terms, but also in terms of their potential to enhance the wellbeing of the country's citizens.

The CSP project evaluation conducted in this study pertained to the entire SA as a country and did not focus on a single company, attempting to determine whether the project is profitable or not. The below descriptions of economic viability are based on a broader view of projects from a government and country point of view.

Economic viability is carried out from the perspective of the economy as a whole and assesses the overall impact of the project on the wellbeing of all citizens. The ultimate purpose is to assess whether a project is economically viable for the country (Mar'ashi, 2018). Although both financial viability and economic viability strive to determine the costs incurred and the resulting benefits of a project, economic viability further considers the viewpoint of stakeholders and how the result of a project aligns with the broader economic and social policies of a country (Oman Essay, 2020).

The World Bank (2022b) clarifies that the economic costs of a project are different from the financial costs. Economic costs are broader and include other positive and negative factors such as environmental impacts. Deng *et al*. (2022:1) emphasise the sustainability of a project. They define sustainability as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. They identify three dimensions of sustainability, namely looking after the environment, the economy, and society (Deng *et al*., 2022:1).

Technology, policy, and regulatory aspects also play a crucial role in the evaluation of the economic viability of a project or investment (Dranka *et al*., 2020:1). Table 2.1 below provides a summary of the main differences between economic viability and financial viability. (The PESTLE analysis and its relevance to economic viability is discussed in detail in paragraph 2.3 after the table).

Table 2.1 – Differences between financial viability and economic viability

Financial viability	**Economic viability**
Focuses on investor's perspective	Focuses on society's perspective
Based on market prices	Based on economic prices
Includes taxes, tariffs, and subsidies	Excludes taxes, tariffs, and subsidies
Reflects the value of a project for a single organisation or entity	Reflects the value of a project for society
Only focuses on economic factors of a PESTLE analysis	Focuses on all factors of a PESTLE analysis, namely Political, Economic, Social, Technological, Legal, and Environmental

2.3 Economic viability and PESTLE analysis

When assessing the economic viability of projects, it is crucial to consider all Political, Economic, Social, Technological, Legal and Environmental (PESTLE) factors, since the main focus is on society rather than on a single entity/organisation or investor. A PESTLE analysis is suitable to assess the economic viability of CSP projects mainly because it covers all the relevant factors.

Therefore, this study applied a PESTLE analysis to assess CSP's economic viability (Reding, 2021).

When used as a framework to evaluate projects, a PESTLE analysis enhances the ability of organisations to investigate the external environment within which it operates (Bismark & Kofi, 2018:97; Peterdy, 2023). A PESTLE analysis also assists in project prioritisation since it can determine whether a project will bring more benefits to society. Furthermore, it provides consistency in high level strategic analysis (Casan *et al*., 2021:5).

The implementation of CSP technologies in SA is aimed at resolving energy shortages for society as a whole and this study assessed the economic viability of CSP at a country level and not for a specific organisation. A PESTLE analysis, being a framework analysis, monitors the macro-environment that has an impact on CSP technology deployment (European Union, 2020:6). According to Singh *et al*. (2021:2), macro-environmental factors are elements that have an impact on an organisation but are beyond the organisation's control. Macro-environmental factors consist of broad environmental elements that exert a substantial impact on almost all organisations and influence the success or failure of their strategies (Mbithi *et al*., 2017). The PESTLE analysis is a great tool for analysing the macro-environmental factors because it involves a broad assessment of the key features of the external environment in which organisations operate (IBISworld, 2020:2; Mbithi *et al*., 2017:197). External factors, as explained by Khalid and Rahman (2019:247), refer to factors outside the organisation's control which are hard to identify but can generate effects that cannot be easily remedied without significant losses. Understanding the effects of external factors is key for every nation to manage risk, control outflow of funds, exploit and benefit from available opportunities (Khalid & Rahman, 2019:247).

CSP is described in this study as a "project" because it involves a series of activities and resources aimed to achieve a certain output, i.e., the ability to provide electricity (Bahadur, 2020). A project, as defined by Siles (2023:1), is a temporary process with a clearly defined start and end date and encompasses a set of tasks and a budget to accomplish a well-defined goal or objective. To further justify the view of CSP plants as a project, the researcher noted that the latest CSP plant construction underway at the time of the study, is known as the "Redstone project". Construction started in 2021 and the planned completion date is towards the end of 2023 (Energy Capital & Power, 2022). The goal of the Redstone project is to provide 480 000 MWh of electricity per annum to 210 000 households and create 2 000 temporary jobs during construction and 100 permanent jobs during operations (Energy Capital & Power, 2022).

From the above, it is clear that CSP technology construction indeed fits the definition of a project, since it is an endeavour that is needed to produce a unique outcome or result at a specified time

using pre-determined resources (Bahadur, 2020:1). CSP projects include scope, timelines, required standard quality and resource utilisation, all of which are aspects in line with normal standard project attributes (Guinan, 2023). Project goals are also expected to be linked to anticipated or desired outcomes in society. This is the case with the Redstone project, which is expected to offset 440 000 tons of GHG emissions (Labuschagne, 2021). Another example is Kathu Solar, a 100 MWh CSP project completed in 2015. It currently generates 330 000 MWh per annum, supplies electricity to 80 000 households and offsets 315 000 tons of GHG emissions per annum. It created 4 500 temporary jobs during construction and 90 permanent jobs during operations, and has the capacity to store energy for three hours to continue generating electricity even after sunset (Energy Capital & Power, 2022).

As mentioned earlier, the assessment of economic viability takes on a broader view than that of financial viability. A PESTLE analysis also takes a broader view of macro-economic factors. This facilitates the understanding of a wider environment and encourages the development of the external and strategic considerations of a project (Casan *et al*., 2021:5; CIPD, 2021). However, Pathak (2020) warns that scholars should be aware of the main risk associated with using a PESTLE analysis, which works on assumptions that might not always be accurate. Figure 2.1 below shows an overview of a PESTLE diagram as depicted by IBISworld (2020:2).

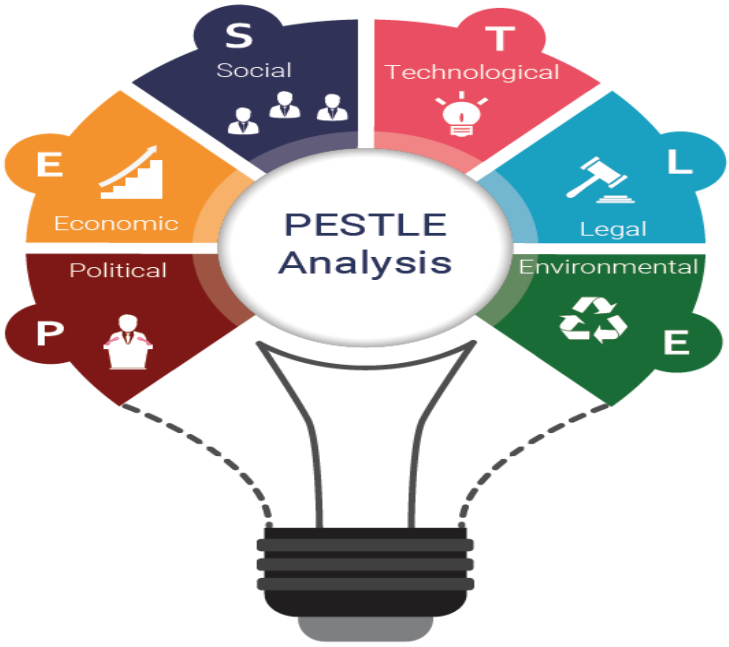

Figure 2.1 – Summary of a PESTLE analysis model
Source: IBISworld (2020:2)

2.4 PESTLE analysis – an outline and determinants of economic viability

This paragraph will further explore economic viability by drawing on the discussion in paragraph 2.2.1. The focus is on the factors that actually determine economic viability from an economic and financial perspective using the six factors of the PESTLE analysis, namely: Political, Economic, Social, Technological, Legal and Environmental factors.

2.4.1 Political factors

Political factors include the way that societies choose different policies to achieve certain desired outcomes through elected individuals who have influence in a country's decision-making structure (Pathak, 2020). Political factors refer to how and to what extent a government intervenes in the economy or a certain industry in the form of policies, political stability or instability, corruption, foreign trade policy, tax policy, labour law, environmental law and trade restrictions, reform, and tariffs (Lewin, 2022). Governments can impact an economy through legislation and policies or through political stability and the status of relations with other nations (Indeed, 2022). In essence, political factors include the political situation of a country, the world in relation to the country (Shatskaya *et al.*, 2016:47), as well as geopolitics. The latter concept is defined by Casan *et al*. (2021:8) as the power between different states and international treaties that may affect or are affected by choices of new technology.

Political factors can have a huge impact on a project's performance, for example, political changes, war, bureaucracy, lack of funding, fraud and bribery, policy changes, and regulations such as tax policies, fiscal policies, and trade tariffs (Khalid & Rahman, 2019:248). Alanzi (2022:12) adds other influences such as government pressure from opposition parties and perpetual government conflict.

Renewable energy transition from fossil fuels has been identified by Burke and Stephens (2017:3) as a political struggle and cannot be effective without confronting and destabilising dominant systems of energy power. Political factors are the main drivers of policy formulation and contribute substantially to RE investment considerations (Ndlovu & Telekdarie, 2020:189). Policy stability is crucial for any country and is the main reason why nations worldwide are failing to reach the long-term energy targets they pledged in the Paris Agreement (Ndlovu & Telekdarie, 2020:189).

The SA government has formulated policies and implemented programmes to address the energy crisis through the IRP, from which the IPP office was established to procure electricity from IPPs (MSSRF, 2017:12). President Cyril Ramaphosa has also shown support for RE towards addressing climate change. He emphasised that climate change is an existential challenge and that our country is committed to play a part in reducing global emissions (Molele, 2021; Wadula, 2021). The commitment from the president shows SA's government's interest towards clean

energy. Furthermore, during the COP conference held from 31 October 2021 to 12 November 2021 in Glascow, Scotland, SA managed to secure about R131 billion in pledges by the European Union, France, Germand and the United States of America to assist SA in its transitioning process from generating electricity primarily from coal to generating electricity using RETs.

The government's commitment and the policies and programmes put into place are crucial political factors that determine economic viability (DE, 2019b:36). However, the regulatory framework has become a risk for SA in terms of enforcing and accelerating RE projects. This is evident in other projects that have encountered delays of more than five months, which has adversely affected investor confidence (Ndlovu & Telekdarie, 2020). But despite the growing sense of urgency in energy transition, the deployment of CSP technologies has been frustrated by democratic procedures (Burke & Stephens, 2017:189). Sung and Song (2021:1) also indicate that most firms are discouraged from investing in new CSP technologies due to the government's failure to implement policies and programmes that are supposed to minimise technological and market uncertainty.

Besides its pledge to the Paris Agreement, the SA government's NDP has introduced an IRP to address the energy capacity challenges. For these purposes, the IPP office was established to implement the REIPPPP (DE, 2019b:8). These commitments by the government play a crucial role in the economic viability of CSP projects since most investors will only be interested in projects that will quickly yield their Return on Investment (ROI). The choice of technology should be balanced to ensure alignment to the government's commitment to the Paris Agreement to help reduce global temperatures by 1.5 degrees Celsius.

In 2020, the government established an initiative called Operation Vulindlela with the aim to drive structural reform and improve economic growth, enable investment, and create jobs (DNT, 2022:1). The African Development Bank Group (2013:9) defines structural reforms as an action by the government targeting economic policy instruments designed to effect changes in the behaviours of the public and/or private economic agents. The aim of such action is to either boost their sustainable and non-inflationary demand addressed to the national economy or increase their productive investments to achieve national economic growth and employment creation targets.

One of the key objectives of Operation Vulindlela is the stabilisation of the electricity supply (DNT, 2022:1). The SA government has indeed increased the threshold for electricity generation licences from 1 MWh to 100 MWh. This means that private entities can generate up to 100 MWh of electricity without a generation licence (DE, 2021:6). Clearly, structural reform constitutes a key aspect within political factors to improve the economic viability of the implementation of CSP

technology. However, if such reform is not implemented, delays will be created in unleashing the potential of CSP in the country.

As mentioned by Aprà *et al*. (2021:385), CSP technology currently faces political challenges, which can have a huge impact on its economic viability as a RE source. It is still not clear whether the latest IRP document, being revised at the time of this research, will include CSP projects beyond 2030. There is also uncertainty as to which political party will be victorious in the 2024 national elections, which will likely change the IRP direction completely (Cilliers, 2022).

Political factors affect governments' ability to provide fair access to energy, maintain the quality of ecological systems, and change attitudes about energy consumption towards prioritising conservation and sufficiency (Burke & Stephens, 2017:2). Governments should also be transparent in processes which call for those communities that have been previously marginalised from the energy sector to be included in new energy strategies (Baker, 2016:1; Szulecki & Overland, 2020:1). For RETs to be economically viable, fair distribution of energy should be imperative. This is evident in the IPP programme where 30% of project valuation focuses on economic development and 70% focuses on price.

2.4.2 Economic factors

Economic factors in general are those elements that affect the fundamental activities of the economy or market. These factors, in turn, influence a country's economic growth and development, as well as the performance of businesses operating within that country (StockMaster, 2022). Economic factors, as defined by Tanner (2021), are the natural resources and skilled manpower that can influence a country's ability to build its economy. Woodruff (2019) adds physical capital and technology, as generally agreed by most economists, as two other important economic factors.

Economic factors are determinants of economic performance that directly impacts an organisation or a country and have resonating long term effects (European Union, 2020:6). Broadly speaking, these factors comprise the state of economy, goods, services, finance, as well as geographic elements influencing the economic environment (IBISworld, 2020:4). Pereira (2023) gives a simplified definition, namely that economic factors are elements that have an impact on the economic conditions on organisations or countries. Vasileva (2018:224) refers to economic factors as the state of the macro-economic environment. Economic factors include economic growth or decline, interest rates, foreign exchange rates, inflation and wage rates, minimum wage, working hours, unemployment rates, credit availability, costs of living, and cost of renewables (Pathak, 2020). According to Srivastav (2023), other factors that can influence the economy are, for instance, interest rates, tax rates, laws, policies, wages, and governmental activities.

The macro-economic environment under economic factors reflects the ability of the government and private sector to support and invest in the development of CSP projects (Lennox *et al*., 2019:3). High interest rates and inflation mean that investors will be discouraged to invest in such projects since there is a high probability that they will not make reasonable returns (Lennox *et al*., 2019:19). Economic factors under RE projects also pertain to the traditional financial viability techniques, called capital budgeting techniques, when evaluating projects (which are explained in detail later in this paragraph) (Demirtas *et al*., 2021:36277).

The main measure of the economy of a country is economic growth, which is the increase in the production of goods and services (Ackerman, 2022). Economic growth is actually the increase in the long-term capability of a country to produce more economic goods to people, as well as the ability to keep up with technological advances (Muthalib, 2017:125). The increase in goods and services is measured by a country's GDP, which is the market value of goods and services produced (Stone, 2017). For a country to keep up with the production of goods and services, its energy availability plays a critical role in productivity growth (Stone, 2017).

Investors in projects rely heavily on the analysis of economic factors to make informed investment decisions, which allows them to know where to invest for optimum returns (StockMaster, 2022). The IMF (2017:3) also notes that governments play a crucial role in economic factors through policy formulation and support to business activities, for example, by subsidising RE projects including CSP. Srivastav (2023) conducted a study on the five main economic factors that have an impact on a country's development, namely education and training, natural resources, power and energy resources, transportation, and communication. Tanner (2021) adds three more factors: capital accumulation, technological resources, and available labour force.

In brief, with regard to economic factors, the economic viability of CSP depends on the ability of the technology to be able to generate electricity when needed and to exert a positive impact on the country's economic growth. Economic growth is explained in detail in the next paragraph.

As simplified by Boldeanu and Constantinescu (2015:330), economic growth is characterised by an increase in a country's GDP, reflecting, in turn, an increase in the national product when measured in constant prices. The determinants of economic growth typically include human resources, natural resources, capital formation, and technological advancement. Constrain in energy production pulls back economic growth, which has been the case since the dawn of the Industrial Revolution (Sharma *et al*., 2019). Studies have shown that RE, which includes CSP technologies, has a positive net employment effect. For example, in 2015, 8.1 million people were employed through RE projects globally (Maradin *et al.,* 2017). SA's economic growth has also been hampered by the electricity crisis and experienced an increased unemployment rate of

33.9% in quarter 2 of 2022 (Stats SA, 2022). The unemployment rate also becomes a key in measuring the economic viability of RETs from a government perspective.

For CSP project evaluation, the traditional financial methodologies, which Drury (2018:312) calls capital investment appraisal methods, are typically used, although many investors seem to prefer two other methodologies, i.e., the Levelised Cost of Electricity/Energy (LCOE), and CBA. The other capital investment appraisal methods include the Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PBP), and Accounting Rate of Return (ARR) (Drury, 2018:312). The following two sections explain the four capital investment appraisal methods and the other two prominent methodologies.

2.4.2.1 Capital investment appraisal methods

(i) Net Present Value (NPV)

The NPV is the present value of cash inflows and outflows over a specified period (Cui *et al*., 2022:2929). The NPV is the present value of the net cash inflows less the project's initial investment outlay (Drury, 2018:313). Dai *et al*. (2022:187) explain that the NPV is the present value of the cash flows discounted at the required rate of return (called the discount rate) for the project compared to the initial investment. A project is accepted when the NPV is greater than zero; thus, a positive NPV indicates that a project should be accepted, and a negative NPV indicates that a project should not be accepted (Drury, 2018:313).

The NPV is a straightforward measurement to evaluate investment projects and considers the time value of money (Dai *et al*., 2022:185). The benefit of NPV is precisely its consideration of the time value of money, as well as of the risks and costs in the calculation, all of which gives investors a basic idea of how much money they can gain in total (Dai *et al*., 2022:186).

The disadvantages of NPV include that both cash flows and the required rate of return are assumed to be fixed, which might not be the case in real life (Liang *et al*., 2022:188). The NPV also ignores the size of the project (size of investment) and cannot indicate investors how long they must wait on average until they can make profit (Dai *et al*., 2022:188). The NPV has been popular in evaluating investments in general, but it is not beneficial to use in long-term projects like CSP when measuring economic viability (Barakat *et al*., 2016).

On average, CSP projects yield positive NPV's (Torres *et al.*, 2021:587; Yasin & Draidi, 2020:256).

(ii) Internal Rate of Return (IRR)

The IRR (also referred to as the marginal efficiency capital or yield on the investment) is a calculation of the discount factor (or discount rate) yielding a NPV equal to zero (Huang *et al*., 2022:74). This means that when the future cash flows of a project are discounted using the IRR, the present value of cash outflows equals the present value of cash inflows, representing the actual return of the project (Barakat *et al*., 2016:4). Alternatively, the IRR can be described as the maximum cost of capital that can be applied to finance a project without negatively impacting the shareholders (Drury, 2018:316). In essence, a project is accepted when the IRR exceeds the company's required rate of return.

The IRR uses relative values rather than absolute values and considers the time value of money. However, Liang *et al*. (2022) state that IRR does not take the size of the investment into account and is not suitable to compare mutually exclusive projects' return, where a decision to invest in an alternative, excludes any possible investment/s in other alternatives. Another disadvantage of the IRR is its assumption that positive cash flows are re-invested at the IRR rate, which is not normally the case in real life (Huang *et al*., 2022:74).

On average, CSP projects' IRR have surpassed the global average IRR benchmark of 10% (Torres *et al.*, 2021:587; Yasin & Draidi, 2020:256).

(iii) The Payback Period (PBP)

The PBP is an indicator that aims to express the number of years (or part thereof) required to recover the investment in a project. As simplified by Barakat *et al*. (2016:4), the PBP is the number of years it will take for the gross value of the cash inflows and the cash outflows to be equal. PBP is actually the length of time that is required for a stream of cash proceeds (net cash inflows) from an investment to recover the original cash layout required by the investment (Drury, 2018:321). The PBP measures how long investors will need to wait until they recovered their initial capital layout or investment (Dai *et al*., 2022:186).

The main disadvantage of the PBP when compared to the NPV and the IRR, is that it does not consider the time value of money, nor cash flows after the PBP (Liang *et al*., 2022:189).

CSP projects showed potential to reduce its average PBP from an average of 18 years to as low as an average of 7.5 years (Torres *et al.*, 2021:587; Yasin & Draidi, 2020:256).

(iv) Accounting Rate of Return (ARR)

The ARR (also known as the Return on Investment (ROI) or Return on Capital) is calculated by dividing the average annual profits from a project into the average investment costs and is

expressed as an annual percentage (Drury, 2018:325). Unlike the other appraisal methods, the ARR does not consider the cash flow generated by a project but focuses on the net income that a project will provide. Consequently, the ARR can be helpful to investors and lenders (Henricks, 2023). The ARR is a simple and quick way to examine a proposed investment to see whether it meets a business's set standard for minimum required return (Henricks, 2023). The main disadvantage of the ARR is that it ignores the time value of money and does not consider the increased risk of long-term projects (Drury, 2018:325).

2.4.2.2 Other prominent methodologies

(i) Levelised Cost of Electricity/Energy (LCOE)

The LCOE is the average total costs of building and operating the asset per unit of total electricity generated over an assumed lifetime (CFI, 2022). The LCOE determines whether the project can break even or be profitable. If not, investors will normally not be interested in investing in that generating power asset (CFI, 2022). LCOE can also be regarded as the minimum cost at which electricity must be sold in order to achieve break-even over the lifetime of the project (Lai & McCulloch, 2017:2). The main aim of LCOE is to give a comparison of different technologies of unequal lifespan, project size, different capital costs, risk, return, and capacities (Lai & McCulloch, 2017:2).

LCOE is preferred for the financial evaluation of energy projects above the traditional capital investment appraisal methods (discussed above) due to the LCOE's ability to measure the average cost in rand per kWh of electricity generated by the system (Aussel, 2018:494). The present value methods such as NPV and IRR normally penalise projects with a longer lifecycle whereas LCOE tries to overcome the longer lifecycle challenge (Barakat *et al*., 2016:4). LCOE is also used to provide an indication of the competitiveness of the electricity generation of a given technology. LCOE has been widely accepted as a measure of the comparative lifetime costs of electricity generation alternatives (Aldersey-Williams & Rubert, 2019:169). Governments rely on LCOE for evaluating policy decisions in relation to differential support between carbon-based and renewable electricity generation (Aldersey-Williams & Rubert, 2019:169), while investors have lauded LCOE for its ability to measure the economic competitiveness of different power generation technologies (Mai *et al*., 2021:1).

Although it reflects the total costs and the amount of electricity generated, LCOE does not consider the monetary value of that energy to the system, which varies by location and time (Mai *et al*., 2021:1). Shah (2020:1) argues that LCOE does not consider all costs associated with an actual financial decision and overlooks project risk. In addition, with LCOE, it is difficult to accurately represent distributed systems, which means that LCOE can sometimes be higher for a smaller system which powers a more efficient but small project (Shah, 2020:1). Timilsina

(2020:5) concurs by stating that LCOE has some limitations when it comes to calculating the unit cost of intermittent and non-dispatchable RETs such as wind, PV and CSP.

(ii) Cost-Benefit Analysis (CBA)

The Cost-benefit analysis is discussed in in paragraph 2.8.

2.4.3 Social factors

In a PESTLE analysis, consideration should be given to social factors that affect the community within the area in which the project is implemented (Matovic, 2020). The three basic social factors are summarised by Lindmark and Lian (2021) as demographics, wealth distribution, and changing cultural attitudes.

Social factors involve the relationship between social behaviour and economics, exploring how economic activities affect social behaviour and how the economy of a country is shaped by social trends and patterns (Gordon, 2022). Social factors pertain to the social environment of a country and include cultural trends, demographics, and population analytics by looking at family structures, level of engagement in communities, acceptance of new technologies, tourism, as well as stakeholder impact (European Union, 2020:6). Social factors also involve activities by individuals or companies in their pursuit of social advancement and improvement of human life by focusing on culture, politics, technologies, and social relations (Hellmich, 2015:4).

Based on these definitions in the context of this study, any energy transition will definitely have an impact on social factors. Therefore, it is crucial to consider these factors when assessing the economic viability of CSP technologies with the aim to transition to other energy sources. South Africa's energy production is dominated by coal, as mentioned previously. However, this does not mean that the country can simply switch to RE without considering, for example, the employees of coal mines and coal power plants. To address the climate change issue, countries must transform their current carbon intensive energy systems into decarbonised systems (Garcia-Casals *et al*., 2019:1). Social factors, as further articulated by Garcia-Casals *et al*. (2019:7), include employment, impact on GDP, and human welfare, as well as economic value creation, improved livelihoods, gender equity, health, education, and reduced GHGs (IRENA, 2017:1).

The discussion below is a summary of the most crucial social factors within a South African context, namely:

(i) Combating poverty and unemployment

Deployment of RETs comes with different challenges that need to be considered for economic viability. A poor energy transition strategy for SA might leave several people unemployed, leading

to excessive poverty for most SA citizens. The country's unemployment rate was 33.9% in the second quarter of 2022, with youth unemployment at 46.5% in the same quarter (Stats SA, 2022).

IRENA (2017:1) argues, though, that countries with the most effective energy transition strategies have demonstrated that the RET's benefits in pursuing the commitments made during 2015 to the Paris Agreement, outweigh its costs as well as the potential consequences of continuing with traditional electricity generation technologies (e.g., fossil fuel plants).

The deployment and implementation of RE technologies has led to the global employment of 8.3 million people (IRENA, 2017:4).

Deployment and implementation of CSP technologies in SA have created both permanent and temporary employment for community members within the are CSP plants, contributing to the improvement of standard of living (IPP Office, 2023:18, Kumar, 2019).

(ii) Improvement of education and skills

Some RE technologies are new and require employees to develop and learn new skills. The more complex the technology, the more difficult it will be to determine economic viability since investors will pursue simple technologies that provide better returns in a short period of time. This means that SA's government will need strong policies that support such technologies in order to maintain stability of the grid. RETs include different types of technologies, while its deployment proves to diversify and improve the skills of a country's labour force, ultimately boosting industrial development and community and social development society (IRENA, 2017:2).

(iii) Establishing equality in SA's population

Global RE deployment has been criticised for having fewer women employed compared to the traditional energy technologies (World Bank, 2022a). A study by the World Bank (2022a) found that SA is the most unequal country in the world with 10% of the population owning more than 80% of the wealth.

SA's policies also play a role in energy transition. Decisions made should be gender neutral and aim towards establishing an equitable energy system, otherwise it might have significant implications on women's empowerment and the level of equality between men and women (Prebble & Roth, 2017).

(iv) Community development

Another aspect to consider is the requirements to obtain electricity generation licenses and obtaining access to RE resources and technologies. These requirements compel project

companies to (i) allocate 1% of annual generated revenue to social development projects, (ii) another 1% of annual generated revenue to black owned enterprise development, and (iii) yet another 8% shareholding being allocated to the establishment of a community trust. As a shareholder of the company, the community trust will earn dividends. These dividends should then be efficiently managed and utilised by the community trust's trustees to benefit the local community by e.g., skills development and to provide opportunities to improve qualifications by availing bursaries to local community members (IPP Office, 2023:18). The Redstone project, which is currently under construction and planned for commercial operations later in 2023, is set to supply clean and reliable electricity to about 210 000 SA households (Acwa Power, 2021). The Redstone project will also offset about 440 000 tons of carbon dioxide emissions, which brings significant health benefits since carbon dioxide is responsible for 60% of GHG emissions (Acwa Power, 2021; Moyo *et al*., 2017:6).

2.4.4 Technological factors

Technology is defined as a device, component of a device or process that is dedicated to the production, storage, and distribution of energy (IEA, 2020). Technological factors include the availability of infrastructure for the necessary support of modern systems (Matovic, 2020:97). The support of modern systems should consider the level of technological development, innovation, amortisation, level of equipment flexibility, automation level, and the rate of technological changes (Matovic, 2020:97). Alanzi (2022:13) notes that technological factors should consider government spending and Research and Development (R&D), adoption of new technologies, and the obsolescence of existing technologies.

For purposes of this study, it is crucial to understand that RE systems sources energy from natural resources such as sunlight and wind (Peter & Mbowa, 2019:1284). The use of these technologies is expected to create higher efficiencies and market competitiveness within organisations and is seen as essential for organisational progress and productivity (Raza *et al*., 2020:574). Technological advancement is also one of the most effective techniques for sustained long-term development (Solarin *et al*., 2022:3).

For RETs to be economically viable, it is critical that technological aspects for each be considered, which include the application, performance or efficiency, and user friendliness of the technology as well as the costs of deploying a specific technology (IEA, 2020:20). Kariuki (2018:2) indicates that technologies often fail due to an overemphasis on hardware while ignoring the complex mix of interconnected social, institutional, economic, and policy issues that can impede success. According to Kariuki (2018:2), technological success is primarily linked to social factors rather than to the technology itself. The rush among RE investors to embrace PV and wind technologies

for swift returns has been observed, while they tend to overlook CSP technologies, which offer distinctive storage systems compared to other RETs (Kariuki, 2018:4).

The main reason for the unbalanced selection of RETs in SA can be attributed to the unstable and inconsistent investment and regulatory framework. The Presidential Economic Advisory Council (PEAC, 2020:3) states that government policies need to reward investments in low carbon innovation technologies. The current regulations, which allow the energy minister to decide which technologies in the IRP document can be pursued, are considered to resemble micromanagement. The impact of the current regulations hampers a better understanding of the economic viability of RE, specifically in terms of achieving a balanced national grid with a well-balanced mix of technologies that complement one another instead of competing. The delays in RETs implementation have already been noted where Eskom, as the SoE and the only entity allowed in terms of the ERA 34 of 2006 to procure electricity generated by IPP's, refused to sign Power Purchase Agreements (PPAs) in 2015, resulting in a wind farm being closed in the Eastern Cape and a solar PV plant in KwaZulu-Natal.

RETs are remarkably diverse and have unique characteristics that can be differentiated by their inherent variability and dispatchability (United Nations, 2015). This study placed a particular focus on comparing CSP and PV technologies since they are the only RETs capable of harnessing solar energy (Mahlangu & Tholip, 2018).

(i) CSP technologies

CSP technologies use mirrors to absorb heat, called Direct Normal Irradiation (DNI), depending on which technology is used (CIF, 2021:4). CSP generates electricity by collecting solar radiation and concentrating it into a small area to generate very high temperatures (SEA, 2017:281). CSP uses mirrors to concentrate and reflect sunlight onto receivers, converting solar energy into thermal energy (Chen *et al*., 2020:2). This concentrated heat from the sun is reflected towards a tube or receiver carrying liquid, such as thermal oil, molten salt, or water. The intense heat produced by the reflection from the mirrors raises the temperature of this liquid to levels sufficient to drive a conventional turbine, ultimately generating electricity (Pitz-Paal, 2018:5). During the day, the heat can be used to generate steam to, in turn, generate electricity and, at the same time, store the heat to be used to generate electricity at night or when there is no sun (CIF, 2021:4).

CSP technology is the most flexible technology when compared to the other RETs mostly due to its ability to store heat and continue to generate electricity after sunset. In contrast, solar PV technology can only generate electricity during the day, and wind technology can only generate electricity when there is wind (Chen *et al.*, 2021:2).

(ii) PV technologies

Suarez (2021b) defines PV as the direct conversion of light into electricity. In this process, solar PV cells absorb light, which knocks electrons out of the cells. Once the loose electrons flow, a current is created, which is captured and transferred into wires, thus generating a direct electric current which is converted into alternating current and distributed into the power network (Suarez, 2021b). PV devices are capable of converting light into electricity and are mostly fabricated from semi-conducting materials, in this case, silicon (Peter & Mbohwa, 2019:1284).

PV systems come in different forms, but consist of two main components, namely a solar module which converts sunlight into electricity, and the balance of systems such as wiring, inverters, mounting structures, battery, and metering (Moyo *et al*., 2017:3). PV relies on the photoelectric effect to generate direct current electricity, utilising solar global horizontal irradiation (Schöniger *et al*., 2021:59). Direct current power then needs to be converted through an inverter into alternating current electricity in a second conversion step (Schöniger *et al*., 2021:59). Battery storage can be integrated before or after the solar inverter and stores the energy in the form of chemical energy. The inverter functions much like a turbine in the case of a CSP plant.

From the above description of PV and CSP, the conclusion can be drawn that the main feature distinguishing these two technologies is that PV uses sunlight and CSP uses the energy from the sun. CSP also has an advantage over PV in its ability to store the energy for use after sunset or when needed to stabilise the grid. PV, on the other hand, cannot store sunlight or solar energy, although there are ongoing developments in storing the electricity in batteries. However, this technology is still in its early stages and tends to be more expensive, especially for storing electricity for longer hours.

Based on the above definitions, the main aspects of PV and CSP technologies that contribute to their economic viability are intermittency, dispatchability, variability, scalability, and energy storage (Tran & Smith, 2017). These aspects are explained below, according to Tran and Smith (2017).

2.4.4.1 Intermittency

Intermittency is defined as unplanned variations in power generated by wind or solar due to changes in weather patterns (Energy Centre, 2018:6). Intermittency is caused by the unpredictability of weather events like cloud formation (Pommeret & Schubert, 2019:2). One example is solar generators that can only generate electricity when the sun shines (Gowrisankaran *et al.*, 2016).

RETs draw power from natural resources and can be affected by environmental, seasonal, and daily cycles which limit their use or efficiency (EnergyX, 2022). Electricity generation technologies where the grid operator has greater temporal control are categorised as dispatchable, while those that vary significantly due to environmental, seasonal, and daily cycle factors are categorised as intermittent (Yang, 2020:2).

These definitions clearly show that the intermittent challenges of PV and CSP technologies have been the main disadvantage of these types of technologies which can only generate electricity when the sun shines.

2.4.4.2 Dispatchability

Dispatchable generation is the type of electricity generation that can be distributed based on electricity demand. It offers high flexibility in terms of load matching and peak matching on short notice, making it useful for covering intermittent RE sources during periods of high demand. Dispatchable electricity generation assist in meeting high electricity demand due to the ability to supply electricity to the grid as and when required resulting to grid stability High electricity demand means that dispatchable generation can provide stability in the grid.

Non-dispatchable generation is the opposite of dispatchable generation. These sources of electricity generation take more time to respond and cannot be dispatched at a moment's notice. They are referred to as intermittent due to their dependence on external weather conditions. Wind, PV, and CSP technologies fall in this category.

In summary, dispatchability plays a crucial role in exploring options towards a balanced mix of technologies that can support each other, ensuring security and sustainability of the grid.

2.4.4.3 Variability

IRENA (2019:8) defines variability as the fluctuating nature of solar resources, which translates into potentially rapid changes in electricity output. It is crucial for the grid to be flexible; in other words, the grid should be able to cope with the variability and uncertainty that wind and solar energy introduce at different timescales and ensure reliable supply to all energy demands (IRENA, 2019:8). Solar energy is inherently variable on small timescales due to atmospheric conditions, meaning that clouds can reduce solar power generation and light.

When assessing the economic viability of RETs, the integrity of the grid to be able to cope with the variability aspect is vital to each technology chosen and it is important for government to provide more support in a balanced approach to encourage investors to fund different RETs.

Challenges with regard to variability also imply that there is a need for storage and refurbishment of existing electricity infrastructure.

2.4.4.4 Scalability

Scalability means that the deployment of RETs can start on a small scale and grow, without the need for a complete replacement of the available infrastructure (Energy21, 2018). The performance of RETs depends mostly on the size of the power plant, and emerging RETs are often developed at small scale before they are adopted into the market. Scalability can determine the feasibility of a technology for large scale-ups. If a scale-up prove to be difficult, the technology will not be feasible for larger and more profitable power stations. Investors tend to be discouraged when there is uncertainty regarding the amount of electricity to be generated or the economic returns that can be realised.

2.4.4.5 Energy storage

Energy storage technologies involve the process of converting energy that is difficult to store to storage forms that are more convenient or economical (Barath *et al*., 2015:749). A variety of storage systems are available, and their efficiency mostly depends on certain parameters such as storage capacity, cost, reliability, size, and lifetime, as well as environmental impact (Barath *et al*., 2015). As SA is introducing intermittent RETs, it can lead to reliability challenges in its electricity systems and, consequently, a mismatch between RE electricity production and electricity demand, causing periods of over or under generation. Under generation usually leads to an energy deficit unless balancing solutions are employed. This will require diverse investment in the energy infrastructure, and both short- and long-term storage applications can be part of the energy portfolio. Silinga *et al*. (2016:4) indicate that PV plant technologies are more cost effective for storing energy up to four hours, while CSP technologies can effectively store energy for more than four hours.

In the light of the above aspects of intermittency, dispatchability, variability, scalability, and energy storage, it is clear that CSP plants are unique with regard to its ability to store energy for usage when there is no sun. CSP provides a relatively continuous source of electricity when compared to PV which provides intermittent supplies (Brunel, 2021). PV technologies struggle to store energy due to the way they utilise sunlight, whereas CSP uses energy, making it more suitable for energy storage and efficiency (Brunel, 2021). For PV technologies, storing electricity in batteries, for example, is also not easy, especially at large power cells (Suarez, 2021b). As explained by Suarez (2021b), CSP with TES capabilities can be used as a complementary solution to solve the intermittency problems of other RETs like PV. CSP has the competitive advantage over PV in its ability to flexibly dispatch electricity at large scale even when there is no DNI. This overcomes the dispatchability challenges that RETs face (Potts & Walwyn, 2020:4).

2.4.5 Legal factors

In a PESTLE analysis, legal factors consider all regulatory aspects in the industry within which a project is built, namely regulation, licensing, and permits required to operate, as well as employment laws and regulations (Peterdy, 2023).

Legal factors are established rules, regulations, and principles of a country through which government passes and enacts various legislative acts to ensure the wellbeing of the economy, protection of assets, and individual rights (Ansah, 2016:769). Legal factors on energy can also include planning, access to resources, grid access, ownership models, and local benefit frameworks (European Union, 2020:6). The laws passed by government can be related to taxation, employment, imports and exports, consumers, environment, licensing, natural resources usage, and energy management (Matovic, 2020:97). Clearly, current legislation, or changes in existing legislation, can have a huge impact on the deployment of new CSP projects (Casan *et al.*, 2021:8).

Non-regulation of the deployment of electricity generation technology leads to investors funding projects that are more profitable in the short term, prioritising monetary gain, while ignoring other crucial factors that cannot be easily quantified (Mauger & Barnard, 2018:3). For the purposes of this research, it is essential that the energy legislation within the SA context is explained. Behr (2019:1-8) breaks down SA legislation policy and framework, explained in detail below.

South African laws and regulations are embedded in the Constitution of the Republic of South Africa 1996 which, as stated in Section 2 of the Constitution of the Republic of South Africa 1996, is regarded as the supreme law of the republic. Section 24 of the Constitution further states that:

> Everyone has the right to:
> - an environment which is not harmful to their health or well-being
> - have the environment protected for the benefit of present and future generations through reasonable legislative and other measures that:
>   - prevent pollution and ecological degradation
>   - promote conservation
>   - secure ecologically sustainable development and use of natural resources, while promoting justifiable economic and social development.

South African energy policies are derived from The White Paper on the Energy Policy of the Republic of South Africa (DME, 1998) published in 1998 of which the main focus was:

- To increase access to affordable energy services,

- To improve energy governance,
- To stimulate economic growth,
- To manage energy related environmental and health impacts, and
- To secure supply through diversity.

The 1998 white paper paved the way for the National Energy Act 34 of 2008 which states that the increased generation and consumption of RE will be an important contributory factor towards attaining the objective of sustainable development (Nene & Naggy, 2021:237). The primary legislation in this regard is the ERA with the objective to establish a national regulatory framework for the electricity supply industry and to establish NERSA, the custodian and enforcer of the National Electricity Regulator Framework (Le Grange, 2019).

Through legislative and other measures, the SA government has formulated the NDP which was prepared by the National Planning Commission (NPC) in 2012. The NDP indicates that, by 2030, the country will have an energy sector that promotes:

- Economic growth and development through adequate investment in energy infrastructure,
- Social equity through expanded access to energy at affordable tariffs and through targeted, sustainable subsidies for needy households, and
- Environmental sustainability through efforts to reduce pollution and mitigate the effects of climate change.

In addition to the NDP, the government also devised the Medium-Term Strategic Framework in 2014 to articulate the state's commitment towards implementing the NDP. South Africa's energy plan is based on the principles set out in the NDP in a form called the Integrated Energy Plan (IEP) and the IRP. The IEP is the overarching energy plan of which the IRP forms an integral part. The IEP provides a road map of the future energy landscape for the country, whereas the IRP focuses on the electricity supply that will allow the country to cost effectively meet the forecasted electricity demand.

In short, the IEP and the IRP are key policies guiding SA's future energy mix. Under the IRP, new generation capacity is procured through ministerial determinations issued by the energy minister. Eskom Holdings SOC Limited, as SoE, owns and controls the national transmission grid. The responsibility for distributing electricity to end users is shared between Eskom's distribution unit and various municipalities. The country's electricity tariffs are regulated by NERSA.

The government took a decision to divide the power generation capacity between Eskom and IPPs. The introduction of IPPs was aimed at reducing the funding burden on government and introducing new technologies that would diversify future electricity supply options to support SA's international commitment to address climate change. This resulted in the introduction of the

REIPPPP. In this programme, the DE is the procurer, while Eskom is the single buyer of the electricity through a single buyer office. The bidding process is organised into what is called “bid windows”. NERSA is also responsible for issuing electricity generation licences and registration for such facilities.

As mentioned by Murombo (2022:114), regardless of how crucial an RET may be for the national grid, it is the energy minister who decides which technologies to pursue. This has become evident in the IRP documents in which energy experts have raised concerns about the exclusion of CSP technologies beyond the 2030 forecast, despite their unique storage capabilities when compared to other RETs (DE, 2019b:59). Murombo (2022:102) further argues that the current RE regulations are ambiguous, discretionary, and only suit small-scale projects. Furthermore, the IRP is inadequate for creating certainty among private investors. Nene and Naggy (2021) claim that, although the energy policies promote an integrated approach to energy planning and regulation, they do not provide explicit methods to help align the current energy sectors with the distribution and generation of energy.

2.4.6 Environmental factors

In a PESTLE analysis, environmental factors pertain to changes in the physical environment or to elements that influence or shape the environment such as (i) increased incidents of extreme weather events, (ii) carbon footprint and climate change impacts, and (iii) stewardship of natural resources (Peterdy, 2023).

The term “environment” refers to the natural, physical surroundings that are shared by all living beings (Kumar, 2018:314), including airspace, water, land, plant, wildlife, and flora and fauna (Podder, 2021). The environment can be seen as an aggregation of all those economic, social, cultural, and natural conditions and facts which influence human life and living organisms (Kumar, 2018:315). Environmental factors involve the impact of changes in the natural environment which include weather, scarcity of raw material, pollution, climate change, waste control, agriculture, and sustainability practices (Shatskaya *et al.*, 2016:50). Bismark and Kofi (2018:106) add energy availability to the list of environmental factors, while Ansah (2016:769) adds geological features, air quality and ventilation, water quality, noise levels, dust, lighting, and health and safety. Josh (2016) views the environment as the conditions in which a person, animal, or plant lives or operates, which include all elements of the physical and biological world, as well as the interaction between them.

Feng *et al.* (2020:1) note that there is a close link between electricity generation and the environment since it is impossible to produce, transport, or consume energy without significant environmental intervention. The burning of fossil fuels, as elaborated by Das (2019:15), is the

main contributor to the emission of GHG, and diverse water pollution challenges are mostly associated with energy usage. It is no doubt that solar power is the future of our planet due to the depletion of non-renewable energy (Das, 2019:15). Renewable energy only contributes about 30% of global energy needs, while the rest is from oil, coal, and gases (IEA, 2022:47).

Based on the definitions above, it can be stated that energy production inevitably involves some interfering with the environment. In line with the study's objectives, the main factors to be considered when determining the economic viability of RETs are GHG, water, land, plants, and wildlife, each of which will be explained below.

(i) Greenhouse gases

Globally, countries have realised that emitting GHGs to the atmosphere through electricity generation is the main reason the planet is currently facing challenges regarding climate change (United Nations, 2015:6). In order to strengthen the global response to the threat of climate change, countries have committed through the Paris Agreement to take actions to conserve and enhance, as appropriate, sinks and reservoirs of GHG (United Nations, 2015:6).

The three main objectives of the Paris Agreement is to, firstly, hold the increase in the global average temperature to well below 2 degrees Celsius above pre-industrial levels, and pursue efforts to limit the temperature increase to 1.5 degrees Celsius. The second objective is to increase SA's ability to adapt to the adverse impacts of climate change, and to foster climate resilience and low GHG emissions development, all while safeguarding food production. The third objective is to ensure that finances flow consistently towards low GHG emissions and climate resilient development (United Nations, 2015:3).

The Paris Agreement came into force on 4 November 2016, and SA has been party to the agreement since ratification on 1 November 2016 (Steenkamp & Naudé, 2018:71). South Africa's electricity generation is dominated by coal and to ensure alignment with the Paris Agreement, any new energy technologies used to generate electricity should also minimise GHG emissions. This is why GHG should be considered when evaluating the economic viability of RE projects (Steenkamp & Naudé, 2018:71). As emphasised by Fatima *et al*. (2021:1), extensive research has indicated that RETs do indeed minimise the depletion of resources, ensuring energy sustainability and reducing GHG.

(ii) Water, plants, and wildlife

While it is important for countries to rigorously pursue their Paris Agreement commitments, they should also exercise caution and ensure that their actions are balanced. This means being mindful of not excessively using water resources and avoiding contamination of both ground and surface

water. Non-agricultural land should be cultivated effectively without occupying land used for food production through agricultural activities, and no threat should be posed to plants and wildlife. Klugmann-Radziemska (2014:107) notes that CSP technologies do use water for cooling, but the amount of water used is less than that used by traditional fossil fuel plants.

(iii) Geographic considerations

Geographic location plays a vital role in determining the availability of CSP technology, the main reason being that CSP resources are considered to be abundant in specific areas where there is high DNI. Selecting an appropriate site for renewables can be challenging since most RETs are also decentralised, unlike the traditional energy sources such as coal, nuclear, and natural gas, which are highly centralised (Union of Concerned Scientists, 2017). The greatest limitation is what the Union of Concerned Scientists (2017) calls “siting”. This involves the necessity to identify suitable locations for structures like wind turbines and solar farms on parcels of land. The process of siting involves negotiations, contracts, and permits, and building relationships with the local community, all of which can lead to increased costs and project delays.

CSP plants are criticised for occupying too much land area when compared to conventional power plants. However, the advantage is that CSP plants are constructed in remote rural areas with lower population (Gross, 2020:1). The Northern Cape is the largest SA province by area, but the smallest by population, which makes it a perfect area for CSP development (Forlano, 2020). In addition, the Northern Cape has one of the highest DNI radiation levels in the world, ultimately favouring CSP development (Global Africa Network, 2017; HelioSCSP, 2020).

Another geographic limitation is the availability of the transmission lines and infrastructure needed to transfer electricity from where it is generated to where consumption takes place.

2.5 General perspectives on the suitability of renewable technologies for electricity generation

This section provides a comprehensive understanding of the suitability of CSP technologies in an SA context, which is part of the first secondary objective of the study. The generic view will assist in composing a general model for determining the economic viability of CSP technologies, which is explained in detail below.

South Africa is located on the southern tip of the African continent which endows the country with a substantial amount of sunlight, providing enough opportunities for CSP development (Akinbani *et al.*, 2021:5078). South Africa receives about 2 500 hours of sunshine per year, placing it among the top three countries in the world with the highest radiation levels (Jain & Jain, 2017:721). These

high radiation levels present opportunities for RE implementation (Jain & Jain, 2017:721). In addition, most of the country's population resides in regions distant from high radiation areas which, in turn, offers ample land availability for the development of solar energy plants (Akinbani *et al.*, 2021:5085).

In spite of the abundant solar energy potential in SA, the country has been battling with an energy crisis since 2007. Load shedding, in particular, continues to have a huge impact on the lives of all citizens, disrupting business activities and placing additional strain on disadvantaged families (Ramaphosa, 2022:4). New energy technologies have also not been fully investigated and the country faces an energy shortfall of about 4 000 MWh due to outdated power plants, inadequate maintenance, policy errors and the devastating impact of state capture (Kumba & Olanrewaju, 2022:753). The electricity shortage means that SA needs to speed up the process of CSP implementation.

South Africa's current electricity generation heavily relies on coal, which has placed the country on the world's top 10 list of GHG emitters and 14th in the world for carbon dioxide emission (Akinbani *et al.*, 2021:5078). Renewable energy (RE) sources (which are finite and environmentally friendly) can seriously reduce the over-reliance on coal (Akinbani *et al.*, 2021). South Africa has also made a commitment to the Paris Agreement to reduce global temperatures to below 1.5 degrees Celsius (McLennan, 2021).

From the above, it is clear that RET is extremely suitable for SA due to the abundance of solar energy available in the country. Therefore, in order for SA to deal with the current energy crisis and align with SA's global commitments, the development of RE through the REIPPPP programme should be accelerated.

2.6 CSP as a renewable energy source and the Cost-benefit analysis

This paragraph discusses CSP technologies' characteristics, nature and requirements, in identifying an describing its determinants of economic viability in a PESTLE analysis. This paragraph answers the first secondary objective of the study: to conduct a literature review to obtain a comprehensive understanding of the economic viability (especially in an SA context) of CSP to identify, analyse, and evaluate all relevant quantitative and qualitative factors/information.

To enhance the reader's understanding, it is important to first establish knowledge about the different types of CSP technologies, which are explained below using Hashim's (2021:8-11) definitions. According to the literature, there are four types of CSP technologies: Parabolic Trough Collector (PTC), Solar Power Tower (SPT), Linear Fresnel Reflector (LFR), and Parabolic Dish

Systems (PDS) (Yasin & Draidi, 2020:254). Below, figure 2.2 shows the different types of CSP technologies. A discussion of each follows after the figure.

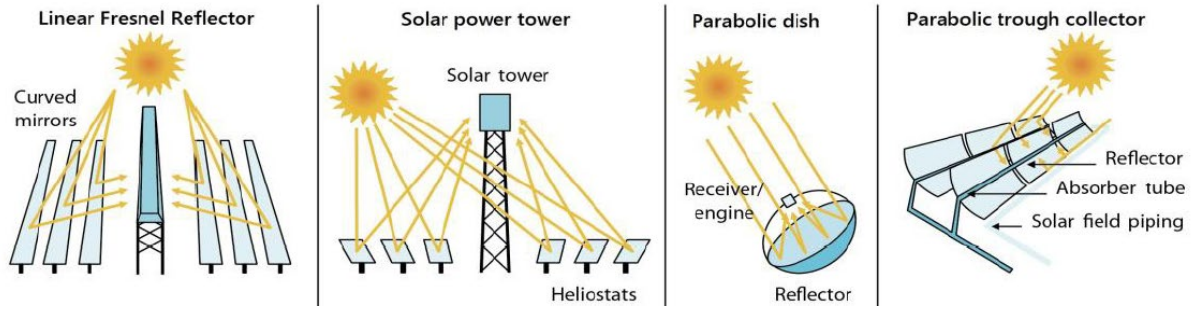

Figure 2.2 – Four major CSP technologies
Source: Chaanaoui *et al.* (2016:784)

(i) Parabolic Trough Collector (PTC)

PTC technologies consist of a group of reflectors that are curved in one dimension, forming a parabolic shape, as depicted in figure 2.2. These reflectors focus the sun rays into an absorber tube that is mounted in the focal line of the parabola. The collector fields comprise several hundred troughs that are placed in parallel rows aligned on the north-south axis. This configuration enables single-axis troughs to track the sun from east to west throughout the day, which means that the device works during daylight hours.

PTC normally relies on oil as synthetic fuel to facilitate an exchange of power from the collector pipes into heat (Akinbani *et al*., 2021:5077-5093; Răboacă *et al*., 2019:1-17). During the generation process, water is boiled and evaporated, running the turbine and driving the plant to create electric energy. PTC technology is considered the most mature, successful, and developed CSP technology for electricity generation (Akinbani *et al*., 2021:5087; Belgasim *et al*., 2018:2). PTC is a high temperature solar thermal utilisation technology with the largest share in the market, and is the most economical compared to other CSP technologies (Yang *et al*., 2020:867).

(ii) Solar Power Tower (SPT)

SPT uses a heliostat field collector, consisting of thousands of heliostats arranged meticulously to reflect the maximum amount of sunlight onto a central receiver positioned atop a solar tower. This field of sun-tracking heliostats reflects and concentrates the sun rays onto the central receiver on top of the tower, compensating for the movement of the sun across the sky. The heliostats are computer-assisted mirrors which individually track the sun along two axes (Răboacă *et al*., 2019:6). The heliostats concentrate the DNI onto a single angle which can be fixed on top

of the tower, placed in a central point. The heat produced by the sun conducts a thermodynamic cycle that generates electricity. SPT uses molten salt as a high temperature HTF, and this storage medium appears to be the most promising for the future of CSP technology. This is due to its cost-effective energy storage, the high capacity factor achievable, greater efficiency of the steam cycle, and its reliable output capacity.

(iii) Linear Fresnel Reflector (LFR)

LFR technology has a parabolic shape and uses long rows of flat or slightly curved mirrors to reflect sun rays onto a downward-facing linear receiver. The receiver is a fixed structure mounted above, and aligned with, the linear reflectors, typically mounted over a tower. During the day, the Fresnel reflectors automatically adjust their alignment towards the sun. From there, the reflected DNI is directed towards the linear tower where there is a receiver, shaped like a long cylinder, containing many tubes filled with water. With high DNI, the water evaporates and under pressure runs into a steam turbine that generates electricity. LFR technology is quite similar to that of PTC, but the main difference is the solar collectors used in the solar field (Belgasim *et al*., 2018:2).

(iv) Parabolic Dish System (PDS)

PDS concentrates sun rays at a focal point supported above the centre of a dish. These concentrators are placed within an assembly that incorporates a two-axis tracking system, allowing them to follow the sun. An engine, along with an electrical generator, is placed to utilise the concentrated heat on the receiver. In essence, PDS consists of a parabolic dish-shaped concentrator that mirrors the DNI onto a receiver located at the focal point of the dish (Răboacă *et al*., 2019:6). The focal receiver is filled with HTF which gets heated to high temperatures, and the dish reflector is attached to an engine or gas turbine to convert the absorbed heat energy into electricity (Belgasim *et al*., 2018:3).

PDS has seldom been deployed commercially for power generation due to its high costs (SolarPACES, 2018). Several studies are being conducted on alternative methods of exploring PDS technology in a more cost-effective way (Belgasim *et al*., 2018:3).

2.6.1 Political factors

2.6.1.1 South African political landscape and CSP technologies

CSP technology deployment currently faces political barriers in SA which can hamper its development, the main reason being the uncertainty on policy instruments to support its development (Aprà *et al*., 2021:385). At the time of this research, the information available for energy planning from the IRP is that there will be no further CSP development beyond 2030. The

last CSP plant being built is the Redstone project which will come into operation towards the end of 2023 (Steyn, 2023). In other words, from the year 2024 until 2050, no CSP development is included in the IRP. It should be noted that the IRP was due for revision in March 2023, but the DE has missed the deadline, which is a clear indication of the lack of political will on the acceleration of RE deployment. Also, it is still not clear whether the revised IRP will have an allocation for CSP technology besides the concerns that were raised by energy experts in the last version of the IRP (DE, 2019b:76). These concerns raised by energy experts included a request that CSP costs should be compared to baseload power generation assets and not wind and PV due to its ability to store energy and supply electricity 24 hours a day (DE, 2019:71).

The South African government needs to increase CSP allocation in the IRP to encourage the participation of local industries and, in this way, increase competition and reduce tariffs (Basson, 2019). According to Mehos *et al*. (2020), CSP development relies heavily on attracting policies from the government, while the SA economy relies heavily on fossil fuel for electricity generation – which means that there is a need for strong political incentives (IMF, 2022:89). Worldwide, CSP technology is still maturing and only few plants exist. Although the technology is capital intensive, it can contribute to the country's economic growth, not only of the host communities, but also of the nation by creating temporary and permanent jobs (Craig *et al*., 2018).

As mentioned earlier, SA's load shedding situation dates back to 2007, 15 years ago, attesting to the absence of political will to resolve the crisis. According to Proctor (2023), load shedding is estimated to have cost the economy about R13 billion in 2023, of which corruption has also played a significant part. To accelerate the deployment of RE projects, the government has started to relax the licence requirements for power generation by reducing the licence threshold from 1 MWh to 100 MWh (Proctor, 2023). The revised licence requirement also implies that generating assets of up to 100 MWh will not require a generating licence to operate facilities, which will minimise delays.

The political battle in moving towards net-zero carbon in 2050 continues between politicians and the energy minister. Mr Gwede Mantashe, the current Minister of Mineral Resources and Energy, has indicated that the country cannot simply switch off SA's usage of coal to succumb to the pressure from developed countries (Cocks, 2022). Efforts made by the government remain fruitless for now due to the new portfolio of Minister of Electricity that was created in March 2023 and whose roles have been clarified by President Ramaphosa only in May 2023 (BusinessTech, 2023). The appointment of the new minister comes in addition to the Minister of Mineral Resources and Energy and the Minister of Public Enterprise – and all three are involved in making decisions about the country's energy supply. Needless to say, this creates a great deal of confusion (BusinessTech, 2023).

As pointed out by Baker and Phillips (2019), the distribution of electricity represents an important but neglected aspect of the politics of energy transition. Electricity distribution faces significant political and economic challenges that are rooted in SA's social and racial inequalities (Baker & Phillips, 2019). Furthermore, there is a lack of political administrative capacity in the country. Labordena (2017) claims that an improved administrative capacity will lead to increased CSP project feasibility and reduced financing costs.

In spite of the above challenges, the country's CSP industry is already demonstrating some potential regarding the 600 MWh allocated in the IRP. Current projects will (i) eliminate about 1.3 million tons of carbon dioxide, (ii) provide electricity to 563 000 households, and (iii) create around 10 000 permanent and temporary jobs from construction through to operations (Craig *et al*., 2017a:19). With proper funding structures, support for CSP R&D, compensation for TES, and political will from the government, CSP technology stands a good change to form part of SA's baseload power supply (Craig *et al*., 2017a:19).

2.6.2 Economic factors

2.6.2.1 Economic growth

In his Medium-Term Budget Policy Statement (MTBPS), the Minister of Finance mentioned that SA's economic growth is currently far too low to address poverty and unemployment challenges – a crisis which requires urgent and decisive action and reform (Godongwana, 2022:1). From 2011 to 2018, the country experienced an average economic growth rate of around 1.7%. This trend will continue to worsen, exacerbating inequality, poverty, levels of unemployment, and consequential social discontent and unrest (IRMSA, 2022:50). South Africa's projected economic growth was around 2.1% in 2022, but this has been revised down to 1.9%, with GDP expected to average 1.6% over the mid-term (Godongwana, 2022:3). This is in line with the global challenge, with the IMF (2022:8) noting that global economic growth has been averaging 3.6% from 1970 to 2021.

The decline in economic growth has also led to a sharp rise in inflation which reduces buying power for household consumption, as can be seen in table 2.3 below. In order to fight inflation, the South African Reserve Bank has continuously increased interest rates, but the value of the rand continues to deteriorate and has lost about 11.9% value when compared to the dollar (Godongwana, 2022:14).

Table 2.3 – Economic growth outlook

Calendar year	2019	2020	2021	2022	2023	2024	2025
Percentage change		Actual		Estimate		Forecast	
Final household consumption	1.2	-5.9	5.6	2.9	1.6	1.7	1.8
Final government consumption	2.1	0.8	0.6	0.8	-1.8	-1.0	0.2
Gross fixed-capital formation	-2.1	-14.6	0.2	4.0	1.9	3.6	3.8
Gross domestic expenditure	1.4	-8.0	4.8	3.6	1.2	1.6	1.8
Exports	-3.4	-11.9	10.0	7.4	1.9	2.8	2.9
Imports	0.4	-17.4	9.5	13.8	1.0	2.3	2.9
Real GDP growth	**0.3**	**-6.3**	**4.9**	**1.9**	**1.4**	**1.7**	**1.8**
GDP inflation	4.6	5.7	6.2	4.1	4.3	4.7	4.6
GDP at current prices (R billion)	**5 614**	**5 557**	**6 192**	**6 572**	**6 956**	**7 406**	**7 884**
CPI inflation	4.1	3.3	4.5	6.7	5.1	4.6	4.6
Current account balance (% of GDP)	-2.6	2.0	3.7	0.2	-0.9	-1.1	-1.2

Source: Department of National Treasury (2022:16).

With regard to the energy crisis, the country is estimated to be losing around R700 million for each stage of load shedding, and nine million litres of diesel are used on the open-cycle gas turbines (OCGT) (Arnold, 2022; IRMSA, 2022:51). To address the crisis, the government needs to accelerate the RE deployment. In this regard, CSP technology has proven to be effective on a larger scale when compared to other RETs. The Redstone 100 MWh CSP project is a good example, being the largest South African RE investment to date at around R11.6 billion. When commissioned later in 2023, it will be able to generate electricity for 24 hours as a result of the 12-hour TES (Energy Capital & Power, 2022). CSP is also changing the energy landscape because all of the plants are situated in the Northern Cape where DNI levels are the highest (Global Africa Network, 2017; HelioSCSP, 2020).

CSP technology can assist in securing the country's energy supply, boosting foreign investment, supporting economic growth and development, and improving our credit rating (McLennan, 2021). RETs also include private investors, which eases the pressure on the fiscus. A total of 30% of RE projects are scored based on economic development obligations through PPAs, while 70% are based on price, adding value to the SA economy (Montmasson-Clair, 2020:5). It should be noted that 49% of CSP value in goods and services can be supplied locally, boosting SA's economic growth (Global Africa Network, 2017).

As mentioned above, the Northern Cape is most suitable for CSP. At the time of research, all CSP plants in the country are based in the Northern Cape with 500 MWh plants already operational and the 100 MWh Redstone project under construction (Acwa Power, 2021). The latter project is expected to spend about R150 million annually on salaries and other expenses for 30 years, with 40% of the total project value to be provided by SA citizens (Global Africa Network, 2017). Redstone's 40% local project value will also lead to improvements in the local manufacture of components, creating permanent and temporary employment benefits (Craig *et*

al., 2018:8). The Redstone project has a total investment value of R11.6 billion which makes it the largest RE project to date in the country and will provide electricity to about 200 000 households round the clock (Acwa Power, 2021). As stated by Kilian (2017), CSP creates an industry as a whole which has a positive impact on job creation and the development of small businesses and skilled communities. South Africa has a good business case when it comes to CSP development due to DNI availability in SA and government's pricing system which aims to compensate TES systems for electricity generation after sunset (McLennan, 2021).

Despite all the benefits, Kilian (2017) has raised concerns regarding Eskom's delaying the signing of IPP projects and the vague updates by the DE Minister on the IRP document. The concerns are exacerbated by labour unions who continue to claim that these RE projects will cause job losses of about 30 000 (Craig *et al*., 2018:8). However, from the literature, it is clear that the benefits of CSP technologies outweigh the costs, taking into consideration the global commitment that the country has made to the Paris Agreement. These benefits for economic growth make the CSP technology viable as an RE source when compared to other RETs.

2.8.2.2 Traditional capital investment appraisal methods

The traditional capital investment appraisal methods for this study refer to the NPV, the IRR, the PBP, and the ARR. In the literature, barely any sources could be found for the ARR relating to CSP technologies. For this reason, the study focused on the other three methods, namely the NPV, IRR and PBP. It should also be noted that investors seem to prefer the LCOE method of evaluation over the NPV, IRR, and PBP. The argument is that the traditional appraisal methods focus mainly on short-term projects rather than long-term projects like CSP technologies, which can be evaluated for up to 30 years (Zhou *et al*., 2019:5). The below three sections will explain in detail the NPV, IRR, and PBP on CSP technologies.

(i) Net Present Value (NPV)

NPV is simply the sum of all future cash flows over the investment's lifetime, discounted to today's value. It is used to determine whether or not an investment or project is worth the effort and resources (Girardin, 2023). Another way of describing NPV is the sum of the present values of all future cash flows generated by a project after accounting for the initial capital investment (Shafiee *et al*., 2020:4). NPV indicates whether the projected earnings generated by an investment exceed the anticipated costs or not (Yasin & Draidi, 2020:257). A positive NPV indicates that the project is viable and profitable, whereas a negative NPV indicates that the project is unprofitable (Girardin, 2023).

Most previous studies have demonstrated a positive NPV for CSP projects, but investors still prefer the LCOE formula to evaluate power generation assets because NPV tends to focus on the short term (Zhou *et al*., 2019:1). In a study conducted by Yang *et al*. (2018:5), some CSP projects showed positive NPV values and others showed negative NPV values. The main reason for negative values was due to the fact that the projects were simulated and assumed no government support in terms of subsidies or grants (Yang *et al*., 2018:5). The negative values on the NPV are a clear indication that, for CSP projects to remain competitive, they still need support from government, while TES storage capabilities should also be compensated for (González-Roubaud *et al*., 2017:136).

Torres *et al*. (2021) found that direct and indirect costs of CSP plants have a significant impact on NPV calculations. According to their study (Torres *et al*., 2021:587), a 68.2% reduction in overall installation costs of CSP plants is associated with an increase in NPV of 76% on SPT, 70% on PTC, 64% on LFR, and 56% on PDS. The highest NPV values obtained from SPT are the technological capabilities of providing high temperatures when compared to the other CSP technologies (Jayathunga *et al*., 2023:133). Torres *et al*. (2021:587) also indicated that other variables like exchange rate and discount rate have little impact on the NPV when studied separately but can greatly improve CSP's economic viability when combined with other parameters.

Ouali *et al*. (2022) argue that the discount rate heavily influences the NPV: an increase in the discount rate is associated with a decrease in the NPV, while a decrease in the discount rate is associated with an increase in the NPV. Annual interest rates further have a significant impact on the NPV and a reduction in interest costs can add more value to CSP's economic viability (Ouali *et al*., 2022). Another study indicates that a 50 MWh CSP plant in the USA (state of Arizona) has shown an NPV of around USD64 million, and research indicates that improved and increased production does increase NPV values of CSP plants (Shafiee *et al*., 2020:1). SPT technology has the potential to further improve the NPV in the long run due to the high temperatures involved, which also improve production (Jayathunga *et al*., 2023:133).

(ii) Internal Rate of Return (IRR)

The IRR measures the return of a potential investment. It assists investors in comparing the profitability of different investments: An investment with a higher IRR is preferable to one with a lower IRR (Henricks, 2023). IRR is simply the discount rate that sets the NPV of all cash flows of a project to zero. It serves as a tool to evaluate the attractiveness of a project (Shafiee *et al*., 2020:4). Although investors still prefer LCOE for RET evaluation, IRR gives a sound estimate of the profitability of a project and is considered a good measure for comparing projects from different countries (Bertsch & Di Cosmo, 2018:22).

The global benchmark IRR for renewable projects is 10%, which makes these projects more competitive when compared to other traditional fossil fuel electricity generation assets (Snieckus, 2020). The IRR for CSP projects can range from 6.5% up to more than 20%, according to a study conducted by Yang *et al*. (2018:1-9), while the SPT has the highest IRR when compared to the other CSP technologies due to its ability to generate high temperatures. The high IRR for the SPT can also be ascribed to the high performance in terms of energy production, capacity factor, and electricity efficiency (Torres *et al*., 2021:588).

In a study by Rivera and Flores (2021:7) on a 50 MWh CSP plant using different assumptions, an IRR range was found between 10.6% and 15.2%. Projects without financing, meaning only investor funds were used, yielded less IRR when compared to projects that were financed through a split of 70% finance and 30% equity. The IRR for the financing options (i) 100% investors and (ii) 70% finance and 30% equity, yielded a similar effect to the LCOE, namely an increase in the first option and a decrease in the second option (Rivera & Flores, 2021:7).

Yang *et al*. (2018) also demonstrated the impact of capital costs on IRR when costs increase or decrease by 20%. A 20% decrease in capital costs for SPT leads to an increase in the IRR from 12.33% to 21.78%, while an increase in capital costs by 20% leads to a drastic reduction of IRR to 6.54%, which is lower than the 10% global benchmark. It is clear from the IRR shown/illustrated here that CSP yields good returns for investors, but still needs substantial support from government. South Africa's introduction of a two-tier pricing option is a step in the right direction since this will compensate CSP's unique capabilities of energy storage and will make CSP competitive with other RETs.

(iii) Payback Period (PBP)

Payback Period simply refers to the length of time that it takes to recover the initial capital investment (Shafiee *et al*., 2020). Most studies have indicated that the PBP of CSP projects tends to be too long, which is mainly due to the substantial initial amount of capital needed (Zhou *et al*., 2019:1). The high capital costs associated with CSP projects have also been the reason why investors opt for PV projects, which are less capital intensive to set up. However, CSP has demonstrated that it can offer significant baseload power benefits in the long run (Yasin & Draidi, 2020:256).

In studies conducted by Yang *et al*. (2018:1-9), Shafiee *et al*. (2020:1-17), and Yasin and Draidi (2020:253-264), the PBP for CSP projects ranged from 7.5 years up to 17.6 years, which confirmed the reluctance of investors to take on these projects without government incentives or grants. Busse and Dinter (2016:53) mention that a significant amount of research has been done

on how to reduce the investment costs of CSP technologies on maintenance and fuel costs and increase production.

Craig (2018:22) argues that key cost drivers should be reviewed to make CSP competitive and to reduce the PBP. These cost drivers are mainly based on (i) continued technological improvements, (ii) competitive procurement, and (iii) a large base of experienced and internationally active developers. The decrease in CSP deployment from 2010 to 2017 has further delayed improvements towards reducing investment costs to improve PBP (Craig, 2018:22). As noted above, SA has introduced a two-tier tariff plan to encourage competitiveness and reward CSP storage capabilities by offering higher rates for electricity generated during peak hours than for electricity generated during standard hours (Craig, 2018:28). The PBP continues to improve globally due to measures put into place to reduce capital costs (Mehos *et al*., 2020:13).

2.6.2.3 Cost-Benefit Analysis (CBA)

A Cost-benefit analysis is discussed in paragraph 2.8.

2.6.2.4 Levelised Cost of Electricity (LCOE)

LCOE is an economic assessment of the average total costs of building and operating a power generating asset throughout its lifetime. This cost is then divided by the total energy output that the asset generates over its operational lifetime (Lai & McCuloch, 2017:2). LCOE represents the present value of the unit cost of electricity over the lifetime of the power generation asset (Shafiee *et al*., 2020:2). LCOE is an economic metric commonly used to compare a wide range of electricity generation technologies and is often applied to investment in research and technology development as well as designing appropriate policies (Dowling *et al*., 2017:1020). LCOE formula is also a principal tool for comparing the plant-level unit costs of different baseload technologies over their operating lifetimes (Schöniger *et al*., 2021:56-57). The metric examines the unit cost of different technologies and considers both capital expenditure and operational expenditure (Xu *et al*., 2022:1328). It measures the lifetime costs of a plant and does not consider revenues (NATO ENSEC COE, 2021:15).

Since it is applied globally, the formula gives investors an idea of how much a power generation asset investment cost per kWh in USD or any other currency which can then be compared against all power generation assets. The parameters typically used for the LCOE formula are geographic location, solar irradiance, capital cost estimates, storage size and efficiency, government incentives, and base year for monetary estimates (Dowling *et al*., 2017:1023). It is important to

note that the LCOE indicates the economic costs of a generic technology, not the financial costs of a specific project in a specific market (Schöniger *et al*., 2021:58).

LCOE aligns more closely with the costs of electricity generation in regulated electricity markets with stable tariffs than with variable prices in deregulated markets (Schöniger *et al*., 2021:56-57). Technology with lower LCOE has been preferred by investors but, due to several structural changes in demand and supply, this preference is being challenged as factors other than the parameters used in the formula come into play (Schöniger *et al*., 2021:56-57). LCOE facilitates a comparison between technologies with varying degrees of capital and fuel intensity (Mai *et al*., 2021:4).

The costs for CSP technologies are currently higher than those of conventional fossil fuel technologies. However, cost reduction opportunities due to large-scale deployment and improvements in technology are expected to decrease (Zhuang *et al*., 2019:2). The costs of CSP projects are mostly dominated by the investment costs, which account for more than 80%, while the rest consists of operational, maintenance, and insurance costs for the plant (Dowling *et al*., 2017:1022). The current CSP market is driven by PTC technology. More than 80% of the CSP power plants in operation or under construction globally are based on PTC technology and most of the available cost information is also based on PTC systems (Mai *et al*., 2021:3). According to Moyo *et al*. (2017:5), some experts have already expressed concerns that the window of opportunity for CSP is closing as solar PV prices continue to fall.

It should be noted, though, that LCOE ignores the feed-in tariffs (FIT) that have been introduced by governments on large electricity utilities (Dijkgraaf *et al*., 2018:82). A further limitation of LCOE is the fact that it does not consider the value of electricity generated within an energy system in a given hour of the year (Kost *et al*., 2018:29). At this point, it should be emphasised that this method is an abstraction of reality, aiming at making different power plants comparable, and is not suitable for determining the profitability of a specific plant (Kost *et al*., 2018:29).

Busse and Dinter (2016:51) argue, however, that although CSP projects might seem to have higher LCOE in comparison to traditional power generation assets, TES for CSP still offer better benefits (such as energy storage). Most studies claim that LCOE undervalues the dynamic flexibility provided by TES and does not consider revenue opportunities provided by electricity markets at different timescales (Zhou *et al*., 2019:2). In this regard, some studies have found that both LCOE and revenue can, in fact, be conflicting metrics for certain designs and market conditions (Dowling *et al*., 2017:1019). As indicated in a cost database compiled by IRENA, CSP's cost dropped by 50% from 2010 to 2020, a decrease which occurred even as the size of these projects' TES systems had increased (IRENA, 2021:125). LCOE for PTC does not decline with

high-capacity factors as opposed to the LCOE for SPT, which tends to decrease as the capacity factor increases (Zhou *et al*., 2019:6). The decrease in LCOE for SPT can be ascribed to the significant lower specific cost of the molten salt energy storage in SPT technology (Zhou *et al*., 2019:6).

Although CSP plants with TES have higher specific investment costs due to its storage system and larger solar field, the increased electricity generation capacity results in a lower electricity generation cost (NATO ENSEC SOE, 2021:12). According to Stevens and Smith (2015), the current perception that PV is cheaper than CSP based on LCOE is misleading. This perception arises because the LCOE formula ignores many factors that are crucial when considering the energy system of a country. This misperception is exacerbated by the fact that PV technology is more mature than CSP, which is still considered somewhat experimental (Rivera & Flores, 2021:8). PV is viewed as a lower-cost, simple, and proven technology at present. However, the situation becomes significantly more complex when the question of storage is brought into the discussion (Rivera & Flores, 2021:2). Although TES also pushes up the costs of CSP plants, it enables higher capacity factors, provides dispatchable generation when there is no sun, and allows for the maximisation of generation during peak demand times (Dowling *et al*., 2017:1020). The incremental costs of CSP are economically justifiable, as CSP plants with storage have a similar or lower LCOE than those without (Dowling *et al*., 2017:1020).

The LCOE model does not account for the potentially significant differences in production characteristics, and CSP with TES has been shown to be far more competitive when compared to wind and PV technologies (Helman & Jacobowitz, 2014:1). CSP with TES also presents a significant opportunity in remote locations, as it can effectively meet operational needs that might be costly to address with other renewable solutions. The method of LCOE allows for a comparison of power plants with different generating and cost structures (Kost *et al*., 2018:30).

The global average LCOE is around 0.182 USD/kWh, with some CSP projects already below the average LCOE costs, for example, a 50 MWh CSP plant in the USA (state of Arizona) with an LCOE of 0.1606 USD/kWh which is below the global average cost (Shafiee *et al*., 2020:14). Another plant, with 100 MWh capacity in Morocco, achieved an LCOE of 0.1303 USD/kWh (Ouali *et al*., 2022:1). A study by Rivera and Flores (2021:7) found two CSP plants, with capacity of 50 MWh each, with LCOEs of between 0.01101 USD/kWh and 0.1207 USD/kWh. The reduction in costs is an indication that CSP technologies have great potential for future deployment given the right location, market conditions, and government financial support (Musi *et al*., 2016:1).

To conclude, the LCOE remains a crucial tool for investors in making investment decisions regarding RETs. At first glance, PV and wind technologies are currently cheaper than CSP plants,

but, when considering storage, CSP is more economically viable in the long run. It is important to mention that the LCOE relies on the parameters used in the formula, and greater support and subsidies from government can make investment in CSP technologies more attractive.

A balanced energy mix is vital, where RETs should complement each other rather than compete solely on LCOE considerations. The complementary approach requires the SA government to attract new investors through subsidies to reduce the LCOE for CSP technologies. As recommended by Musi *et al*. (2016), continued government support is needed to ensure that the technology matures and becomes competitive with PV, which is CSP's main competitor.

2.6.3 Social factors

2.6.3.1 Poverty and unemployment

South Africa is grappling with challenges related to poverty and unemployment, with the number of people living below the Lower Bound Poverty Level (LBPL) of USD2 per day estimated to be 39% in 2009 and 40% in 2015 (CIF, 2020:22). Labour unions have raised concerns about the potential loss of 90 000 job in mining as the country moves to RETs (Cocks, 2022). Most CSP plants are located in isolated areas, which are mostly rural areas with poor communities characterised by high levels of poverty and unemployment. Furthermore, these areas often face poor service provision and fragmented governance structures (Baker & Phillips, 2019:10).

There is also a concern that the transition to RE may primarily benefit the already wealthy individuals at the expense of basic service provision to the poor. Baker and Phillips (2019:6) argue that, although most people have access to electricity, affordability remains a challenge for the most disadvantaged communities, who still rely on paraffin, wood, and coal – leading to air pollution, respiratory illness, and incidents such as shack fires.

A case study conducted by CIF (2020:38) in one of SA's CSP plants has demonstrated that these plants bring some benefits to surrounding communities in the form of employment opportunities which, in turn, lower the poverty levels in those areas. CSP installation has also led to access to electricity, to hospitals and schools, and to road network improvement (Karim *et al*., 2019:3). The benefits further include the bidding requirements from the government, which include a consideration of communities in a 50 km radius from the plants, 1% project revenue to be allocated to social development, 1% of revenue to black owned enterprise development, and 8% shareholding to be allocated to the local community. Renaud *et al*. (2020:24) emphasise that the deployment of CSP plants should create capacity building in municipalities and communities to enable a smooth JET process.

The SA government has attempted to empower communities through the IPP office which bases evaluation criteria on price (70%) and economic development (30%) (IPP Office, 2023:18). To date, IPP projects have created around 68 237 job years for SA citizens, with 49 264 during construction and 19 125 during operations (IPP Office, 2023:18). Job years are the equivalent of a full-time employment opportunity for one person for one year (IPP Office, 2023:26). The main social benefits of CSP plants is the stimulation of the economy, poverty reduction, and job creation at local level (Fedkin & Duttto, 2020).

2.6.3.2 Education and skills

CSP technology has been regarded as a young technology in SA and still requires significant R&D (Nel, 2015:48). The six CSP plants already operational in the country were built by foreign companies – referred to as engineering, procurement, and construction (EPC) contractors – due to the lack of necessary skills and required international accreditation among local companies (Craig, 2018:33). With the JET, employees from coal mining and traditional coal power stations will have to be re-skilled to ensure their employability in the new RE projects (Wemanya & Adow, 2022:5). The main challenge is that most coal mining and power stations are located in the Mpumalanga and Limpopo provinces, while RE projects, including CSP plants, are situated on the other side of the country. All of the CSP plants are located in the Northern Cape due to the high DNI needed for these plants (CIF, 2020:15).

It is imperative that the special skills, knowledge, and expertise possessed by EPC be transferred to local companies (DLR, 2021:10). This transfer should be supported by the government and made a requirement in the bidding documents for RE projects. In addition, continuous R&D is crucial since there is currently limited research in the field (DLR, 2021:10). Potts and Walwyn (2020:14) concur by stating that knowledge is needed in the areas of design, manufacturing, operations, and maintenance of the plants. Individual training will be essential for the efficient operation and maintenance of plants to avoid unnecessary production errors. This training initiative will, in turn, create job opportunities to trained individuals (Potts & Walwyn, 2020:14).

2.6.3.2 Equality

South Africa is one of the most unequal countries in the world, ranking first among 164 countries in the World Bank's (2022a:1) global database, indicating a lack of inclusive education, health, and basic services. Factors such as location, gender, age, parental background, land ownership, and race are the dominating factors driving inequality, while an unjust energy transition can create or expand further inequalities (World Bank, 2022a:1).

The Climate Investment Funds (CIF, 2020:9) reported that about 3 500 people in SA have the same amount of wealth as about 32 million people. This inequality has, among other things, led to distrust in the government, exacerbated by highest level of corruption and poor management. Despite the fact that, by 2012, about 87% of SA households were connected to the grid, affordability for the poor and marginalised communities remains a challenge, and some households resort to illegal electricity connections (Baker & Phillips, 2019:2).

As argued by Terrapon-Pfaff *et al*. (2019:2), RETs tend to focus more on technological and regulatory considerations while ignoring local livelihood dimensions. Therefore, a JET should address inequality, create jobs, alleviate poverty, foster resilience to climate impacts and energy instability, provide access to affordable electricity, leaving no one behind.

CSP will play a huge role in addressing some of these inequalities due to the opportunities that it can offer the local communities through enforced economic development obligations prescribed in the PPAs and monitored by the IPP office (CIF, 2020:7). The DLR (2021:32) has estimated that a 50 MWh CSP plant will create about 2 000 direct and indirect jobs during construction and 50 permanent jobs thereafter for the operations and maintenance of the plant. Wemanya and Adow (2022:5) also predict that RE projects will create about 50 000 jobs per year in the construction, operations, and maintenance of these plants.

2.6.4 Technological factors

The commercial deployment of CSP technologies started in 1984 in the United States. From 2005 to 2016, electricity generation from CSP increased from 0.04 GWh to 11.9 GWh globally (Bošnjaković & Tadijanović, 2019:68). The global projection is to have 11% of electricity generation from CSP technologies equating to 954 GWh by 2050 (Aprà *et al*., 2021:377).

The type of technology used in CSP is important for determining its economic viability. CSP, although still an emerging technology, is not as mature as PV technology at present (Aprà *et al*., 2021:377). Among CSP technologies, PTC is recognised as the most mature and commercially tested compared to other CSP technologies (Jayathunga *et al*., 2023:132). The total installed capacity for CSP plants globally has around 81% of generation capacity allocated to PTC, while Solar Power Tower (SPT) has only a share of 14% at the time of research (Jayathunga *et al*., 2023:134). The latest research developments show the potential of SPT due to its high temperature capabilities, leading to a shift in deployment preferences from PTC to SPT (Aprà *et al*., 2021). As stated by Craig (2018:14), newly built CSP technologies are SPT due to the high temperatures it can create, and its promising heat-to-electricity conversion efficiencies.

South Africa currently has seven CSP plants planned until 2030, with a total capacity of 600 MWh. Six plants are operational and generating 500 MWh, while the seventh plant is in construction at

the time of research and is expected to start operating towards the end of 2023 (Craig, 2018:120). The dominant factor for CSP's economic viability is its ability to store heat during the day and continue to generate electricity after sunset (Basson, 2019). This storing of heat is called TES and will be explained in detail below.

In general, CSP plants can be divided into three components, namely the solar field, the power block, and the TES.

(i) The solar field

The solar field concentrates DNI received from the sun and converts the solar energy into thermal energy. This heat is used to produce steam, which, in turn, drives the power block to generate electricity (Belgasim *et al*., 2018:2). In a PTC, rows of parabolic trough collectors/mirrors track the sun's position and concentrate solar incident rays on a receiver, where the solar irradiation is absorbed by solar-selective absorbing coating. This absorbed energy is converted into thermal energy and delivered to the HTF for the power generation cycle (Yang *et al.*, 2020:867).

The solar energy absorbed by the receiver depends on many parameters. The receivers of the solar field, especially those in continuous operation for long periods, are normally susceptible to damage. Common issues include vacuum loss, broken class, and hydrogen permeation. Such damage may lead to a sharp increase in receiver heat loss and attenuation in solar absorption (Yang *et al.*, 2020:867). Heat loss and HTF freeze protection temperature exert a negative effect on the performance of plants, while solar energy absorption exerts a positive effect on electricity generation (Yang *et al.*, 2020:878).

(ii) The power block

The power block uses the thermal energy collected by the solar field to generate steam through a heat exchanger (Belgasim *et al.*, 2018:2). The power block normally used in solar power plants is a regenerative ranking cycle which rely on a steam turbine generator to produce electrical energy. The efficiency of the steam turbine usually increases as the main steam temperatures rise (Yang *et al.*, 2020:867). This poses a challenge to HTF because it is generally unable to operate at high temperatures greater than 400 degrees Celsius, which is typical for a 100 MWh steam turbine. This means that, as the main steam temperature increases, the input energy from the HTF at design condition decreases due to the high cycle efficiency, while the net electricity output remains at the same level for the high temperature.

The power block of the CSP plant often has to operate under off-design conditions due to fluctuations of incident solar irradiation and changes in electricity demand on the grid (Yang *et al*., 2020:870). Nevertheless, the CSP power block follows existing principles of power generation and can use existing conventional power generation facilities. It can therefore easily be incorporated into existing plant designs to form hybrid systems (Craig *et al*., 2017b:16).

(iii) Thermal energy storage (TES)

This technology, also called two-tank molten salt, comprises two separated tanks in which all the molten salt is used simultaneously as HTF, and thermal storage material can be stored at two temperature levels (Py *et al*., 2017:4). The molten salt stores the thermal energy by change of temperature (Moyo *et al*., 2017:6). During the sunniest hours of the day, the internally over-scaled solar field of the plant delivers heat power that is shared between the power block and the TES unit (Craig, 2018:137). When the output heat power from the solar field falls lower than the nominal feeding power required by the power block, the TES unit starts to contribute to balancing this power (Py *et al*., 2017:4). Therefore, by using the TES unit, the power block of the plant is fed at nominal power and delivers constant electric power to the grid (Py *et al*., 2017:4).

This approach allows the reduction of maintenance costs of the power block and increases its lifetime expectancy. The TES system uses a thermos-solar grade molten salt (Borge-Diez *et al.*, 2022:2). Molten salt technology is mostly preferred due to its maturity, its ability to ensure the desired performance and meet project requirements, and its extensive use for energy storage (Borge-Diez *et al.*, 2022:11).

Figure 2.3 below is a schematic diagram of a PTC plant with all three CSP components, namely the solar field, power block, and TES system.

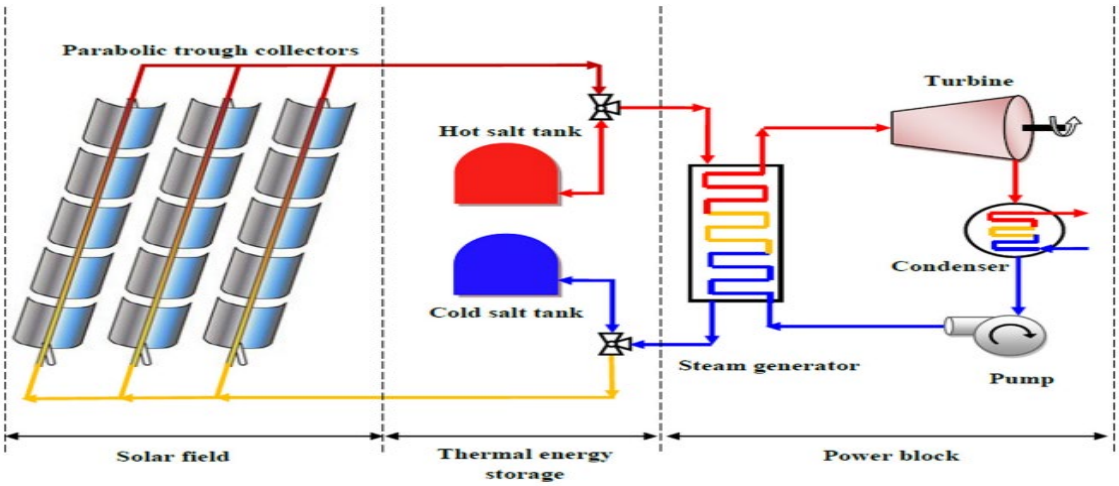

Figure 2.3 – Components of a CSP plant
Source: Belgasim *et al.* (2018:4).

2.6.4.1 Thermal energy storage (TES)

TES is the temporary storage of energy by heating or cooling a storage medium so that the stored energy can be used at a later stage for power generation (EASE, 2017:43). TES converts the direct fraction of solar radiation into heat, which can then be used to produce steam, similar to the process in traditional thermal power plants (Py, 2017:2). The TES process is somewhat different from the PV process, which converts the entire solar radiation into electricity (Py, 2017:2). In general, solar energy is intermittent, which means that solar energy has power variations which cause instability in the grid due to solar energy's dependence on the availability of sunlight and wind. This variability can occur on different timescales, ranging from hours and days to years (Wu *et al*., 2022:1).

As elaborated by Thaker *et al*. (2019), the heat under TES systems can be stored for longer durations, which allows the CSP plant to operate even when solar energy is intermittent. There are two ways of dealing with intermittency. The first is by using backup systems that burn fossil fuel or biomass, and the second is to store the heat during sunny periods for use at night (Pelay *et al*., 2021:3).

TES typically comprises a two-tank arrangement in which the molten salt is used as HTF, and thermal energy material can be stored at two temperature levels (Pelay *et al*., 2021:12). The molten salts used are in a solid state at room temperature and become liquid at the higher operational temperatures, making them suitable for heat storage and HTF (Bauer *et al*., 2021:539). When the thermal energy in the molten salt of the HTF is ready to be used, it is sent to a heat exchanger where the heat is extracted and used to boil water, producing steam to run a steam turbine (Craig, 2018:12). This process extends the duration of electricity generation, unlike

PV technologies which can only effectively store electricity for four hours or less. CSP with TES can effectively store energy for more than four, and up to fifteen, hours (Sarbu & Sebarchievici, 2018:3).

TES is one of the most attractive aspects of CSP when compared to other RETs because it allows precise controllability and stability of electrical supply even during the night or days when there is no sunlight (Khan *et al*., 2022:3). TES has the potential to be an important enabler of increased renewables penetration in energy systems and increases the economic viability of CSP technologies (IRENA, 2020:14). CSP with TES also provides dispatchable energy which creates flexibility on the electricity grid (Gao *et al*., 2022:2).

According to EASE (2017:36), TES technology combined with CSP guarantees the continuous supply of process heat generated from fluctuating renewable electricity and relevant when higher shares of renewables are in the energy system. The heat generated by the TES system can be stored large scale and last for days without minimal losses – which is why electricity can be dispatched as and when required at night or during cloudy periods (Khan *et al*., 2022:3).

It is clear from the literature that the shift from traditional fossil fuel electricity generation to RE without storage will present serious intermittency challenges to the stability of the national grid. The ability of CSP plants to address intermittency challenges makes the technology unique when compared to other RETs. Py (2017:2) adds that PV power stations produce erratic or unreliable electricity to the grid, which poses major risks to stability and security of supply, unlike TES which balances solar radiation daily.

The current CSP plant project under construction in SA, Redstone, will be able to store energy for about 12 hours, resulting in 24-hour electricity generation a day (DBSA, 2022). The Redstone project will have the longest storage capacity in terms of hours when compared to the other six CSP plants already in commercial operation. As mentioned previously, the current cost structure in the country utilises a two-tier billing system for production, with different rates applied to Eskom between peak and off-peak hours. This system is well suited for CSP technologies and guarantees the dispatch and delivery of energy at competitive costs, with extended storage periods of more than four hours (Silinga *et al*., 2015:2).

Stevens and Smith (2015) contend that, as RE penetration deepens, the need for utility-scale renewable generation with storage technology is increasingly important to mitigate intermittency problems. The innovative aspect of CSP is that it captures and concentrates the sun's energy to provide the heat required to generate electricity, rather than using fossil fuel or nuclear reaction (Craig, 2018:12). CSP is distinct from PV in that PV generates electricity at midday, experiences

a drastic decline throughout the course of the day, until it ceases production at night, necessitating expensive battery storage (World Bank, 2021).

In the light of the above, CSP has many benefits for SA's energy transition since it can also serve as baseload like traditional fossil fuel plants. South Africa has already committed to the fight against global warming and without CSP implementation we will not be able to achieve this. Figure 2.4 below shows the sharp increase of global projections for TES technology needed in order to align with the Paris Agreement.

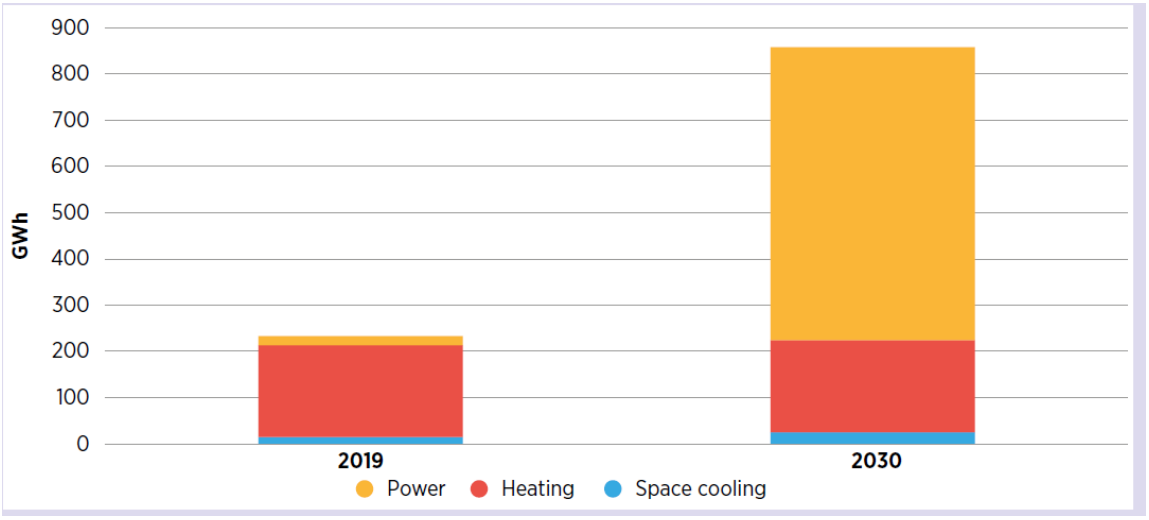

Figure 2.4 – Global projections for TES technology
Source: IRENA (2020:19)

Another advantage of TES is that the heat can also be used for purposes other than generating electricity, making it even more economically viable when compared to other RETs (Jayathunga *et al*., 2023:132). Heat from CSP can be used for district heating systems, industrial process heating, and water desalination (Jayathunga *et al*., 2023:132). Desalination is a technique used to remove salt from sea water, converting it into safe portable and usable water (Thimmaraju *et al*., 2018:333). Desalination is increasingly becoming crucial due to the global shortage of fresh water (Thimmaraju *et al*., 2018:334).

As explained by González-Roubaud *et al*. (2017:136), TES can solve the mismatch between solar energy supply and electricity demand by (i) mitigating short fluctuations during unstable weather conditions, (ii) shifting the generation period to peak hours when energy demand is high, and (iii) extending the generation period when solar resources are unavailable, thereby acting as baseload power. Yousef *et al*. (2021:1099) also argue that, instead of comparing PV and CSP, these technologies can be integrated to complement each other. This will (i) assist in reducing

costs, (ii) provide dispatchability and reliability, (iii) provide flexible operations, and (iv) lead to greater utilisation of power generating equipment.

2.6.5 Legal factors

The countries most successful in applying CSP have proven that this technology needs support from government through legislation in order to compete with other RETs. This support includes investment in R&D, regulated quantities of generated electricity, and regulated prices (World Bank, 2021). Most countries are currently updating their policies to promote the development of RE and to ensure a balanced approach to the energy transition. The ultimate aim is to achieve their commitment made to the Paris Agreement (Seetharaman *et al.*, 2019:2).

The IRP was set out in October 2019 to provide the SA government with a plan for energy infrastructure. The IRP allocated about 6 000 MWh of new PV, 14 400 MWh of wind to be commissioned by 2030, and 600 MWh of CSP technology (World Bank, 2021). The allocation of energy production by technology shows the level of biasness from our government. As mentioned previously, energy experts have raised concerns regarding the IRP's omission of CSP technology beyond 2030 (DE, 2019b). Pressure from stakeholders have also emphasised the need to revise the IRP. Revision was supposed to be completed by March 2023, a deadline that has been missed by the Department of Mineral Resources and Energy (Steyn, 2023).

Seetharaman *et al.* (2019:2) argue that, for RETs to be successful, certain regulatory barriers should be dealt with, including a lack of strong national policies, bureaucratic and administrative hurdles, inadequate incentives, impractical government targets, and a lack of standard certification. The government has further been criticised for vesting too much power in the energy minister, for instance, in choosing which RETs should be implemented. This has created red tape and has led to the country not meeting targets in terms of the implementation of RE projects.

As indicated by Renaud *et al*. (2020:13), our country has a highly regulated electricity sector, which makes it extremely difficult for businesses or investors other than Eskom to generate their own electricity and sell to other entities outside Eskom or to the grid. The ERA was the first piece of legislation allowing private participation in the power sector (Renaud *et al*., 2020:13). Impractical government targets were set, for example, that the government would revise the IRP document every two years after its inception in 2010, while the 2013 and 2016 changes were only finalised in 2019 (Steyn, 2023). Potts and Walwyn (2020:11) also note that different sectors of government pursue their own policies to support their plans without considering synergy with other departments. All of this creates misalignment and regulatory gaps.

The current costs of CSP seem higher than those of other RETs, but its benefits with regard to storage capabilities outweigh the costs. These benefits can be realised through government support via incentives, loans, tax exemptions, and cost base compensation (World Bank, 2021). CSP's economic viability also depends on the need for government to support the R&D of this technology to ensure that local companies are able to compete with international companies (Craig *et al*., 2017b:1). Enforcement of localisation policies by government will also lead to reduced imports of material, which, in turn, will create more opportunities for local companies to compete with their international counterparts (Craig *et al*., 2017b:1).

2.6.5.1 Government commitment

The SA government's commitment to the Paris Agreement implies that it has to devise a robust strategy for a JET. This would mean a move away from our current energy production which is dominated by coal. Such a JET will take time and requires strong political will from the government (Nel, 2015:59). The rollout of ministerial determinations to procure energy in terms of Section 34 of the ERA is a signal that the government is committed to RE deployment. However, this commitment should also be reflected in the revision of the IRP document every two years, as well as in the re-revisit of technology allocation, which should be aimed at stabilising the national grid (Renaud *et al*., 2020:1).

It should be mentioned, though, that, in 2015, RE procurement came to a standstill due to contradicting statements from ministers and the absence of ministerial determinations, until February 2020 (Renaud *et al*., 2020:13). These delays were also caused by Eskom which refused to enter into PPAs with IPPs in 2015 – issues that were resolved only in 2018 (Renaud *et al*., 2020:13).

Mr Ramaphosa has made commitments to the wealth nations that SA will continue to pursue our commitments to the Paris Agreement. In this regard, these nations have pledged about R155 billion to support the country towards a JET. It is currently not clear how this funding will be received, or how SA government will spend these funds (Cocks, 2022). The fact of the matter is that our government will need a total of R850 billion for the next two decades to fund the energy transition and it is unclear where the shortfall amount will come from.

CSP projects need support / funding to be able to compete successfully with other RETs. This has been proven essential in countries with successful CSP deployments (Xu *et al*., 2022:1334). A strong commitment from the government and support for CSP technology through tax incentives, FIT, and subsidies make CSP technologies more competitive and economically viable than other RETs. Investors and funders of CSP projects need clear guidelines from the government in terms of how CSP support will be provided by government. In the absence of

proper support from government, investors and funders will continue to favour wind and PV which currently have a lower LCOE when compared to CSP (Yasin & Draidi, 2020:253).

2.6.5.2 Structural reform

Governing and reforming the SA electricity industry are proving to be an enormous challenge. One of the reasons might be that this industry is characterised by various vested interests from different stakeholders, which hamper policy regulation and planning (Baker & Phillips, 2019:4). This is why the REIPPPP has been delayed by stakeholders like Eskom, who refused to sign up for IPP projects in 2015. This was not in line with the IRP programme and the government's instructions for Eskom to embark on the IRP programme. However, Eskom argued that it was too expensive (Miller, 2016).

The adjustments made to the generating licences threshold from 1 MWh to 100 MWh have opened doors to more opportunities for CSP since IPPs can now be generated up to 100 MWh with suppliers not having to apply for a generating licence (IEA, 2023). This also means that the DE will have to revisit the IRP document and consider adding more CSP capacity until 2030 and beyond (DE, 2019b:95). The main reason for less allocation of CSP in the IRP is the cost of CSP, which is currently very high when compared to PV and wind when the LCOE cost model is applied. However, this model does not factor in the storage capabilities of CSP technologies, which is why government support and reforms are needed (Xu *et al*., 2022:1329).

The implementation of reforms in the country is intended to change the structure of the economy to reduce input costs and barriers to entry, while increasing competition to create new opportunities for inclusive growth, investment, and employment (NPC, 2022). The programme launched by the government, Operation Vulindlela, focuses on reforms and can be seen as a sign of commitment towards the acceleration of reform. However, Operation Vulindlela's progress has been questioned by the IMF (2023), which indicates that the obstacles to private sector investment should be removed and competition to reignite economic growth should be encouraged. This links with the concerns raised by energy experts regarding the non-allocation of CSP technologies after 2030, as mentioned previously (DE, 2019b:64).

2.6.6 Environmental factors

2.6.6.1 Greenhouse gases, water, plants, and wildlife

GHG is defined as any gaseous compound that is capable of absorbing infrared radiation by trapping and holding heat in the atmosphere (Lallanilla & Means, 2022). Infrared radiation, also

referred to as infrared light, is radiant energy that is invisible to the human eye but can be felt as heat. All objects in the universe emit some level of infrared radiation (Lucas, 2019).

Two of the most obvious sources of radiation are the sun and fire (Lucas, 2019). Some atmospheric gases would absorb and re-emit this infrared radiation down to the earth's surface, in a process called the greenhouse effect (WMO, 2022). The greenhouse effect leads to a mean surface temperature that is 33 degrees Celsius higher than it would have been if it were not there (Denchak, 2019).

Earth has a natural greenhouse effect due to trace amounts of water vapour, carbon dioxide, methane, and nitrous oxide in the atmosphere (WMO, 2022). In general, the greenhouse effect is beneficial because it warms up the planet to comfortable average temperatures to support life. Without it, the earth would be a freezing and uninhabitable place.

The main risk, however, comes when greenhouse gases are amplified by human activities which disturb the natural greenhouse effect, leading to abnormal temperatures experienced on earth (Lallanilla & Means, 2022). Higher concentrations of GHG and carbon dioxide cause extra heat to be trapped and global temperatures to rise (Denchak, 2019). Human activities mostly responsible for this are deforestation and those driven by the burning of fossil fuels like coal, oil, and gas for electricity, heat, and transportation (Denchak, 2019). The rise in temperatures has reached its peak in 2016, being the warmest year on record (Lallanilla & Means, 2022).

CSP generation has proven to be more environmentally attractive than traditional fossil fuel power plants and other RETs (Matos *et al*., 2022:1). CSP has little environmental impact with almost no GHGs during operations (Moyo *et al*., 2017:5). Furthermore, solar energy has proven to have a low emission footprint: fossil fuel emits between 1.4 and 3.6 pounds of carbon dioxide per kWh, gas emits between 0.6 and 2 pounds of carbon dioxide per kWh, while solar energy emits between 0.07 and 0.2 pounds of carbon dioxide per kWh (Moyo *et al*., 2017:6). Carbon dioxide is responsible for over 60% of GHG emissions, the largest contributor to climate change, and has become a serious threat to energy supply (González-Roubaud *et al*., 2017:133).

The Paris Agreement supports net-zero carbon by 2050. In order to achieve this, the signatories would need between USD100 billion and USD500 billion from 2010 to 2030. Using environmentally friendly fuels can play a role in mitigating GHGs and, in turn, favour economic growth (Aman *et al*., 2015). From 2011 to 2012, a 2.1% increase in global energy consumption was experienced, and 2.4% average increase from 2000 to 2012. A rise of 56% total world energy usage has been projected from 2010 to 2050 (Aman *et al*., 2015:1191).

The current energy needs are dominated by fossil fuel technologies, which, as established above, emit high amounts of GHGs in the atmosphere, creating climate change challenges (Global Climate Change, 2023). Harnessing the energy from the sun can lead to the reduction of GHG, stabilisation of graded land, increased energy independence, job opportunities, rural electrification, and improved quality of life (Global Climate Change, 2023). This means that there is a need to mitigate climate change, safeguard energy security, and increase the sustainability of human activities, all of which prompts the need for a rapid transition from carbon intensive fuel to RE. Solar energy has great potential through PV and CSP technologies (Craig, 2018:12).

Increasing the contribution of renewables like CSP technologies, is imperative towards lowering global GHG emissions and meeting climate goals (Kommalapati *et al*., 2017:2). Solar energy is a free and abundant resource from which electricity can be generated (Kommalapati *et al*., 2017:2). As mentioned before, CSP has proven to be more environmentally attractive than fossil fuel technologies and provides GHG emission mitigation opportunities (Matos *et al*., 2022:1). CSP has, however, received criticism, which will be discussed below.

One point of critique is the fact that CSP currently uses more water when compared to coal, nuclear, and gas, but dry cooling can reduce water usage significantly (Bošnjaković & Tadijanović, 2019:69-70). Employing dry cooling in CSP technology can also reduce water usage by about 80% during the life cycle of a CSP plant, although dry cooling is ineffective in areas with temperatures above 38 degrees Celsius (Bošnjaković & Tadijanović, 2019:70).

The TES system has been criticised for emitting GHGs through its usage of molten salts and pipes (O'Leary, 2019). The criticism is based on the limitation of using salt for storing heat within certain temperature ranges and in the absence of alternative heating options. O'Leary (2019) claims that changing from steel pipes to ceramic pipes can enable higher temperatures. Aman *et al*. (2015:1198), however, found that the dry cooling methods used in CSP technologies increase costs. Bošnjaković and Tadijanović (2019:70) concur by stating that these costs can increase by 10% for capital costs and 1.5% for power consumption costs, which push the LCOE up by 7.5%. But Hernandez *et al.* (2014:770) argues that these costs can be offset by about 87% up to 227% over a 20-year period.

CSP plants need to be located in areas where there is high DNI, which might further create challenges for land use. Yet, again, as argued by Hernandez *et al.* (2014:774), there is about 25% of land globally that is being degraded. Using this land could lead to proper rehabilitation and additional usage for other activities such as agriculture which, in turn, will aid in food security.

The construction of CSP plants causes soil erosion, which might create challenges for biodiversity unless proper rehabilitation is done during the operation of the plant. One example of these challenges is the occurrence of birds mistaking the mirrors used in CSP plants for bodies of water, leading to injury and mortality (Hernandez *et al.*, 2014:769). Also, the tall towers of SPT technology have faced criticism for causing bird collisions, impacting air-traffic control, and visual disturbance for nearby community members due its reflection of sunlight. However, it has been demonstrated that the benefits of CSP technologies outweigh the costs (Hernandez *et al.*, 2014:769).

Another concern regarding birdlife has been raised by Jenkins *et al*. (2017:3). CSP plants affect their habitat and many bird populations become displaced. CSP hardware and ancillary infrastructure have also been shown to cause collisions and burn injuries. This challenge can be addressed by conducting a proper environmental assessment before and during construction and monitoring during operations since, in most plants, it has been noted that birds and other species become accustomed to, for example, the CSP mirrors (Jenkins *et al*., 2017:3).

In spite of the above criticism, materials can easily be recycled and re-used in CSP plants (Craig, 2018:12). CSP can be an important contributor to the decarbonisation of global energy systems due to minimum carbon emissions per unit of energy generated. CSP is renewable and clean, plentiful, and cheaper when TES is used, and requires less maintenance and is environmentally friendly.

2.6.6.2 Geographical considerations

It is projected that, by the year 2030, 42% of global energy will be RE. This means that a large area of land will be needed to deploy RETs in regions where there is adequate wind and sunshine and high DNI (Craig *et al*., 2017a:14). From 2010 to 2040, the global energy demand is projected to increase by 56% (Craig *et al*., 2017a:14). Gross (2020:1) indicates that wind and solar generation are more land intensive and need to be widely distributed, which would require about 10 times as much land per unit of power produced than coal or natural gas power plants. This challenge requires governments to ensure proper planning and zoning, converting brown fields or degraded agricultural land, facilitating rooftop solar, and expanding transmission infrastructure (Gross, 2020:1).

RETs rely on areas where the source of energy can be harnessed. This is in contrast with fossil fuel technologies that can be deployed in strategic areas, ideally, remote and far away from communities. This, however, creates challenges since RETs, like PV and CSP, will have to be deployed in areas of land where there is enough sunshine and high solar irradiation, which might be close to communities but far from transmission power lines (Hernandez *et al*., 2014:771).

Land scarcity has become a global problem because some technologies might have to be deployed in agricultural land, impacting food security. But, as argued by Hernandez *et al.* (2014:771), reducing the distance between rows of PV modules and mirrors for CSP technologies and deploying them in remote areas can create more space for deployment. For CSP technologies to be economically viable, governments need to create a conducive environment by ensuring that proper policies are put into place for land use. These policies should protect the communities in which the technologies are deployed, as well as private sector participants and other stakeholders, like non-governmental organisations.

Besides having the highest level of solar radiation in Africa, the Northern Cape has an abundance of land, most of which is flat, making it ideal for the application of CSP technologies (Craig, 2018:25). South Africa's annual DNI is around 2 816 kWh/m^2/per year in the Northern Cape. This is higher than in Spain, who is currently the global leader of installed CSP generation capacity. The DNI for SA indicates that there is a huge potential for CSP deployment.

2.8 Economic viability and Cost-benefit analysis

2.8.1 Cost-benefit analysis

A Cost-benefit analysis (CBA) is the process of comparing the projected costs to the expected benefits of a project (Stobierski, 2019). For the purposes of this study, CSP is regarded as a project. As mentioned in paragraph 4.2.2, CBA is used in conjunction with capital investment appraisal techniques to assist in evaluating the economic viability of (new) power generating technologies/methods as well as for energy transition projects (transition from pre-existing traditional energy systems to RE technology systems) (Gudlaugsson *et al*., 2021:1).

The main purpose of CBA is to determine whether a project or investment is sound, justifiable, and feasible, presenting a baseline to indicate which of the benefits of the project are greater than the costs (Landau, 2021). This purpose also assists decision makers (investors) to gain a comprehensive understanding of the potential economic expenditure and economic gains associated with the project under evaluation (Gudlaugsson *et al*., 2021:1).

Gudlaugsson *et al*. (2021:1) further clarifies that CBA should be based on an overall assessment of a project, by considering all costs and benefits. These costs and benefits are determined by (i) identifying all costs and benefits of the evaluated project, (ii) quantifying these identified costs and benefits in monetary terms, and (iii) calculating net result of the costs and benefits (Stobierski, 2019).

When alternative investment opportunities are analysed and compared, CBA assists in identifying the most cost-effective investment alternative (Landau (2021).

A project (or investment) is considered economically viable when the project yields a positive net economic contribution to society after all costs and benefits have been accounted for. In other words, a project is economically viable when the economic benefits of the project exceed the economic costs., consequently benefitting the society. Although the Hydrogen Sustainability Alliance (2023) states that all financial, social, and environmental costs and benefits should be included in a CBA, all costs and benefits (whether direct or indirect) of relevant political, technological, and legal factors should logically also be identified and included. However, the above statement made by the Hydrogen Sustainability Alliance (2023), could (i) include political costs and benefits with social costs and benefits since political factors ultimately impacts social factors, (ii) include technological costs and benefits with financial costs and benefits, (iii) include legal costs and benefits under other factors where it is expected to incur, e.g., financial, social, and environmental factors.

A CBA will ultimately be performed as part of a PESTLE analysis' economic factors, although it will consider relevant costs and benefits of all PESTLE factors, to determine and evaluate the economic viability of CSP as RE source.

2.8.1.1 Advantages and disadvantages of a Cost-benefit analysis

Advantages of a CBA includes the following: (i) a CBA simplifies complex decision making in projects, (ii) a CBA assists in uncovering or identifying a project's hidden costs and benefits, (iii) a CBA ensures the unbiased selection of projects, and (iv) a CBA considers cost and benefit items not having market costs/prices that would normally be neglected with traditional project evaluation processes (Goel & Sharma, 2022).

Disadvantages of a CBA (due to its limitations), as indicated by Stobierski (2019), include: (i) difficulty in identifying and predicting all relevant variables, in which case, incorrect data may distort results, (ii) CBA is mostly suitable for short to medium term projects (although CSP projects are long term projects, covering a lifetime between 20 and 30 years) due to changes in inflation and interest rates (Landau, 2021), (iii) conventional CBA (i.e., only focusing on monetary values of costs and benefits), neglects qualitative "costs" and "benefits".

2.8.2 Cost-benefit analysis for CSP as RE source

CSP plants' benefits outweigh its costs, especially when considering combatting climate change and SA's commitment to the Paris Agreement (implicating SA's commitment to transition from traditional (outdated) non-renewable resources to renewable resources (RE) sources as basis electricity generation (Renaud *et al*., 2020:24). As emphasised by Fatima *et al*. (2021:1), extensive research has indicated that RE technologies do indeed (i) minimise the depletion of

non-renewable energy resources (e.g., coal), (ii) ensures sustainable electricity generation and supply, and (iii) substantially reduce GHG emissions.

CSP plants' primary benefit is the possibility to generation additional revenue when a TES systems are incorporated into CSP plants. Another major benefit of CSP plants is CSP's ability to enhance grid stability by dispatching generated electricity to the grid as and when required. Another benefit of CSP plants is CSP's capability to provide varying temperature heat for industrial processes and water purification activities (which can be used in CSP plants itself) (Zhou *et al*., 2019:1), is yet another benefit of CSP plants.

The operations and maintenance cost of CSP plants are currently ranging between USD20/MWh and USD40/MWh, consisting of insurance costs, annual operational costs (ranging from 0.5% to 1% of the initial capital outlay, excluding maintenance costs), and maintenance costs (primarily represented by mirror cleaning cost and mirror replacement cost) (Reuters Events, 2018).

The main concern about CSP plants is the required initial capital investment which is very high in comparison to other RE technology projects (e.g., wind and PV). Higher investment consequently incurs higher financing costs. Higher financing costs will, as a result, negatively impact CSP's positive net economic contribution to society. On the other hand, CSP plants' benefits completely outweigh its costs, possibly leaving room to absorb increased financing costs.

However, required investment in CSP plants has drastically declined over the past years. Actual investment in the KaXu Solar One project amounted to USD891 million (operations commenced during 2015), while budgeted investment in the Redstone project amounts to USD210 million (operations planned to commence towards the end of 2023). This decrease in CSP's investment cost is very encouraging for investors, while challenging the decision of the SA government's not to invest in further projects after the Redstone project is completed.

2.9 Economic viability and SWOT analysis

2.9.1 SWOT analysis

The acronym SWOT analysis is used for Strengths, Weaknesses, Opportunities and Threats analysis. a SWOT analysis identifies and describes a project's (or investment's) anticipated strengths, weaknesses, opportunities, and threats that may feature in achieving a project's objective over its expected lifetime (Lupu *et al*., 2016:4). Strengths and weaknesses are typically internal attributes of the project, while opportunities and threats are typically external attributes within a project's environment.

Igliński *et al*. (2021:6) and Uhunamure and Shale (2021:6) further explains a SWOT analysis's components as follows:

- **Strengths** – are the project's characteristics giving the project advantages over other projects. Strengths may therefore, for example, provide a project with a competitive advantage/s, improved performance, and faster than projected growth.

- **Weaknesses** – are a project's characteristic shortcomings, placing the project at a disadvantage to other projects (e.g., low profitability, operational inefficiency, etc.).

- **Opportunities** – are external factors (opportunities) presented due to conditions in, and/or by participants in the project's environment in which it operates. Such opportunities could (and should) be exploited to the project's advantage.

- **Threats** – are external factors (threats) presented due to conditions in, and/or from participants in the project's environment in which it operates. Threats typically poses danger in some form for the project, potentially negatively influencing, for example, a project's performance, success, or even existence.

In doing a SWOT analysis, the identification, description and analysis of its components should incorporate a critical thinking process to identify potential strategies on how: (i) strengths can be built on to the project's advantage, (ii) opportunities can be exploited/utilised to ultimately present new strengths or to supplement existing strengths (and vice versa), (ii) weaknesses can be eliminated, or the influence thereof on the project at least be minimised, (iii) threats can be managed to ultimately minimise its probability and/or negative impact on the project (Lupu *et al*., 2016:4).

2.9.2 SWOT analysis and the evaluation of economic viability

The advantage of a SWOT analysis is that it presents useful information on expected future performance and viability of projects, considering both internal and external qualitative factors that may influence the economic viability of a project. (i.e., strengths and weaknesses being internal factors, and opportunities and threats, external factors).

Identifying and listing a projects' anticipated strengths, weaknesses, opportunities, and threats may also assist in the identification of a project's costs and benefits, being unidentified or overlooked at this stage. These identified anticipated strengths, weaknesses, opportunities, and threats may also have associated costs and benefits that should be considered in the Economic factors and Cost-benefit analysis. An example is the incorporation of TES into CSP, is unique to

CSP, providing CSP with a competitive advantage over other RE technologies. This strength has both cost implications (implementation cost and increased operating and maintenance cost, etc.) and benefits (increased electricity generation capacity and increased revenue, etc.). (TES and CSP is discussed in chapter 5, paragraph 5.3.1.4).

2.10 Summary

Chapter 2 provided the literature review, addressing the first secondary objective, namely, to conduct a literature review to obtain a comprehensive understanding of the economic viability and suitability (especially in an SA context) of CSP. Economic viability involves the evaluation of all monetary and non-monetary aspects to ensure that a project's total benefits exceed the total costs. The economic viability definition from the literature review assisted to derive the determinants of economic viability, namely, the political, economic, social, technological, legal and environmental factors which constitutes a PESTLE analysis. Investors in electricity generation projects uses Cost-benefit analysis to supplement PESTLE analysis in evaluating the economic viability of RE projects, while it has been indicated that a SWOT analysis could also be fruitfully used to supplement the evaluation of the economic viability of RE projects.

With regard to capital investment appraisal techniques, LCOE is the preferred technique for electricity generation investment projects, although investors have criticise the LCOE for not factoring in TES in LCOE's formula and consequently undervaluing CSP projects having TES capability integrated.

The most dominating factors for CSP's economic viability under a PESTEL analysis is the (i) environmental benefits by CSP of minimal GHG emissions to the atmosphere, the (ii) technological capabilities of CSP to store energy and continue to generate electricity after the sunset, and (iii) political instability in South Africa resulting to the government excluding CSP development beyond 2030. Under the CBA, the main dominating costs of CSP is the high initial capital outlay which makes it difficult for CSP to compete with wind and PV. The dominating benefit is additional revenue generated through peak production by the TES system's stored energy. The main strengths of CSP plants are the TES system capabilities for storing energy, the weakness is high initial capital outlay and the complexity with regards to operations and maintenance. Opportunities include the high potential for CSP plants to generate high temperatures in the future which will result in increased production and revenue. CSP technology faces a threat from PV due to future battery storage which can compete with TES.

From the literature, it is clear that CSP technologies provide a unique service of energy storage through TES which is not provided by any other RET. With these storage capabilities, CSP can

provide clean energy round the clock similar to the traditional fossil fuel generating assets. This is what makes CSP economically viable as a renewable source.

3. CHAPTER 3: RESEARCH METHODOLOGY AND DESIGN

3.1 Introduction

Chapter 3 addresses the second secondary objective of the study, which is to design an empirical study to collect sufficient, relevant, and trustworthy data in order to determine whether CSP (in an SA context) could be a viable RE source. This chapter outlines the research methodology and design that were used to define the nature of the research and the specific procedures and techniques applied to identify, select, process, and analyse the information gathered.

Chapter 3 starts by identifying research paradigms and indicates which paradigm was followed in the study. Research approaches are then discussed, focusing on the reasons why certain approaches were chosen for the study. Various aspects will be explained with regard to research design and methodology, followed by ethical considerations and a chapter summary.

Research methodology involves a particular, logical way of doing research, supported by relevant assumptions, to address a research problem (Patel & Patel, 2019:48). Research methodology is the science of studying how a research problem can be addressed scientifically (Patel & Patel, 2019:48). This entails an understanding of research perspectives, approaches, beliefs, and philosophies, which should be differentiated from research methods which encompass the techniques for data collection such as questionnaires, interviews, and focus group discussions (Sakyi *et al*., 2020:296).

3.2 Research paradigm

For consumers of research work, it is crucial to understand the researcher's claims and world view (Ugwu *et al*., 2021:116). Research is expected to meet certain criteria and be based on the relationship between research paradigms and methodological choices made throughout the process (Ugwu *et al*., 2021:116). When a specific paradigm is followed within a piece of research, it becomes easy for the researcher to make informed methodological choices, regarding, for example, research approaches, designs, and methods (Ugwu *et al*., 2021:116).

A paradigm is a basic belief system and provides a theoretical framework with assumptions about ontology, epistemology, methodology, and methods (Rehman & Alharthi, 2016:51). Khatri (2020:1435) describes a paradigm as the researcher's world view, while Kivunja and Kuyini (2017:26) defines it as a philosophical way of thinking, a basic set of beliefs, and a world view that guides research action and/or an investigation. The world view that Kivunja and Kuyini (2017:26) mention refers to (i) the perspective, (ii) thinking, (iii) school of thought, and (iv) a set of shared beliefs, all of which inform the meaning or interpretation of research data. A paradigm is regarded by Khan (2014:224) as a framework or a set of assumptions that explain how the world

is perceived, including basic assumptions, the important questions to be answered or puzzles to be solved, the research technique to be used, and examples of what scientific research looks like.

Siddiqui (2019:255) defines a research paradigm as a cluster of beliefs and dictates which, for scientists in a particular discipline, influence what should be studied, how research should be conducted, and how the results should be interpreted. A paradigm implies the philosophical position of researchers about the nature of a matter, about what can be known, and about how this knowledge can be attained (Siddiqui, 2019:255). The following paragraphs (3.2.1 and 3.2.2) explain in detail the concepts of ontology, epistemology, positivism, and interpretivism, and draw a conclusion on the assumptions used in this study.

3.2.1 Ontology and epistemology

Ontology is the nature of reality, being, existence, or humanity, and provides an understanding of the things that constitute the world as they are known, as well as what human beings can know about reality (Khatri, 2020:1436; Kivunja & Kuyini, 2017:27; Rehman & Alharthi, 2016:51). Antwi and Hamza (2015) add that ontology involves the assumptions concerning the nature of knowledge or reality or the way the researcher defines truth and reality.

The assumptions made by the researcher on the data gathered is crucial to the nature of reality (Ugwu *et al*., 2021:118). Ontology provides an understanding of the things that constitute reality (Ugwu *et al*., 2021:118). When it comes to research, ontology primarily relates to fundamental concepts constituting the themes that need to be analysed with the aim to make sense of the meaning embedded in the data collected (Ugwu *et al*., 2021:118).

Epistemology, on the other hand, pertains to the nature and theory of knowledge that inform the research. It also relates to the relationship between the knower and what is known and involves how knowledge is gained from different sources (Khatri, 2020:1437). Epistemology includes views on truth and legitimate knowledge, as well as the process in which the researcher comes to know the truth and reality (Antwi & Hamza, 2015:219).

From these definitions, knowledge seems to be the cornerstone of epistemological assumptions. Kivunja and Kuyini (2017:27) identify four types of knowledge that can be gathered: (i) intuitive knowledge, (ii) authoritative knowledge, (iii) logical knowledge, and (iv) empirical knowledge. Intuitive knowledge relies on beliefs, faith, and intuition, while authoritative knowledge is derived from data gathered from knowledgeable people, books, and leaders in organisations. Logical knowledge puts emphasis on reason being the surest path to knowing the truth, while empirical knowledge emphasises the understanding that knowledge demonstrates objective facts and is best derived through the senses and experiences (Kivunja & Kuyini, 2017:27).

This study is based on epistemological assumptions related to empirical knowledge and the gathering of data through semi-structured interviews using open-ended questions. The study involved interaction with participants, face to face or through other platforms convenient to the participants. This is different from using ontological assumptions favouring a distance between the researcher and the entity being examined.

3.2.2 Positivism and interpretivism

Positivism is a world view in research that is grounded in what is known as the scientific method of investigation (Kivunja & Kuyini, 2017:30). This method involves experimentation, observation, and reason. It is based on experience, facts, and measurable entities and relies on deductive logic and the formulation of hypotheses (Kivunja & Kuyini, 2017:30).

Positivism assumes that reality exists independently of humans and is not mediated by our senses, but governed by immutable laws (Rehman & Alharthi, 2016:53). Positivists assume that there is no objective knowledge that is independent of thinking and reasoning by humans (Shah & Al Bargi, 2013:257). Positivists also strive to understand the social world the same way one can understand the natural world. The belief is that, in nature, there is a cause-and-effect relationship between phenomena and, once established, this can be predicted with certainty (Shah & Al Bargi, 2013:254).

Positivists further believe in the possibility of discovering truth since human behaviour is predictable, which is caused by both internal pressures and external forces which lead to the fact that knowledge reflects what is out there (Kamal, 2019:1391). Positivist assumptions are more suitable for verifying hypothetical theories or models that already exist or are newly discovered. These verified theories will then emerge as new pieces of knowledge (Park *et al*., 2020:4). Positivism is a grounded world view and is primarily used to generalise theories or models as a sort of law through some means of verification. This does not mean that new theories cannot be generated (Park *et al*., 2020:4).

The positivist paradigm has been criticised by many scholars for its failure to differentiate the social sciences from the natural sciences and for dealing with human beings like any other natural object (Shah & Al-Bargi, 2013:256). Some researchers have even argued that the positivist approach is no longer valid in modern research (Rehman & Alharthi, 2016:53).

Interpretivists, on the other hand, explore individuals' perceptions, share their meanings, and develop their insights about an observed case (Shah & Al Bargi, 2013:257). Unlike positivism, interpretivism aims to understand and interpret human and social science. It is concerned with subjective meaning, seeking to recognise the individual's interpretation and understanding of a

phenomenon. The belief is that researchers cannot distance themselves from the object being observed, the subject matter, and the methods applied in the study (Shah & Al Bargi, 2013:257).

Interpretivism was established to respond to positivism's dominance over the years and rejects the notion that a single, verifiable reality exists independent of our senses (Rehman & Alharthi, 2016:55). Interpretivists believe in socially constructed multiple realities. This implies that truth and reality are created and not discovered; it is not possible to know reality because it is always mediated by our senses (Rehman & Alharthi, 2016:55).

Interpretivist researchers mostly use verbal instead of statistical data. They employ methods that generate qualitative data and, although numerical data can be involved in these studies, they are not relied upon (Rehman & Alharthi, 2016:56). Interpretive research is also called qualitative research, which is in line with this study which followed a qualitative method of research (Quinlan, 2017:1).

Based on the above discussion, this study can be characterised by an interpretation of words (rather than numerical numbers) which were used as part of data gathering from participants. The interpretive approach was found to be more suitable than a positivist approach due to the fact that there are many factors that might have an effect on CSP's economic viability.

This study identified patterns and made inferences and did not start from pre-determined concepts. Therefore, the study applied inductive reasoning and not deductive reasoning. Inductive research is not based on a hypothesis that needs to be proven, but new knowledge might be acquired from the research. This is the reason why this study followed inductive rather than a deductive reasoning (Askarzai & Unhelkar, 2017).

As indicated by Park *et al*. (2020:6), inductive reasoning is mostly suitable for qualitative research and other scholars refer to it as constructivism. Adom and Ankrah (2016:2) define constructivism as an approach that believes that people construct their own knowledge and understanding of phenomena through experience and reflecting on their experience. Researchers applying inductive reasoning would commonly obtain knowledge from a literature review and collect and analyse qualitative data. From this, they will develop a new theory or model as new knowledge based on the new understanding (Adom & Ankrah, 2016:2).

Deductive reasoning, as indicated by Park *et al*. (2020:5), is mostly used by positivists. It is based on existing knowledge by formulating hypotheses and theories which are verified by using many quantifiable data points. If the validation of the theory is satisfactory, the theory will be considered law-like, while, if not satisfactory, the overall research will be deemed as new knowledge.

With regard to research objectives, this study followed an epistemological assumption related to interpretivism with a focus on inductive reasoning since the research did not start from a specific concept or theory. Instead, a literature review was conducted (Chapter 2), on which the data collection was based. From the literature, semi-structured, open-ended questions were formulated for the interviews with the participants. By conducting interviews, the researcher was able to enter the world of the participants, and their interpretation of their reality formed the basis of the study. The study collected verbal data rather than statistical data, and new truth and reality were created and not discovered.

3.3 Research methodology

Research methodology is a systematic way of solving a research problem. It is also understood as the science of studying how research can be done scientifically (Patel & Patel, 2019:48). In research, the methodological steps followed by a researcher are studied to uncover the logic behind these steps; hence it is crucial for the researcher to be familiar with both concepts of research “methods” and “methodology” (Patel & Patel, 2019:48).

The three most prominent research methods are (i) qualitative, (ii) quantitative, and (iii) mixed method research. Up until the 20th century, the quantitative method has been dominant in the study of natural science such as biology, chemistry, physics, and geology, which are concerned with investigating phenomena that can be observed and measured (Tubey *et al*., 2015:224).

Researchers within the social sciences became dissatisfied with having to use quantitative methods for generating knowledge. The argument was that the aim of research should be to understand the meaning that events have for the phenomena or objects being studied (Hameed, 2020:11). They started to explore alternative methods of research, from which qualitative methodology developed. Thus, in short, qualitative research attempts to increase the understanding of why things are the way they are in the social world and why people act the way they do.

Sakyi *et al*. (2020:296) confirm that researchers should be able to differentiate between methods of research and methodology. Methods relate to data collection instruments such as questionnaires, interviews, and focus group discussions, while methodology relates to research perspective, approaches, beliefs, and philosophies. This study followed the epistemological assumption that is related to interpretivism using a qualitative methodology. The following paragraph will explain quantitative, qualitative, and mixed methods of research.

3.3.1 Quantitative, qualitative and mixed methods of research

(i) Quantitative research

Quantitative research produces data that can be statistically analysed and whose results can be expressed numerically (Aliyu *et al*., 2015:17). According to Bhawna and Gobind (2015), quantitative research can be viewed as a systematic empirical investigation of observable phenomena via statistical, mathematical, or computational techniques with the objective of developing and employing mathematical models, theories, and/or hypotheses pertaining to phenomena.

A concise definition of quantitative research has been proposed by Maree *et al*. (2019:184), namely that it is a systematic and objective process of using numerical data from a selected subgroup of the relevant population to generalise the findings to this population. Quantitative research is characterised by objectivity, numerical data, and generalisability (Maree *et al*., 2019:184).

Quantitative methods have been portrayed as superior to qualitative methods. Qualitative researchers have opposed this notion with the counterargument that there are certain social and behavioural research questions that cannot be answered by applying quantitative methods (Askarzai & Unhelkar, 2017:24).

(ii) Qualitative research

Shareia (2016:3839) defines qualitative research as “an approach to the study of the social world which seeks to describe and analyse the culture and behaviour of humans and their groups from the point of view of those being studied”. Qualitative research can be seen as an exploratory way of conducting social investigations that is concerned with understanding the complex interrelationships between different variables, whereas quantitative researchers are interested in explanation and control (Shareia, 2016:3839). Qualitative researchers believe that knowledge is constructed and not discovered as per quantitative researchers’ belief (Shareia, 2016:3839).

In qualitative research, the relationship between the researcher and the subject is a close one and the researcher is often seen as an insider. This provides a better view of the context being studied. In contrast, the relationship between a quantitative researcher and the subject is usually brief or non-existence, with the researcher seen as an outsider (Shareia, 2016:3839).

As explained by Mohajan (2018:2), qualitative research is a form of social action that stresses the individual’s interpretation and attempts to make sense of their experiences to understand their social reality. Qualitative research employs interviews, diaries, journals, classroom observation and immersion, and open-ended questionnaires to obtain, analyse, and interpret the data content analysis of visuals and textual material and oral history (Mohajan, 2018:2).

Qualitative research can also be regarded as exploratory due to the explanations it provides on how and why a particular social phenomenon or programme operates in a particular context. Khan (2014:225) adds that qualitative research is an inquiry process of understanding based on distinct methodological traditions of inquiry that explore a social or human problem. The researcher builds a complex, holistic picture, analyses words, reports details of informants, and conducts the study in a natural setting.

The current study identified patterns in data collections and applied qualitative data analysis techniques to make sense of the data. The study included an empirical investigation to enable the researcher to collect sufficient, relevant, and trustworthy data to determine whether CSP (in an SA context) could be considered a viable RE source. The decisions regarding which technology to be procured within the IPP programme are mostly made based on both human behaviour and decisions. This is the main reason why this study gathered and analysed data from participants using semi-structured, open-ended questions and qualitative data analysis methods.

(iii) Mixed methods

This research method interlinks both qualitative and quantitative elements to provide an integrated response to the research question – a response which is usually deeper than would have been possible with either method alone (Halcomb & Hickman, 2015:41). As indicated above, quantitative methods involve the collection and analysis of numerical data, whereas qualitative methods involve narrative or experiential data. Mixed method research refers to research that integrates both qualitative and quantitative data within a single study (Halcomb & Hickman, 2015:41).

According to Hafsa (2019:45), mixed method research is the collection, analysis, and integration of quantitative and qualitative data and can be conducted in a single or in multiple studies. In this research, the methods are combined at all stages of the study, from phrasing research questions, to sampling, to data collection, to analysis and, finally, to interpretation. Mixed methods offer the scope of blending various research design constituents to seek the best solution to the research problem (Hafsa 2019:45).

Mixed method inquiry can help researchers gain a more comprehensive understanding of the results and provide answers to a wide range of research questions (Fàbregues *et al*., 2020:2). Mixed method research is still in its infancy and while several such studies have been done recently, many have been criticised by scholars, arguing that mixed methods can lead to poor quality research (Askarzai & Unhelkar, 2017).

3.4 Research design – Empirical research

Maree *et al.* (2019:80) define a research design as "a plan or strategy that moves from the underlying philosophical assumptions to specifying the selection of participants, the data-gathering methods to be used and the data analysis to be done". Studies adopt this plan before any commencement of data collection so as to achieve the research objective in a valid way; in other words, the aim is to translate a research problem into data for analysis to provide relevant answers to research questions (Asenahabi, 2019:76). A research design should provide a proper plan, structure, and strategy of investigation to obtain answers to research questions with optimal control of variables (Asenahabi, 2019:78).

The selection of participants in this study was based on their knowledge of CSP technology. Therefore, this specific target population was used to ensure that fairly eligible participants were interviewed. Choosing the target population also ensured that the selected participants had the ability and opportunity to provide the most accurate information or data (Asiamah *et al*., 2017:81). Using this target population was in line with the sampling method of non-probability sampling. Semi-structured interviews were conducted with eight participants, at middle and senior management level, to provide more insight on CSP technologies.

To sum up, qualitative methods require the researcher to be close to the participants. In this study, face-to-face interviews (in person or using Zoom, Microsoft Teams, Google Meet and Skype according to the participants' preference), were conducted with the participants to gather data (Shareia, 2016:3839). The main objective of the study was to answer the research question rather than to generate or discover new theory. Themes and patterns were derived from the data set linked to the collected data (Majumdar, 2019:200). The study applied a thematic analysis for data analysis and interpretation, as explained later in the chapter.

3.4.1 Target population

A target population, as defined by Glen (2019), is the group of which the researcher wants to gain more understanding. The target population is expected to have specific attributes of interest and relevance (Asiamah *et al*., 2017:1612). The target population should be sufficiently exclusive so that participants who do not represent the study's needs and who might misrepresent the population of interest are not included. In other words, the target population should represent the group in such a way that the researcher and other stakeholders understand the nature and extent of this particular group (Casteel & Bridier, 2021:344).

The Northern Cape is the only SA province with CSP plants at the time of this study. There are seven CSP plants in the Northern Cape, of which one is under construction and planned to be commissioned later in 2023. The target population for this research comprised senior managers of two CSP plants who have strategic information and experience on the CSP technology. Senior managers would be able to provide both quantitative (financial) and qualitative information on CSP and assist in obtaining a balanced view in addressing the research objectives.

3.4.2 Sampling and sampling size

According to Taherdoost (2016:18), for research to be meaningful, data should be collected from a relevant, unique case since it is not possible to collect data from all cases. Researchers normally have neither the time nor the resources to analyse the entire population and apply sampling techniques to reduce the number of cases to be studied (Asiamah *et al*., 2017:1615). Thus, sampling is the method of selecting a representative subset of the population, called a sample, which makes the research work more accurate and economical (Showkat & Parveen, 2017:3).

Sampling methods are classified into two major methods: probability and non-probability sampling (Maree *et al*., 2019:214). Probability sampling, as defined by Mweshi and Sakyi (2020:185), involves the use of any strategy in which the sample is selected in such a way that every unit in the population has a known, non-zero, and equal chance of being selected. Probability sampling is based on the notion that people or events are selected because they are representative of the entire population. This method affords confidence to the researcher that the results will be accurate and unbiased, and it allows him to estimate how precise the data are likely to be (Mweshi & Sakyi, 2020:185). Acharya *et al*. (2013:330) define probability sampling as the gold standard in sampling methodology and emphasise that it ensures generalisability of the results to the target population.

In contrast, non-probability sampling uses non-randomised methods to draw a sample and involves the judgement of the researcher in purposefully selecting participants (Showkat & Parveen, 2017:7). In non-probability sampling, units do not have equal chance of being included (Pace, 2021:9). The non-randomised criteria are based on availability, geographical proximity, or expert knowledge of the individuals selected (Pace, 2021:9). In non-random sampling, the population parameters are normally unknown or not possible to individually identify (Pace, 2021:3). Sharma (2017) concurs by stating that this is a selective or subjective sampling method which relies on the researcher to select the units to be studied, unlike probability sampling, where all units have an equal chance of being included (Etikan & Bala, 2017:215). Non-probability sampling allows the researcher to generate valuable insights or develop new insights regarding

the phenomenon being studied. This sampling technique is considered less expensive, less complicated, and easier to apply than probability sampling (Showkat & Parveen, 2017:7).

According to Omona (2013:179), non-probability sampling can be seen as biased sampling, yet appropriate when the goal is not to generalise to a population but to obtain insight into a phenomenon, an individual, or an events, as is typically the case in qualitative research. Non-probability sampling has been identified as having a higher risk for research bias than probability sampling (Pace, 2021:8). As argued by Sharma (2017), applying non-probability sampling is not a good strategy when trying to prevent researcher bias, and the major disadvantage of this method lies in its subjective nature, especially when no clear criteria are used.

For the purposes of this study, non-probability sampling was found to be both practical and cost effective. Thus, certain individuals were selected who have knowledge of the CSP plants from both a strategic and operational point of view. Semi-structured interviews were conducted with four senior managers from each of the two CSP plants selected.

The other reason for choosing non-probability sampling was that it is more suitable for qualitative research and the individuals chosen are assumed to be “information rich” (Omona, 2013:179). Non-probability sampling does have some limitations, as emphasised by Maree *et al.* (2019:219). The method does not make use of random selection of the population and therefore one should take extreme caution with regard to drawing important conclusions about the population.

According to Maree *et al*. (2019:219-220), there are four non-probability sampling types:

(i) **Convenience sampling** – In this method, population units are selected based on the fact that they are easy and conveniently available. This is usually a quick and cheap method. The researcher typically selects the closest participants who are readily accessible or available (Showkat & Parveen, 2017:8).

(ii) **Quota sampling** – This type of sampling first categorises individuals required for the sample with pre-determined quotas. Convenience sampling is then applied until the quotas have been reached. As mentioned by Etikan and Bala (2017:215), individuals sharing the same characteristics are then approached to participate in the research. This process continues until the desired sample size is achieved.

(iii) **Snowball sampling** – This type of sampling is normally used in cases where it can be exceedingly difficult to find the population and requires making contact with one or

more individuals belonging to the population. From the people contacted, the researcher asks information about others with the same characteristics who can be contacted next. This type of sampling is usually employed with isolated or hidden populations whose members are not likely to be found unless with cooperation from a known individual. This person will, with time, develop trust with the researcher and will give referrals to others in the same network (Mweshi & Sakyi, 2020:191).

(iv) **Purposive sampling** – This type of sampling is typically applied in special situations with a specific purpose in mind. With purposive sampling, the researcher decides what needs to be known and sets out to find people who are willing to provide the information by virtue of their knowledge and experience.

Based on the above descriptions of non-probability sampling methods, and considering the research question, this study used purposive sampling. The participants were deliberately chosen based on their seniority in the CSP plants with a view that they will be knowledgeable about CSP technology. The expectation was that this will provide insight into the economic viability of CSP technologies as an RE source.

3.4.3 Data collection techniques

Data collection refers to the way in which the information is collected and used and the explanations that can be generated (Paradis *et al.*, 2016:263). In order to gain insight into the data collected, qualitative research requires data that are holistic and rich, allowing themes and findings to emerge through careful analysis (Barrett & Tywcross, 2018:63). The last part of this paragraph section focuses on aspects relevant to identifying and justifying the technique used in this study. Data collection techniques include the following:

(i) Literature reviews (documents and textual data)

This data collection method is suitable when the researcher wants to investigate changes in official, institutional, or organisational views on a specific topic. Typically, the aim would be to document the context of certain practices or to investigate the experiences and perspectives of a group of individuals who have engaged in written reflection (Paradis *et al*., 2016:264). Documents and textual data provide a systematic and objective means to make valid inferences from written data in order to describe and quantify specific phenomena (Bengtsson, 2016). The written reflection, as indicated by Paradis *et al*. (2016:264), can take on a number of forms such as research articles, government reports, organisational policies and protocols, letters, records, films, photographs, art, meeting notes, or checklists.

(ii) Interpretations (visual data)

This method is a collection of methods used to understand and interpret images. Maree *et al.* (2019:103-104) assert that images might also be able to reveal some sociological insight that is not accessible by any other means. Researchers use images to supplement other data sources in creating new knowledge (Maree *et al.,* 2019:103-104).

Glaw *et al*. (2017:1) indicate that there are two effective visual methods such as auto photography and photo elicitation. With auto photography, participants are asked to take photographs of their environment and then use the photographs as actual data, capturing their world with subsequent knowledge production (Glaw *et al*., 2017:1). With photo elicitation, photographs or other visual media are used in an interview to generate verbal discussion, the aim being to create data and knowledge. This method usually evokes deep emotions, memories, and ideas (Glaw *et al*., 2017:1).

(iii) Observations (events / behaviour)

This is a method of gathering information through the senses. This allows the researcher to investigate and document what people do in their everyday lives and gain understanding about their behaviour (Paradis *et al*., 2016:264). Busetto *et al*. (2020:3) distinguish between participant and non-participant observation. With the former, the researcher becomes part of the observed setting, and with the latter, the researcher is present but not part of the observed setting.

Observations can be a powerful tool in qualitative research, as emphasised by Barrett and Twycross (2018:63-64), giving the researcher an opportunity to capture a wide range of information, such as verbal and non-verbal communication, actions, and environmental factors within a setting. Observation techniques can be regarded as the basis of everyday social life for researchers. They involve the act of watching, evaluating, drawing conclusions, and commenting on interactions and relations (Ciesielska *et al*., 2018:33).

(iv) Surveys

Questions contained in surveys to obtain qualitative data are normally open-ended in a free-text format. They are ideal for documenting perceptions, attitudes, beliefs, or knowledge within a clear and pre-determined sample of individuals (Paradis *et al*., 2016:263). Surveys are usually concerned with the present and attempt to determine the current state of the phenomenon being investigated. They serve as a useful tool when the researcher is studying several variables using a large sample and rigorous statistical analysis (Paradis *et al*., 2016:263).

(v) Interviews

Researchers conduct interviews to gather information on a one-on-one basis following a series of pre-determined questions or a set of areas of interest (Paradis *et al*., 2016:263). Interviews are used to document participants' account or perception of, or stories about, attitudes and responses to certain situations or phenomena. The data are used to generate themes, theories, and models (Paradis *et al*., 2016:263).

Structured interviews are fully controlled by the researcher and leave the participants no room for flexibility, whereas semi-structured interviews depend on how the participants respond to the question or topic laid across by the researcher (Adhabi & Anozie, 2017:89). In a structured interview, the participants are asked the same questions in a similar way to ensure that the replies can be aggregated to fit the objective of the study (Rashidi *et al*., 2014:28).

Unstructured interviews are controlled conversations that shift towards the interest of the researcher; in some cases, the researcher will not have pre-planned questions (Paradis *et al*., 2016:263). Unstructured interviews are shaped by the individual situation and context, making the participant feel relaxed and unassessed. The researcher takes on the assumption that not all participants will necessarily understand questions worded in the same way as with structured interviews (Qu & Dumay, 2011:245).

Semi-structured interviews are the most commonly used qualitative research method. The focus is to incorporate a series of broad themes to be covered during the interview to help direct the conversation towards the research question (Qu & Dumay, 2011:246). McIntosh and Morse (2015:1) contend that the purpose of semi-structured interviews is to ascertain the participant's perspectives regarding an experience pertaining to the research topic. This enables the researcher to assess, confirm, validate, refute, or elaborate on existing knowledge and the discovery of new knowledge (Paradis *et al*., 2016:263).

(vi) Focus group discussions

This is a method that uses semi-structured group interviews to collect data (Paradis *et al*., 2016:263). Usually, there is a group leader who supervises the group, and the methods of collecting the data from the focus groups may differ in design (Adhabi & Anozie 2017:90). Focus groups provide rich information because the researcher can step back and let the focus group enter into a free-flowing discussion (Barrett & Twycross, 2018:63).

3.4.3 Data collection technique applicable to this study

For the purposes of the study, semi-structured interviews were conducted with eight participants to obtain their views about the research question, more specifically about CSP technology. In this way, the researcher was able to obtain rich information and link this to the information gathered through the literature review.

To allow the participants to be free to respond to the questions as they wish, the researcher asked pre-prepared, open-ended questions. This method of questioning is unique among other interview methods due to the degree of relevance it provides to the research topic while remaining responsive to the participants (McIntosh & Morse, 2015:1). All participants were asked the same questions in the same order. Therefore, it was easy for the researcher to not only compare the data collected, but also numerically transform and quantify the data. Semi-structured interviews also afforded the researcher the opportunity to respond with follow-up questions according to the interviewees' responses.

The interviews took about one hour each and were conducted individually. Microsoft Teams, Google Meet and Skype (depending the preference of the participant) were used to conduct interviews with seven of the participants, while a personal face-to-face interview was conducted with one participant.

The participants selected for interviews included CEOs and CFOs to provide the researcher with strategic information with regard to CSP plants. Plant managers and operations managers, on the other hand, are involved with the day-to-day operation of these plants and were therefore selected to provide the researcher with information on understanding CSP's viability from an operations point of view. Consequently, two questionnaires were prepared: the first questionnaire is Interview questionnaire: Plant managers and operations managers (appendix 5) and the second is Interview questionnaire: Chief Executive Officers and Chief Financial Officers (appendix 4).

3.4.4 Data analysis and interpretation

Qualitative data analysis is the "classification and interpretation of linguistic (or visual) material to make statements about implicit and explicit dimensions and structures of meaning-making in the material and what is represented in it" (Flick, 2013:5). The main aim of data analysis is to arrive at generalisable statements by comparing various materials or various texts or several cases (Flick, 2013:5). The focus of qualitative data analysis is on the meaning of events and actions rather than the statistical significance and relationships between variables (Ngulube, 2015:3). Qualitative data analysis puts aside perceived notions about expectations in the research analysis and is guided by the data at hand (Ngulube, 2015:3).

Kahlke (2014:38) lists three qualitative data analysis methods, i.e., phenomenology, ethnography and grounded theory. Archer (2018:1) mentions two more, namely narrative studies/research and case-study research, and Braun and Clarke (2006:2) add a sixth, called thematic analysis. The latter method was used in the study. All the methods are discussed below.

(i) Thematic analysis

This involves identifying, analysing, and reporting patterns, also referred to as themes, within data. This method then organises and describes the data set with the intention to further interpret various aspects of the research topic (Braun & Clarke, 2006:7).

Thematic analysis, which is often used in qualitative research, provides concise description and interpretation in terms of themes and patterns from a data set by analysing, identifying, and finally reporting the most probable and major themes from the data set (Majumdar, 2019:197).

Thematic analysis is subcategorised into inductive thematic analysis and deductive thematic analysis. Inductive thematic analysis identifies themes from the data which are strongly linked to the collected data set, while deductive thematic analysis is mainly driven by the researcher's theoretical framework and research interest and provides a more detailed analysis of some specific aspects of the data (Majumdar, 2019:220).

The identification of themes is also divided into two types, namely semantic and latent themes (Braun & Clarke, 2006:13). Semantic themes are themes within the explicit or surface meaning of the data and the analysis does not go deeper beyond what a participant has said or what has been written (Braun & Clarke, 2006:13). Latent themes, on the other hand, are the underlying ideas, assumptions, conceptualisations, and ideologies that are theorised as shaping or informing the semantic content of the data (Braun & Clarke, 2006:13).

Thematic analysis makes sense of the data collected without moving towards the discovery of a theory, unlike grounded theory which focuses on discovering theories (Archer, 2018:16).

(ii) Narrative studies/research

This method is primarily used to gather linguistic data of people telling stories about their lives (Maree *et al*., 2019:118-119). In narrative research, researchers collect, analyse, and retell these stories in terms of a narrative of the experience (Maree *et al*., 2019:118-119).

Although Floersch *et al*. (2016:411) have noted that narrative research can be difficult to define, they explain that this method is more about problem solving, conflict, interpersonal relations,

human experience, and the temporality of existence, all of which gives a sequential meaning to our daily existence.

Ntinda (2018:3) defines narrative research as a family of approaches with a focus on stories used by people to describe and make sense of certain aspects of their lives. Stories in narrative research become raw data themselves and they become a narrative of human experience that is able to produce data in a narrative form. The most notable examples are solicited stories, oral stories, written autobiographies, and biographies (Butina, 2015:190).

(iii) Phenomenology

This technique is based on real-world experiences gained from everyday situations and relations, and it engages individuals or participants who have first-hand experience (Maree *et al*., 2019:119-120). The main objective of phenomenology is to gain an understanding from an individual as to what their experiences mean to them (Maree *et al*., 2019:119-120). From their responses, a description of general or universal meaning is derived as the essence thereof, and the researcher has to set aside any bias or personal judgement (Maree *et al*., 2019:119-120, Gill, 2020:4).

As Khan (2014:226) explains, phenomenological research is primarily about studying several individuals that have shared an experience. Most methods used for data collection are interviews with individuals, although documents, observations, and art may also be considered. Phenomenology can also be described as a science that aims to establish knowledge of essences which must bring pure expression describing these essences which makes themselves known in intuition (Gill, 2020:4).

(iv) Grounded theory

This technique is employed to describe individual experiences by generating and discovering new theories from the data collected from participants who have experienced a process or phenomenon (Maree *et al*., 2019:120). The assumption of grounded theory is that theory should be inductively derived from the investigation of a certain phenomenon. In other words, theory is discovered, developed, and provisionally verified through systematic data collection and analysis of data pertaining to that phenomenon (Maree *et al*., 2019:120).

According to Floersch *et al*. (2016:409), some researchers have argued that data alone contain the theory to be generated and developed. Others have challenged this notion by stating that data alone cannot generate new theories, but that the interpretation and analysis of data actually generate and discover new theories.

(v) Ethnography

This method is a “qualitative data analysis technique where the researcher describes and interprets the shared and learned patterns of values, behaviours, beliefs, and language of a culture sharing group” (Maree *et al*., 2019:120-121). Ethnography focuses mostly on a specific group that shares the same culture. This can be teachers in a school or a community social work group. The assumption is that human behaviour is mostly intentional and observable, and the research is focused towards understanding the reasoning behind people’s actions (Maree *et al*., 2019:120-121). Ethnographical research follows a qualitative approach with the potential to yield detailed and comprehensive accounts of different social phenomena which can include actions, behaviour, interactions, and beliefs (Reeves *et al*., 2013:1365).

(vi) Case study

Maree *et al*. (2019:121-123) define this method as the empirical inquiry into a contemporary phenomenon or a case, set within a real-world context, especially when the boundaries between the phenomenon and context are not clearly evident. The “case” refers to a bounded entity which can be a person, an organisation, a behavioural condition, an event, or other social phenomena (Maree *et al*., 2019:121-123).

Case-study research involves the exploration of an individual, group, or phenomenon. This includes an analysis and comprehensive description of an individual case with the aim to identify variables, structures, forms, and patterns of interaction between the participants in the situation or to assess the performance of work or progress in development (Starman, 2013:31). In brief, case-study research focuses on a particular case and seeks to gain insight into the complexity and uniqueness of a particular project, policy, institution, programme, or system in real life (Starman, 2013:31).

According to Braun and Clarke (2006:16), the six steps set out below – and applied in this study – can be followed to do a qualitative research analysis:

Step 1: Familiarising yourself with the data

Data in this research were collected through semi-structured interviews using a pre-prepared questionnaire consisting of open-ended questions. This step was to ensure data familiarisation with the depth and breadth of the content. Step 1 also ensured that the researcher gained some prior knowledge of the data before starting with the analysis.

Step 1 requires repeated reading of the data and searching for meanings and patterns in the data. The researcher achieved this by taking notes and marking ideas for coding, which is the next

step. The semi-structured interviews were conducted on a personal face to face manner, but other electronic alternatives were used according to the participants' preferences, such as Microsoft Teams, Google Meet and Skype. All interviews were recorded (with consent of the participants. Audio-recorded data were transcribed into text to allow for note taking and marking to facilitate coding and identification of themes from the data for the purposes of theme analysis.

Step 2: Generating initial codes

Saldaña (2013:3) defines a code as "most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data". Clarke and Braun (2013:3) refer to step 2 as the coding stage where labels need to be generated to identify some crucial features of the data that are relevant to the research question. Linneberg and Korsgaard (2019:6) define coding as the process of identifying segments of meaning from the data and labelling them with a code.

Step 3: Searching for themes

As indicated by Vaismoradi *et al*. (2016:101), themes in thematic analysis can constitute an attribute, descriptor, element, or concept which organises a group of repeating ideas and enables the researcher to answer the study question. Themes include codes (identified in step 2) that have a common point of reference as well as a high degree of generality which unifies ideas regarding the subject of inquiry. These themes reveal elements of subjective understanding from the participants.

Step 3 further involves analysing and sorting the identified codes into candidate (potential) themes and collating all the relevant coded data extracts within the identified themes. The researcher should ensure that all the themes are coherent and represent a meaningful pattern in the data relevant to the research question (Clarke & Braun, 2013:3). At the end of step 2, the researcher has a draft of identified candidate themes. These candidate themes are revisited and reviewed in the next stage.

Step 4: Reviewing themes

Step 4 involves reflection on the candidate themes identified in step 3. The aim is to ensure that these themes tell a convincing story about the data gathered from the participants. This is achieved by defining the nature of each theme and the relationship among the themes (Clarke & Braun, 2013:3). The reviewing of themes ensures that the study's primary objective and other applicable objectives are addressed.

Step 4 involves the following two levels of reviewing. Firstly, reviewing is done at the level of the coded data extracts by reading all the collated extracts of each theme and determining whether

they form a coherent pattern. If the candidate theme forms a coherent pattern, step 5 follows. If the candidate themes do not form a coherent pattern, they need to be reworked or discarded from the analysis. Once there is satisfaction that all the candidate themes capture the shape of the coded data, step 5 can commence.

Step 5: Defining and naming themes

Step 5 involves (i) defining and refining the themes to be used for thematic analysis (in doing so, sub-themes may be identified and defined for some of the themes); and (ii) mapping the codes (generated in step 2) to the themes (and sub-themes, if identified). Once the theme and code mapping has been finalised, step 6 can commence.

Step 6: Producing the report

Step 6 is the final stage, which involves the write-up of the report. This step provides a concise, coherent, logical, non-repetitive, and interesting account of the story that the data tell within and across the themes. For this study, step 6 is provided in chapter 5. The inclusion of step 6 in chapter 5 shows that the fourth secondary objective was achieved, namely, to evaluate the economic viability of CSP as an RE source, draw conclusions, and make recommendations, based on the literature review and the empirical findings.

3.4.5 Qualitative data analysis and interpretation methods applicable to this study

The primary objective of the study was to evaluate the economic viability of CSP as an RE source, using a CBA, in contrast to using the grounded theory method which aims to generate and discover new theory. The research was conducted at two CSP plants in the Northern Cape, which constitute more than one case; hence, the case-study method was not chosen.

Participants did not tell life stories such as the case in narrative research. Instead, they were interviewed using a pre-determined set of questions to gain insight into CSP technology and its economic viability based on their experience and expertise of this technology. The study's focus was mostly based on the work experiences of the eight participants, which is why a thematic analysis was selected over phenomenology with its focus on the life experiences of individuals and the meaning they ascribe to these experiences. The research participants worked for different companies, which means that they might have shared different cultures, unlike in ethnographic research which involves a cultural group sharing the same patterns of values, behaviours, beliefs, and language.

In applying thematic analysis, themes in the data were identified to capture the meanings that are relevant to the research question. Unlike grounded theory, thematic analysis aims to make sense of the data collected without moving towards the discovery of a theory (Archer, 2018:16).

The study used pre-existing themes identified from a theoretical framework linked to the study's primary objective. The identification of pre-existing themes is associated with deductive thematic analysis, while the identification of themes from the data set is associated with inductive thematic analysis (Majumdar, 2019:220). Therefore, based on the aforementioned discussion, this study followed a deductive thematic analysis. Using deductive thematic analysis aligns the themes identified to the study's primary objective and other applicable objectives, which is also supplemented by additional themes identified. The questionnaires were prepared and divided into sections keeping these themes in mind.

Themes that are based on a further interpretation of the participants' responses and the identification of underlying ideas and assumptions in these responses are referred to as latent themes (Braun & Clarke, 2006:13). Themes that are identified within the explicit meaning of data, while analysis is not searching deeper into the responses of the participants, are referred to as semantic themes (Braun & Clarke, 2006:13). This study used latent themes; thus, themes were identified, and the data were analysed by searching deeper into the responses of the participants.

Step 1 of the thematic analysis required the researcher to familiarise himself with the data. The researcher conducted semi-structured interviews, transcribed the responses of the eight questionnaires (each questionnaire for each participant) and repeatedly went through the transcribed responses to address step 1 as indicated above. Steps 2, 3, 4 and 5 required the researcher to (i) generate codes from the data gathered, (ii) search for themes, (iii) review themes, and (iv) define and name themes. In addressing steps 2 to 5, the questions asked in the two questionnaires were divided into different sections aligned to the themes identified. Step 6, which is the report of the data analysis and interpretation, conclusions, and recommendations, is covered in chapter 5.

3.4.6 Data validity, reliability, and trustworthiness

3.4.6.1 Data validity

Qualitative studies are expected to produce solid and descriptive data which represent an interpretive understanding of the truth that should be open and transparent (Maree *et al*., 2019:143). Readers should also be able to follow the procedures of data gathering, analysis, and interpretation (Maree *et al*., 2019:143). Research should have a clear audit trail of decisions and

interpretations made during the course of the process. Although Noble and Smith (2015:34) argue the appropriateness of using the terms “validity” and “reliability” in qualitative research, quantitative research also relies on the concepts of validity, reliability and generalisability, which might bring confusion.

Data appropriateness is overly crucial when it comes to qualitative research. This involves the accurate account of the experiences of participants within and beyond the immediate context, which the researcher has to verify to guarantee robust results (Spiers *et al*., 2018:1). The onus to ensure validity lies with the researcher and not the reader. In brief, validity is concerned with the appropriateness of how the data are gathered, reviewed, analysed, and reported.

In this study data were collected through semi-structured interviews and transcribed from audio to text to allow for smooth data analysis. Electronic data is stored on an external hard drive which is safely stored. During the semi-structured interviews, the researcher followed a questionnaire template to take notes. The same template was sent to the participants two weeks before the interviews so that they could familiarise themselves with the questions.

Data were analysed using hard copy documents, including the transcriptions of the audio recordings and the questionnaire template. The audio-recording device was used only for the purposes of the research. All hard copy documents were put into a hard copy file which was used only to file the research work and was put in a secured environment to avoid tampering of the data by an external party.

The study used the same documents for manual coding, which involved highlighting codes, identifying, and reviewing themes which were fed into the data analysis report. The audit trail clearly indicated how the researcher identified the codes, how these were used to develop themes, and how the themes were linked to the research question. The report in chapter 5 will also be substantiated by transcripts from the data, and the reader will be able to reference this to the data if needed for verification.

3.4.6.2 Data reliability

Whereas data validity is concerned with the appropriateness of how the data were gathered, reviewed, analysed, and reported, reliability is concerned with the consistency of the analytical procedures (Noble & Smith, 2015:34). Reliability refers to the soundness of the research in relation to the application and appropriateness of the methods undertaken and the integrity of the final conclusion.

As emphasised by Sinha (2017:102), research needs to ensure stability, accuracy, and precision of measurement with regard to the procedures. All of this should be well documented so that other researchers can repeat the procedures and achieve the same results. Data in research are normally subjected to two types of evaluation: external criticism and internal criticism (Mohajan, 2018:15). External criticism pertains to the authenticity or genuineness of the data and should be considered first. Internal criticism examines the accuracy of the data and is applied after the data have been established to be authentic. Thus, external criticism establishes the validity of the data, and internal criticism establishes the reliability of the data.

To avoid using generic qualitative research methods, the researcher chose to analyse and report the data using a step-by-step guide of thematic analysis as prescribed by Braun and Clarke (2006:6). By using thematic analysis, the researcher ensured that the reader would understand the methods that were followed. Specifically, the study applied deductive thematic analysis to provide direction to the reader on the epistemological assumptions made. Latent theme analysis was used (discussed in paragraph 3.4.4 (i)).

3.4.6.3 Trustworthiness

Trustworthiness refers to the degree of confidence in research data, interpretation, and methods used to ensure the quality of a study (Connelly, 2016). Trustworthiness is often described as the equivalent of data reliability and data validity within naturalistic research (Precision Consulting, 2020). Naturalistic research is concerned with phenomena as they exist in their natural setting and can include behavioural patterns one can observe or perspectives that a researcher can learn about through interviews (Precision Consulting, 2020).

For a study to be considered trustworthy, Connelly (2016) states that it should be able to follow required protocols and procedures. A study is deemed to be trustworthy when the reader of the research report can evaluate its reliability and determine the extent to which the emerging data and constructs can be accepted (Gunawan, 2015:11). Stahl and King (2020:26) emphasise that, due to the subjective nature of trustworthiness in qualitative research, building trust is imperative. Readers of qualitative research should be given text so rich in detail that the event or the object of description becomes real or almost tangible (Stahl & King, 2020:26).

Most researchers recommend four general criteria of trustworthiness: credibility, transferability, dependability, and confirmability, which will be explained in detail below (Cope, 2014:89):

(i) Credibility

This criterion refers to the truth of the data or the participants' views and the interpretation and representation of these by the researcher. Credibility is enhanced when the researcher verifies

his description of the findings with the participants (Cope, 2014:89). Credibility also determines the extent to which the findings are aligned with reality and the quality of the relationship among the reported findings (Stahl & King, 2020:26). A qualitative study is considered credible when the descriptions of human experience can be immediately recognised by individuals that share the same experience (Cope, 2014:89).

(ii) Transferability

This refers to findings that can be applied to other settings or groups (Cope, 2014:89). Transferability generalises the study findings and attempts to apply them to other situations and contexts (DeVault, 2019). The extent to which the findings are useful to other settings is different from other aspects of the research in that readers actually determine how applicable the findings are to their situations (Connelly, 2016).

(iii) Dependability

This refers to the consistency of data under similar conditions and can be achieved when another researcher concurs with the decision trails at each stage of the research process (Cope, 2014:89). Connelly (2016) refers to dependability as the stability of the data over time and across the conditions of the study. This stability should also provide transparency regarding the research processes to demonstrate that they are indeed dependable (Precision Consulting, 2020).

(iv) Confirmability

This criterion pertains to the researcher's ability to demonstrate that the data represent the participants' responses and not the researcher's biases or viewpoints (Cope, 2014:89). Confirmability is the neutrality or the degree to which findings are consistent and could be repeated. Methods for adhering to this criterion include maintenance of an audit trail of analysis (Connelly, 2016). Confirmable findings should be the result of the experiences and ideas of informants, rather than the characteristics and preferences of the researcher (Precision Consulting, 2020). DeVault (2019) points to the importance of other researchers being able to replicate the results to show that those results were a product of independent research methods rather than conscious or unconscious bias.

In the light of the above criteria for achieving trustworthiness, this research was qualitative in nature and data were gathered through semi-structured interviews. The participants held senior to middle management positions, which assisted the researcher in gaining more insight on CSP technologies of which the participants had expert knowledge. Responses were gathered in physical and electronic format, which can be verified. The study applied thematic analysis to the data, which is clearly set out under paragraph 3.4.5. The data analysed reflected the views of the

participants rather than those of the researcher. Their views were aligned with reality in terms of the current electricity crisis in the country. It is envisaged that these views will be recognised by individuals sharing the same experiences in the energy space.

3.5 Ethical considerations

This research was conducted under the guidelines of the NWU, and all the minimum ethical clearance requirements were met. Approval was granted by the Economic and Management Sciences Research Ethics Committee of the university after all the conditions specified in the approval letter had been met by the study.

The following guidelines were adhered to during the collection, review, analysis, and reporting of the data.

3.5.1 Permission and informed consent

To gain permission for conducting the study, a letter of approval (appendix 1) was sent to the organisation where the participants work. The letter included a draft response letter to be signed the organisation, provided in appendix 2, indicating that the organisation granted permission for the research to be conducted.

As noted by Arifin (2018:30), participants should be competent to give consent and give their consent freely or voluntarily, with full understanding of what the research entails. Once permission was granted by the entity, a letter of consent, as shown in appendix 3, was sent to the participants to invite them to participate in the research. Acknowledgement was indicated by the signing of the letter and sending it back to the researcher. The letter clearly stipulated that participation is voluntary and that participants can withdraw at any time. Once the participants gave their consent, the researcher sent the relevant questionnaire to the participants, i.e., the questionnaire for plant managers and operations managers or the questionnaire for CEOs and CFOs.

3.5.2 Confidentiality

Confidentiality is concerned with offering respect and protection to research participants through the assurance of confidentiality of the information they shared and anonymity by not revealing the identity of either the individual or the entity involved (Halai, 2006:6). The identity of the participants remained confidential throughout the entire research, and the write-up report of the thematic analysis will not indicate any names.

All the information gathered is stored on a password-protected hard drive which will be kept and destroyed as per the university's guidelines. The hard drive and the audio recorder were used for purposes of the research only and no other information was, or will be recorded and/or saved on these devises. All hard copy documents will be kept in a separate hard copy file specifically for the research. The researcher has not identified any confidentiality risks with regard to this research and, as per the ethical clearance from the NWU, the risk of the study was identified as low.

3.5.3 Integrity

Integrity in qualitative research mostly has to do with the trustworthiness of the data/process and whether the claims made can be warranted (Levitt *et al*., 2021:360). Integrity is the degree to which researchers and readers are convinced that a particular study has captured a significant experience or process related to the topic (Levitt *et al*., 2021:360). The research design and procedures need to support the research goals, be informed by the researcher's approaches to inquiry, and be tailored for the fundamental characteristics of the subject matter and the participants. August and Tuten (2008:83) add that, for research to have integrity, researchers must ask themselves how the readers could be persuaded that their findings of the inquiry are worth taking account of. The researcher should pay more attention to the quality, the value, and honesty of their work.

South Africa's current energy crisis at the time of this research more than justifies the topic of this study. Furthermore, the methodologies and methods applied towards achieving the research objectives are expected to assist the reader in gaining a deeper understanding of the findings, all of which can be referenced back to the data collected by the researcher. The significant experiences of the participants are also highly relevant to the energy industry, as well as with regard to the CSP perspective. The data analysis applied in this study was not a generic method, but a thematic analysis. The study drew from previous research in this field, as evident in the literature review. This also assisted in providing a deeper understanding of the types of questions that were asked to the participants in the semi-structured interviews.

3.6 Summary

Chapter 3 introduced the research methodology adopted in this study, followed by a discussion of the different research paradigms, namely ontology, epistemology, positivism, and interpretivism. It was pointed out that this study followed the epistemological paradigm of interpretivism.

The qualitative, quantitative, and mixed methods approaches were explained, indicating that a qualitative methodology was chosen for the study. The rationale for this decision was the interpretive nature of the participants' experiences.

The chapter then clearly defined the research design adopted for the study by discussing the target population and how sampling was conducted. Data were collected through semi-structured interviews and thematic analysis was used, among other methods, to analyse the data collected.

The chapter addressed the criteria for validity and reliability of the data. Lastly, the ethical considerations, specifically permission to conduct the study, informed consent, confidentiality, and integrity were discussed.

4. CHAPTER 4: RESEARCH RESULTS, ANALYSIS, AND DISCUSSION

4.1 Introduction

The main purpose of chapter 4 is to address the third secondary objective of the study, which is to describe, explain, and analyse the research findings to determine the second secondary objective. Consequently, this chapter presents the data collected during the semi-structured interviews with eight participants who have rich knowledge of CSP technology and the energy industry. The chapter discusses the data collected by means of two types of questionnaires and provides reasons why these two questionnaire types were used. Each questionnaire type was divided into sections, discussing why this was necessary.

The interviewees' responses are presented in the order of the questionnaires' sections and the questions they were asked. Chapter 4 summarises and draws conclusions from the data gathered during these interviews. The recommendations regarding CSP's economic viability as an RE source are made in chapter 5.

4.2 Data collection: Questionnaires and interviews

4.2.1 Participants and interviews

The researcher conducted eight interviews at two CSP plants in the Northern Cape Province. The interviewees consisted of one CEO, one CFO, one plant manager, and one operations manager from each of the two identified CSP plants. This gives a sample size of four senior managers (two CEOs and two CFOs) and four middle managers (two plant managers and two operations managers).

Semi-structured interviews were conducted using questionnaires adapted for senior management and middle management. The interviews were scheduled for an hour each, although the actual length of the interviews ranged from 45 to 60 minutes. Electronic or face-to-face interviews were conducted depending on what was suitable and practical for the participant. The electronic interviews were conducted using either Zoom, Teams, or Google Meet. During the interviews, the interviewer asked the questions, and the responses provided by the participants were written down on a pre-printed questionnaire template. Where possible and practical, interviews were audio recorded to facilitate data and thematic analysis and for referral and record keeping purposes.

As indicated in chapter 3, approval was obtained from company management for the interviews to be conducted with the selected participants (see appendix 1) while consent was obtained from each participant individually (see appendix 3) before the interviews were conducted. The

interviews were conducted between July 2023 and September 2023. Data collected during interviews were analysed using thematic analysis (discussed in chapter 3).

4.2.2 Questionnaires

The participants interviewed were deliberately chosen based on their seniority in the CSP plants with the view that they will provide the researcher with insightful knowledge about the CSP technology to understand the economic viability of CSP as a RE source. For the purpose of this study, it was practical and cost effective to use a non-probability sampling method by selecting certain individuals who have knowledge of the CSP plants from a strategic point of view as well as operational point of view as explained in detail in chapter 3. Semi-structured interviews were conducted with two senior managers and two middle managers from each of the two CSP plants chosen. The main reason for choosing non-probability sampling is that it is more suitable for qualitative research and the individuals chosen are assumed to have valuable information (Omona, 2013:179).

As mentioned above, two questionnaires were developed and administered:

- The first questionnaire was developed for plant managers and operations managers, i.e., Interview questionnaire: Plant managers and operations managers (see appendix 5). The main objective of this questionnaire was to gather data about (i) the educational background of participants, their roles and responsibilities, and their experience relating to the energy industry and with CSP technology; (ii) CSP strengths and weaknesses, CSP production inefficiencies, and CSP-PV hybrid systems; and (iii) determinants of economic viability, PESTLE analysis, and CBA.

- The second questionnaire was developed for CEOs and CFOs, i.e., Interview questionnaire: Chief Executive Officers and Chief Financial Officers (see appendix 4). The main objective of this questionnaire was to gather data about (i) the educational background of participants, their roles and responsibilities, and their experience relating to the energy industry and with CSP technology; (ii) CSP strengths, weaknesses, opportunities, and threats; (iii) determinants of economic viability, PESTLE analysis, and CBA; and (iv) stakeholder considerations when investing in CSP, and existing CSP expansion possibilities and storage capabilities.

Each questionnaire was divided into sections with the aim to group together questions related to a specific topic/theme and to ultimately facilitate thematic analysis. The purpose of each question in a specific section is discussed in the next paragraph (4.2.3). The sections in each questionnaire include the following:

- Section 1: Participant's information
  Section 1 was included in both questionnaires.

- Section 2: Concentrated Solar Power (CSP) systems/technologies
  Section 2 was included in both questionnaires.

- Section 3: Determinants of economic viability and PESTLE analysis
  Section 3 was included in both questionnaires.

- Section 4: Other general aspects
  Section 4 was included in Interview questionnaire: Chief Executive Officers and Chief Financial Officers. The aim was to gather additional data about stakeholder considerations with regard to investing in CSP, and existing CSP expansion possibilities and storage capabilities. The additional data pertained to the long-term strategic view of these CSP plants and were deemed suitable questions to pose to CEOs and CFOs who are not involved in the day-to-day operation of CSP plants, like plant managers and operations managers, but are concerned with the future of the organisation.

4.2.3 Interview questions

The questions were formulated to achieve the primary objective of this study, which is to evaluate the economic viability of CSP as an RE source, using a CBA. From the literature review in chapter 2, a general model for the determinants of economic viability using a PESTLE analysis was formulated (see table 2, in paragraph 2.2.2 of chapter 2) and applied to determine CSP's economic viability. This study applied a CBA to determine the economic viability of CSP and, therefore, the interview questions were formulated to gather more information about PESTLE analysis, CBA, strengths, weaknesses, opportunities, and threats.

- Interview questions in **Section 1**: Participant's information
  Section 1 in both questionnaires contains exactly the same questions. The purpose of these questions was to get all the participants' academic qualifications, roles, responsibilities, and experience in the energy industry and in CSP technology. The data gathered from this section ultimately provided insight into the respondent's in-depth knowledge regarding CSP technology. The longer the experience of a participant in the CSP industry, the more valuable the data were expected to be to support the study's primary objective.

- Interview questions in **Section 2**: CSP systems/technologies
  Section 2 in both questionnaires specifically deal with CSP technologies. The main reason for these questions was to gain a better understanding of CSP's strengths, weaknesses, opportunities, and threats.

  Plant managers and operations managers are involved in the day-to-day operations and maintenance of a CSP plant. Therefore, these managers were expected to provide valuable operational information about CSP strengths and weaknesses, the CSP production inefficiencies that they experience during operations and maintenance, and whether the country can efficiently use CSP-PV hybrid systems.

  CEOs and CFOs oversee the management and controlling of the entire CSP project. Therefore, they were expected to provide valuable strategic information about CSP strengths, weaknesses, opportunities, and threats.

- Interview questions in **Section 3**: Determinants of economic viability and PESTLE analysis
  Section 3 in both questionnaires focused on the determinants of economic viability and the components/factors of a PESTLE analysis (i.e., Political, Economic, Social, Technological, Legal, and Environmental factors).

  Because of their involved in the daily operations and maintenance of a CSP plant, plant managers and operations managers were expected to be able to rank in order of importance the components/factors of a PESTLE analysis and CBA. These managers were further required to provide operational information about (i) whether SA can further invest in CSP plants, (ii) whether PV can be regarded as a lower cost alternative to PV, whether (iii) SA has the necessary engineering and operational skills to realise the full potential of CSP, (iv) whether CSP creates permanent employment, (v) the percentage of local skilled labour involved in CSP, (vi) the benefits of TES, and (vii) future improvements to reduce operations and maintenance costs of CSP.

  Based on their strategic involvement in the CSP plant, the CEOs and CFOs were expected to be able to rank the importance of the components/factors of a PESTLE analysis and CBA. CEOs and CFOs were further required to provide strategic information about (i) the financial risks and opportunities of CSP plants, (ii) the challenges in obtaining the required finances for CSP projects, (iii) whether SA can further invest in CSP plants, (iv) whether PV can be regarded as a lower cost alternative to PV, (v) whether the country has the necessary engineering and operational skills to realise the full potential of CSP, (vi)

whether CSP creates permanent employment, and (vii) what the local and national community benefits are from CSP plants.

- Interview questions in **Section 4**: Other general aspects
  Section 4 was only included in Interview questionnaire: Chief Executive Officers and Chief Financial Officers. The reason was to obtain an understanding about (i) stakeholder considerations when investing in CSP, (ii) whether it would be possible to increase CSP capacity once it has been set at certain levels and whether there is compensation for generating electricity during peak hours, and (iii) any plans to incorporate PV with existing CSP plants. Responses to these three additional questions were expected to provide valuable information on future developments in CSP technology and be useful in drawing final conclusions and making recommendations (chapter 5).

4.3 Data collected during interviews

Paragraph 4.3 presents the responses (data) as provided by the eight participants. The responses are presented as per section in the two questionnaires respectively. A summary of each question's responses is provided, linked to the study's research objectives. Thematic analysis (as described in chapter 3) of the responses is presented in the next paragraph (paragraph 4.4).

4.3.1 Section 1: Participant's information (qualifications, responsibilities, and experience)

4.3.1.1 Interview questionnaire: Plant managers and operations managers

The responses of the participants in section 1 of the questionnaire are presented in table 4.1 below, while a summary thereof is provided at the end of this paragraph (4.3.1.1).

Table 4.1 – Responses from participants – section 1 of questionnaire: Plant managers and operations managers

RESPONSES – SECTION 1: INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS		
	QUESTION	**RESPONSE**
1	What are your formal qualifications after school?	Plant manager 1: Master's degree in architectural design. Plant manager 2: Master's degree in business leadership (MBL), and Bachelor of Technology in electrical engineering. Operations manager 1: Master's degree in industrial process management. Operations manager 2: Bachelor of Technology in chemical engineering.
2	Please describe your main duties and responsibilities in your current position (other than the normal duties and responsibilities as plant manager or as operations manager).	The participants' main duties and responsibilities are as follows: • Operations management and management of the operations team. • Maintenance planning. • Operations coordination (especially coordination of operational challenges with the project company). • Production management, management of safety compliance, and management of environmental activities.

RESPONSES – SECTION 1: INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS		
	QUESTION	**RESPONSE**
		• Production cost management and production efficiency management. • Managing contractor evaluation on site.
3	How long have you been in your current position?	Plant manager 1: 6 months' experience Plant manager 2: 4 years' experience Operations manager 1: 3 months' experience Operations manager 2: 2 years' experience The longest experience out of the four participants is 4 years, and the shortest experience is 3 months. This provides an average of 1.7 years' experience for all the participants.
4	How long have you been employed in the energy industry?	Plant manager 1: 19 years Plant manager 2: 10.5 years Operations manager 1: 8 years Operations manager 2: 9 years

RESPONSES – SECTION 1: INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS		
	QUESTION	**RESPONSE**
		The most experience is 19 years, and the shortest experience is 8 years, with an average of 11.6 years' experience for all participants.
5	How long have you been employed or involved in CSP technology?	Plant manager 1: 6 months Plant manager 2: 10.5 years Operations manager 1: 8 years Operations manager 2: 9 years The longest experience is 10.5 years, and the shortest experience is 6 months, with an overall average experience of 7 years for all the participants.

The responses above indicate that all the participants have post-graduate qualifications, with an average of 11.6 years and 7 years of experience in the energy industry and CSP, respectively. The participants have less than five years of experience on average in their current roles. However, the participants' experience in CSP and the energy industry were determined to be sufficient to provide reliable information about the economic viability of CSP technology. The experience of the participants provided reasonable evidence for the researcher that the data gathered from them would be reliable and help to achieve the primary objective of the study.

4.3.1.2 Interview questionnaire: Chief Executive Officers and Chief Financial Officers

The responses of the participants to section 1 of the questionnaire are presented in table 4.2 below, while a summary thereof is provided at the end of this paragraph (4.3.1.2).

Table 4.2 – Responses from participants – section 1 of questionnaire: Chief executive officers and financial officers

RESPONSES – SECTION 1: INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS		
	QUESTION	**RESPONSE**
1	What are your formal qualifications after school?	CEO 1: Master's degree in engineering business management, and master's degree in electrical engineering. CEO 2: Post-graduate qualification in civil engineering technology. CFO 1 and 2: Chartered Accountant (CA (SA)).
2	Please describe your main duties and responsibilities in your current position (other than the normal duties and responsibilities as CEO or as CFO).	The participant's main duties are as follows: • Overseeing plant operations and performance. • Contract management (especially disputes with EPC company). • Managing finances, banking, investor relations, and human resources. • Liaising with the board of directors.
3	How long have you been in your current position?	CEO 1: 7 years CEO 2: 4 months CFO 1: 7.4 years

RESPONSES – SECTION 1: INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS		
	QUESTION	**RESPONSE**
		CFO 2: 7 years The longest experience out of the four participants is 7.4 years, and the shortest experience is 4 months. This provides an average of 5.4 years' experience for all the participants.
4	How long have you been employed in the energy industry?	CEO 1: 13 years CEO 2: 35 years CFO 1: 7.4 years CFO 2: 10 years The longest experience is 35 years, and the shortest experience is 7.4 years. This provides an average of 16.4 years' experience for all the participants.
5	How long have you been employed or involved in CSP technology?	CEO 1: 13 years CEO 2: 4.5 years CFO 1: 7.4 years

RESPONSES – SECTION 1: INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS		
	QUESTION	**RESPONSE**
		CFO 2: 7 years The longest experience is 13 years, and the shortest experience is 4.5 years. This provides an average of 7.9 years' experience for all the participants.

The responses above indicate that the participants have an average of 16.4 years and 7.9 years of experience in the energy industry and CSP technology respectively. The participants have 5.3 years of experience on average in their current roles. The participants' experience in CSP and the energy industry was considered to be sufficient to provide reliable information about CSP technology's economic viability. The experience of the participants provided reasonable evidence for the researcher that the data gathered from them would be reliable and help to achieve the primary objective of the study.

4.3.2 Section 2: CSP systems/technologies

4.3.2.1 Interview questionnaire: Plant managers and operations managers

The responses of the participants to section 2 of the questionnaire are presented in table 4.3 below.

Table 4.3 – Responses from participants – section 2 of questionnaire: Plant managers and operations managers

RESPONSES – SECTION 2: INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS		
	QUESTION	**RESPONSE**
6	Do you experience any logistical issues with regard to imported CSP spare parts? Please elaborate.	Participants indicated their opinions (with an X) and elaborated as follows: *Indication:* | *Elaboration:* |

<table>
<tr><th colspan="3">RESPONSES – SECTION 2:
INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>Yes

X X X X</td><td>• CSP plants are located far away from industrial areas, and this makes it very difficult to source spares and get them on time.
• The spares' ordering system is inefficient within the CSP plants.
• CSP is a new technology in South Africa, while most spares are sourced abroad, causing delays in deliveries.
• Geographical location, as indicated by one participant, causes delays during operations and maintenance of CSP equipment/plants, but not during construction.</td></tr>
<tr><td>No

-</td><td>-</td></tr>
</table>

The above responses indicate that there are logistical issues with regard to imported CSP spare parts. The logistical issues include unavailability of spares caused by delays in deliveries. These delays, in turn, are mainly caused by the fact that the geographical locations of CSP plants are remote.</td></tr>
<tr><td>7</td><td>What would you regard as the strengths and weaknesses of CSP technology?</td><td></td></tr>
<tr><td></td><td>7.1 Strengths</td><td>Participants indicated strengths of CSP technology as follows:
• CSP has low primary costs compared to other traditional electricity generation technology due to its usage of the sun as the source of energy (thus, being RE).
• CSP harnesses energy from the sun, regarded as clean energy, unlike traditional electricity generation technology which uses coal and gas.</td></tr>
</table>

RESPONSES – SECTION 2: INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS		
		• CSP has lower maintenance costs compared to other electricity generation technology; primary costs for SCP are significantly reduced due to usage of the sun's energy. • CSP has the ability to store energy during the day and continue to generate electricity at night. • CSP's reliance on the sun contributes to combating climate change; the process of harnessing energy from the sun does not emit harmful gases to the atmosphere. • CSP is a dispatchable energy, allowing production adjustment to meet grid requirements. This means that CSP can supply electricity to the grid as and when required to meet demand. • CSP creates jobs and improves economic growth; CSP employs about 90 permanent employees during operations and maintenance phase. • The longer CSP is implemented, the more robust it becomes in terms of its reliability due to experience gained from existing CSP plants. • CSP plants can operate for 20 to 30 years, allowing investors to obtain their required ROI. To sum up, the responses indicate that CSP's ability to continue electricity generation at night (for a lifespan of 20 to 30 years) makes it unique in comparison to other RETs (e.g., wind and PV). Furthermore, CSP's reliability

RESPONSES – SECTION 2: INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS		
		increases over time as more experience is gained in this new technology.
	7.2 Weaknesses	Participants indicated some weaknesses of CSP technology as follows: • CSP plants require a large area of land for development. Consequently, it is difficult to build in highly populated areas. • Climate change and the consequential change in weather patterns affect DNI levels. • CSP relies on the availability of a large amount of spares to operate compared to other RETs like wind and PV. • Initial capital outlay for CSP is very high. Unlike wind and PV, CSP plants require a traditional turbine generator to generate electricity which is also used by traditional electricity generation technology. As a result, the power block section of a CSP plant has a similar design than the traditional electricity generation technology. • CSP plants are located in arid areas to take maximum advantage of high DNI levels. Consequently, CSP plants are normally located in arid areas with less annual rainfall and water scarcity. • CSP can only be built in areas where DNI levels are sufficiently high to maintain certain minimum temperatures, enabling the technology (CSP) to generate electricity efficiently.

RESPONSES – SECTION 2: INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS		
		In summary, the high initial capital outlay of CSP projects is the main concern of participants. The responses also indicate that climate change has an impact on DNI. One participant indicated that the DNI forecasted during project development differs from actual DNI experienced during operations and maintenance of CSP plants. (DNI is a measurement of the amount of solar radiation received per unit area by a surface, a crucial factor for the efficiency of CSP technology). CSP plants need high solar radiation to maintain certain minimum operating temperatures, enabling CSP technology to efficiently generate electricity. Another participant indicated that water shortages had led to production losses at their plant, since CSP needs water for (i) steam generation and (ii) cleaning of mirrors and tubes.
8	Please state any ***controllable production inefficiencies*** experienced to date in your organisation's CSP plant and briefly indicate what can be done in the future to eliminate these inefficiencies.	Participants indicated controllable production inefficiencies they had experienced as follows: • Human error due to a lack of necessary skills, resulting in production losses. • Dirty mirrors and tubes, resulting in less energy harnessed from the sun, and production losses. For the mirrors and tubes to be effective in harnessing energy from the sun, it should always be kept clean. • Failure to manage the TES system reduces energy storage capabilities, ultimately resulting in production inefficiencies.

RESPONSES – SECTION 2: INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS		
		• A lack of skilled personnel leads to CSP plant losing opportunities to capitalise on good weather conditions. • Turnaround time for addressing breakdowns is very slow due to a lack of skilled personnel. • Poor preventative maintenance due to unavailability of spares. • Problems in CSP plants are mostly experienced during the first five years of operation due to a lack of skilled personnel. Participants indicated the following that needs to be addressed to eliminate production inefficiencies: • Training and development of personnel. • Improved mirror cleanliness, utilising new cleaning technologies and cleaning material. • Improved availability of spares to facilitate timeous preventative maintenance, ultimately avoiding corrective/reactive maintenance. (Corrective/reactive maintenance is done when a breakdown occurs, while preventive maintenance is done to prevent corrective maintenance.) • Improvement in Eskom's grid stability. Grid stability ensures the availability of Eskom's transmission lines, facilitating the uninterrupted supply of electricity to the grid by CSP plants.

<table>
<tr><th colspan="3">RESPONSES – SECTION 2:
INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS</th></tr>
<tr><td></td><td></td><td>• Reduced staff turnover. The shortage of skills results in CSP plants having to recruit employees from other CSP plants, leading to a high number of employees leaving their current jobs to join other CSP plants.

In short, the main contributors to production inefficiencies include a lack of skilled personnel (who need substantial training and development), and the unavailability of spare parts remains a concern due to CSP technology being new to the country.</td></tr>
<tr><td>9</td><td>Some countries around the world are already using a CSP-PV hybrid systems to optimise CSP’s strength to storing energy to be used when there is no sun. Do you think South Africa can also efficiently use CSP-PV hybrid systems? Please elaborate.</td><td>Participants indicated their opinions (with an X) and elaborated as follows:

<table>
<tr><th>Indication:</th><th>Elaboration:</th></tr>
<tr><td></td><td></td></tr>
<tr><td>Yes

X X X X</td><td>• PV can be used during the day while charging the TES system for production of electricity at night through CSP.
• South Africa’s electricity demand is very high. CSP-PV hybrid systems can increase electricity generation capacity to address electricity shortages.
• CSP-PV hybrid systems in SA can reduce reliance on coal and gas by traditional electricity generation technologies, and as a result, reduce harmful gas emissions.
• CSP-PV hybrid systems can also optimise land usage, consequently reducing the utilisation of agricultural land for stock, cattle, and game farming. CSP-PV hybrid systems can reduce the LCOE and attract new CSP</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th colspan="3">RESPONSES – SECTION 2:
INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td></td><td>investment. CSP-PV hybrid systems reduce the size of the solar field, meaning less usage of mirrors and tubes, and, consequently, reduced operations and maintenance costs.</td></tr>
<tr><td>No

-</td><td>-</td></tr>
</table>

The above responses indicate that CSP and PV can complement each other, rather than compete, in the future.</td></tr>
</table>

4.3.2.2 Interview questionnaire: Chief Executive Officers and Chief Financial Officers

The responses of the participants to section 2 of the questionnaire are presented in table 4.4 below.

Table 4.4 – Responses from participants – section 2 of questionnaire: Chief Executive Officers and Chief Financial Officers

RESPONSES – SECTION 2: INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS		
	QUESTION	**RESPONSE**
6	What would you regard as the ***strengths and weaknesses*** associated with the implementation of CSP technology?	
	6.1 Strengths	Participants indicated the strengths of CSP technology as follows: • The ability of CSP to store energy during the day to continue to generate electricity after sunset. • CSP uses less water compared to traditional electricity generation technologies.

RESPONSES – SECTION 2: INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS		
	QUESTION	**RESPONSE**
		• CSP plants are compensated for peak production. Peak production occurs when there is high demand for electricity, during which time RETs, like PV, cannot generate electricity due to less or no sunlight. • Minimal pollution experienced with CSP plants compared to traditional electricity generation technology, which is good for the environment. CSP plants use the sun to harness energy, being regarded as a renewable source of energy. • CSP plants use RE (i.e., the sun) in comparison to traditional electricity generation, which uses coal and gas (non-RE sources) to generate electricity. • CSP is an internationally proven technology, although it is new to SA. • CSP is unique and advantageous when compared to PV due to CSP's TES capabilities. PV can only generate electricity during the day since it cannot store energy for electricity generation at night, whereas CSP technology can (due to its TES capability). In brief, the responses indicate that CSP's unique TES capability provides a major advantage for CSP above other RETs that do not have TES capabilities.
	6.2 Weaknesses	Participants indicated the weaknesses of CSP technology as follows:

RESPONSES – SECTION 2: INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS		
	QUESTION	**RESPONSE**
		• CSP has high initial capital outlay compared to wind and PV. A CSP plant needs (i) a solar field to harness energy from the sun, (ii) a salt system (TES) to store energy during the day for electricity generation at night, and (iii) a power block to turn the turbine generator to generate electricity. These components are expensive and require a higher initial capital outlay. • CSP technology is new to South Africa and, due to its complex nature, requires highly skilled personnel to operate and maintain. • There are challenges with the tubes, e.g., maintaining the tubes' vacuum, hydrogen content of the tubes (leakages), high operating temperature of the tubes (reducing its lifespan), and cleaning problems of tubes and mirrors (due to dust accumulation / soiling rate). • It takes longer to construct CSP plants compared to other RETs (e.g., PV). CSP can take up to three years to construct while PV can be implemented as quickly as within six months. • It is difficult to source CSP technology spare parts, which leads to production losses. Most of the OEMs are based overseas and this causes prolonged lead times for spares delivery.

RESPONSES – SECTION 2: INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS		
	QUESTION	**RESPONSE**
		In summary, the high initial capital outlay of investment for CSP projects is the main concern raised by participants. Other concerns are operational challenges experienced with CSP since it is new technology in SA.
7	What would you regard as the ***opportunities and threats*** associated with the implementation of CSP technology?	
	7.1 Opportunities	Participants indicated the following opportunities of CSP: • PV can easily be integrated with CSP. • Owing to skills and spare part scarcity in SA, great potential exists for local manufacturing of spare parts and local skills development and training. • Opportunities for skills transfer to SA from international CSP experts. • CSP research is done locally by the University of Stellenbosch. • CSP has the potential to store the sun's energy during the day for usage during night-time for electricity generation. Consequently, electricity can be generated for longer hours. This contributes to minimising load shedding. • Although CSP is a new technology in SA, it presents opportunities for further development in the country due to high DNI levels, providing the minimum temperature needed by CSP.

RESPONSES – SECTION 2: INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS		
	QUESTION	**RESPONSE**
		In summary, participants indicated that CSP has great potential for future development in SA. Development includes CSP-PV hybrid systems and opportunities to increase TES hours.
	7.2 Threats	Participants raised concerns about the following threats regarding CSP technology: • Risk of other RETs (such as PV battery storage and wind turbines) that might be further developed in the future at lower costs compared to CSP technology. • Eskom's financial instability, damaged infrastructure, and grid unavailability. CSP projects rely on Eskom's financial stability for revenue and grid availability to supply generated electricity. • CSP plants are very complex to operate and, currently, experience prolonged production losses due to a lack of skilled personnel. • There is a high expectation for jobs by local communities where CSP plants are situated. CSP plants each employ about 90 permanent employees during operations and maintenance, and this number (90) is regarded as very low by local communities. In summary, there is great concern of new technologies that might compete against CSP due to scarce skills. Also, less jobs are created compared to traditional electricity generating technologies.

4.3.3 Section 3: Determinants of economic viability and PESTLE analysis

4.3.3.1 Interview questionnaire: Plant managers and operations managers

The responses of the participants to section 3 of the questionnaire are presented in table 4.5 below.

Table 4.5 – Responses from participants – section 3 of questionnaire: Plant managers and operations managers

<table>
<tr><th colspan="3">RESPONSES – SECTION 3:
INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS</th></tr>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td>10</td><td>Political factors refer to factors indicating how and to what extent a government intervenes in or regulates the economy of the country or a certain industry, and other politically related factors.

Please indicate the importance of the following political factors relevant to CSP technology as an RE source (please indicate with an X).</td><td>Participants indicated (with an X) the importance of political factors as follows:

<table>
<tr><td colspan="2">Labour laws / legislation</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
X
X X X</td></tr>
</table>

<table>
<tr><td colspan="2">Local trade restrictions</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>X
X X
X
-
-</td></tr>
</table>

<table>
<tr><td colspan="2">Environmental policies / legislation</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
X
X
X X</td></tr>
</table>

<table>
<tr><td colspan="2">Other political factors</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
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</table>
</td></tr>
</table>

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS

<table>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td>11</td><td>Economic factors, in general, refer to factors affecting the fundamental activities of the economy or market, ultimately influencing a country’s economic growth and development and how businesses (and related projects) within that country perform.

Please indicate the importance of the following economic factors relevant to CSP technology as an RE source (please indicate with an X).</td><td>Participants indicated (with an X) the importance of economic factors as follows:

<table>
<tr><td colspan="2">Availability and condition of goods and services</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
X
X X
X</td></tr>
</table>

<table>
<tr><td colspan="2">Wage rates</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
X
X X
-
X</td></tr>
</table>

<table>
<tr><td colspan="2">Working hours</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
X X
-
X X</td></tr>
</table>

<table>
<tr><td colspan="2">Transport</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
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X X X
X</td></tr>
</table>

<table>
<tr><td colspan="2">Other economic factors</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
-
-</td></tr>
</table>
</td></tr>
<tr><td>12</td><td>South Africa currently has seven operating CSP plants with a total planned capacity of 600 MWh (of which 500 MWh have</td><td>Participants indicated their opinions (with an X) and elaborated as follows:</td></tr>
</table>

RESPONSES – SECTION 3: INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS			
	QUESTION	**RESPONSE**	
	reached commercial operation). The remaining 100 MWh are planned to reach commercial operation later in 2023. Would you recommend further investments in CSP over and above the existing CSP plants? Please elaborate briefly.	*Indication:* Yes X X X X	*Elaboration/reasons supporting their opinion:* • CSP increases the availability of electricity in SA while the country is currently struggling with load shedding. • SA needs additional electricity generation capacity to supply for high demand. • The Northern Cape is a perfect location for electricity generation by CSP due to the high DNI levels in the province, meeting the minimum requirements of CSP plants and, ultimately, optimising the efficiency of CSP plant electricity generation. • The future opportunity to integrate PV with CSP will maximise electricity generation and ultimately reduce cost per kWh. • Traditional electricity generation technology can generate electricity 24 hours a day (e.g., coal and gas plants), while wind turbines can generate electricity whenever sufficient air movement (wind) is available. Furthermore, CSP can also generate electricity for 24 hours depending on the TES capabilities (e.g., maximum hours that the TES can store energy). • CSP has a huge opportunity for cost reduction on initial capital outlay. CSP takes longer to construct (up to three years) compared to PV (e.g., can be implemented as quickly as six months). The more CSP is developed, the more experience is gained; this can reduce

<table>
<tr><th colspan="3">RESPONSES – SECTION 3:
INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS</th></tr>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td></td><td>construction duration and, as a result, reduce the initial capital outlay.</td></tr>
<tr><td>No

-</td><td>-</td></tr>
</table>

The responses above indicate that there is great potential for CSP beyond the Redstone project that is currently under construction. Participants still view CSP as a viable technology within an SA context.</td></tr>
<tr><td>13</td><td>In your opinion, what are the main drivers of the operation and maintenance costs of CSP plants?</td><td>Participants stated the following main cost drivers of operations and maintenance of CSP plants:

Operations:
Number of employees.
Material and consumable usage.
Cleaning of the solar field.
Insurance.
HTF costs.
Quantity of chemicals used.
Data monitoring and operating system.
Maintenance:
Spare parts usage.
Solar field.
TES system.
Power block.
Cleaning of mirrors and tubes in the solar field.</td></tr>
<tr><td>14</td><td>In your own view, do you regard PV as a lower cost alternative to CSP, considering the overall benefits of each of</td><td>It was very difficult for all four participants to provide a straightforward yes or no. However, the respondents elaborated as follows:</td></tr>
</table>

<table>
<tr><th colspan="3">RESPONSES – SECTION 3:
INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS</th></tr>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td>these RE sources? Please elaborate and provide reasons supporting your opinion.</td><td>• PV is only cheaper when generating electricity at a smaller scale. However, with large-scale electricity generation, CSP is more cost efficient than PV.
• A participant indicated that, when a TES system is incorporated into CSP (enabling electricity generation at night), CSP becomes cheaper than PV.
• Although small-scale PV electricity generation is cheaper than CSP, the benefits of CSP's daytime energy storage capabilities need to be considered.
• CSP has more advantages than PV and receives compensation for peak production due to the TES system.
• The ROI might be favouring PV on the short term, while CSP provides a long-term ROI.

This was a difficult question for the participants since they could not provide a direct yes or no answer. However, they indicated that PV is only a lower cost alternative when generating electricity at a smaller scale. Generation of electricity at a larger scale favours CSP.</td></tr>
<tr><td>15</td><td>Social factors refer to the social environment of a country and include those factors that influence or are influenced by an investment, e.g., poverty and unemployment, education and skills, equality, cost of living, cultural trends, demographics, population analytics, family structures, community engagement,</td><td>Participants indicated (with an X) the importance of social factors as follows:

<table><tr><th colspan="2">Education and skills of labour force (available to CSP)</th></tr><tr><th>Importance:</th><th>Indication:</th></tr><tr><td>Not at all</td><td>-</td></tr><tr><td>Slightly</td><td>-</td></tr><tr><td>Moderately</td><td>-</td></tr><tr><td>Very</td><td>-</td></tr><tr><td>Extremely</td><td>X X X X</td></tr></table></td></tr>
</table>

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS

<table>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td>acceptance of new technologies, tourist and stakeholder impact, skilled community, and human life improvement.

Please indicate the importance of the following social factors relevant to CSP technology as an RE source (please indicate with an X).</td><td>
<table>
<tr><th colspan="2">Alleviation of unemployment (in local community)</th></tr>
<tr><th>Importance:</th><th>Indication:</th></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>-</td></tr>
<tr><td>Moderately</td><td>X X</td></tr>
<tr><td>Very</td><td>X</td></tr>
<tr><td>Extremely</td><td>X</td></tr>
</table>
<table>
<tr><th colspan="2">Cost of living and improvement of standard of living</th></tr>
<tr><th>Importance:</th><th>Indication:</th></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>-</td></tr>
<tr><td>Moderately</td><td>X</td></tr>
<tr><td>Very</td><td>X X</td></tr>
<tr><td>Extremely</td><td>X</td></tr>
</table>
<table>
<tr><th colspan="2">Community engagement</th></tr>
<tr><th>Importance:</th><th>Indication:</th></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>-</td></tr>
<tr><td>Moderately</td><td>-</td></tr>
<tr><td>Very</td><td>X</td></tr>
<tr><td>Extremely</td><td>X X X</td></tr>
</table>
<table>
<tr><th colspan="2">Stakeholder impact</th></tr>
<tr><th>Importance:</th><th>Indication:</th></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>X</td></tr>
<tr><td>Moderately</td><td>X X</td></tr>
<tr><td>Very</td><td>-</td></tr>
<tr><td>Extremely</td><td>X</td></tr>
</table>
<table>
<tr><th colspan="2">Other social factors</th></tr>
<tr><th>Importance:</th><th>Indication:</th></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>-</td></tr>
<tr><td>Moderately</td><td>-</td></tr>
<tr><td>Very</td><td>-</td></tr>
<tr><td>Extremely</td><td>-</td></tr>
</table>
</td></tr>
<tr><td>16</td><td>Do you think South Africa has the necessary engineering and operational skills to realise the full potential of CSP technology? Please explain.</td><td>Participants indicated (with an X) their opinions and explanations/reasons supporting their opinions as follows:</td></tr>
</table>

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS

<table>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>Indication:</td><td>Explanation/reasons:</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Yes

X X X</td><td>• Eskom is a valuable source for supplying CSP plants with employees who possess the required skills.
• South Africa does have the labour force with the required skills, while the challenge currently is employees' remuneration and benefits.
• CSP plants are located in remote areas, while employees with the necessary skills are only available in industrial areas; which makes it very difficult to source skilled personnel.
• Part of the CSP plant (i.e., the power block) is similar to traditional electricity generating technology. This makes it easy for the labour force to adapt to the entire CSP technology.
• South Africa has currently enough CSP plants for further skills development.</td></tr>
<tr><td>No

X</td><td>• Since CSP is a new technology in SA, a great deal of training by educational institutions in CSP technology is needed.</td></tr>
</table>
<table>
<tr><td>Additional information provided:</td></tr>
<tr><td></td></tr>
<tr><td>One participant indicated that the slow pace of CSP development in SA poses a high risk of losing skills in the future.</td></tr>
</table>
</td></tr>
<tr><td>17</td><td>Do CSP plants create long-term permanent employment after construction of the CSP plant? If yes, how many permanent jobs would be / were created by your organisation's CSP plant?</td><td>Participants indicated their opinions (with an X) and estimated the quantity of permanent jobs created as follows:
<table>
<tr><td>Indication:</td><td>Estimated permanent jobs created:</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Yes</td><td>• CSP plant 1: 100 jobs; and</td></tr>
</table>
</td></tr>
</table>

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS

<table>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>X X X X</td><td>• CSP plant 2: 89 jobs.</td></tr>
<tr><td>No

-</td><td>-</td></tr>
</table>
</td></tr>
<tr><td>18</td><td>Is this CSP project currently using local skilled labourers to operate and maintain the CSP plant? If so, what percentage of the total skilled labourers involved in the CSP project are local skilled labourers (in comparison to foreign skilled labourers)?</td><td>Participants indicated their opinions (with an X) and percentages of local and foreign labourers as follows:

<table>
<tr><td>Indication:</td><td>Estimated percentages:</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Local skilled labour only

X X X X</td><td>• CSP plant 1:
Local skilled labour: e.g., 100%.</td></tr>
<tr><td>Both local and foreign skilled labour
-</td><td>• CSP plant 2:
Local skilled labour: e.g., 80%; and
Foreign skilled labour: e.g., 20%.

The participants indicated that CSP is still new in SA compared to other countries (e.g., European countries like Spain) and, as a result, still needs foreign skills to assist with the operations and maintenance of the plant.</td></tr>
<tr><td>Foreign skilled labour only

-</td><td>-</td></tr>
</table>

In brief, CSP plant 1 has 100% local skilled labour and CSP plant 2 has 80% local skilled labour, with 20% foreign skilled labour.</td></tr>
<tr><td>19</td><td>Technological factors refer to the availability of infrastructure for the necessary support of modern systems, including technological development,</td><td>Participants indicated the importance of technological factors as follows (with an X):

<table>
<tr><td colspan="2">Availability of technology</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
</table>
</td></tr>
</table>

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS

	QUESTION	RESPONSE
	availability of technology, cost of technology, innovation, technological flexibility, automation levels, rate of technological changes, government spending on technology, R&D, new technology adoption, etc. Furthermore, RET factors include intermittency (which is unplanned variations in the power generated by wind or solar due to changes in weather patterns), dispatchability (dispatchable generation is the type of electricity that can be distributed based on the electricity demand; this can be very flexible in terms of load matching and peak matching on short notice; can also be useful to cover intermittent RE sources when the demand is high), variability (variability is the fluctuating nature of solar resources, which translates into potentially rapid changes in electricity output), scalability (i.e., the deployment of RETs can start on a small scale and grow without the need for a complete replacement of the available infrastructure), and energy storage (the ability of RETs to store energy for use at a later stage). Please indicate the importance of the following technological factors relevant to CSP technology as an RE source (please indicate with an X).	Not at all - Slightly - Moderately - Very X X Extremely X X *Cost of technology (investment in technology)* *Importance:* / *Indication:* Not at all - Slightly - Moderately - Very X X Extremely X X *Maintenance cost* *Importance:* / *Indication:* Not at all - Slightly - Moderately X X Very X Extremely X *Frequency of maintenance* *Importance:* / *Indication:* Not at all - Slightly - Moderately X X Very - Extremely X X *Technological flexibility and adaptability* *Importance:* / *Indication:* Not at all - Slightly - Moderately X Very X Extremely X X *Level of automation* *Importance:* / *Indication:* Not at all - Slightly X Moderately X X Very - Extremely X

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS

	QUESTION	**RESPONSE**
		RETs:

Intermittence capacity	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X
Very	X X
Extremely	X

Dispatchable electricity distribution	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X X
Very	-
Extremely	X X

Variability in electricity output	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X X
Very	-
Extremely	X X

Expandability of electricity generation capacity (scalability)	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X X
Very	X
Extremely	X

Energy storage capacity (storing energy for later use)	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	-
Extremely	X X X X

Other technological factors	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-

RESPONSES – SECTION 3: INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS		
	QUESTION	**RESPONSE**
		<table><tr><td>Very Extremely</td><td>- -</td></tr></table> In summary, energy storage for CSP continues to be relevant when determining CSP's economic viability, and all the participants ranked energy storage as extremely important.
20	A CSP plant can incorporate TES, which stores energy either in a form of sensible heat or as latent heat (e.g., using molten salt), which enables these plants to continue to generate electricity whenever needed, day or night. Are there any benefits of the TES system for CSP? Please elaborate.	The participants stated the following benefits of incorporating a TES system into a CSP plant: • Enables a CSP plant to continue generating electricity when there is no sun. • Improves the reliability and dispatchability of the CSP plant. • Enables a CSP plant to meet the variable and dynamic electricity demand. • Has environmental benefits (it minimises the need for using fossil fuels for electricity generation, reduces gas emissions, and, in turn, combats climate change). • Provides grid flexibility. • Enables CSP plants to generate electricity after sunset, including peak production (e.g., peak production is a period where demand for electricity is very high). As a result, electricity generated by CSP plants is compensated at a higher rate than normal production and consequently contributes 80% of CSP revenue generated.

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS

<table>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td>21</td><td>Legal factors refer to established rules, regulations, and legislation used by a government to ensure the wellbeing of a country’s economy and the protection of assets and individual rights, e.g., laws and regulations governing tax, employment, licensing, extraction of natural resources, energy management and planning (including grid access), ownership models, access to resources, etc.

Please indicate the importance of the following legal factors relevant to CSP technology as an RE source (please indicate with an X).</td><td>Participants indicated (with an X) the importance of legal factors as follows:

<table>
<tr><th colspan="2">Laws and regulations – operational</th></tr>
<tr><th>Importance:</th><th>Indication:</th></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>-</td></tr>
<tr><td>Moderately</td><td>-</td></tr>
<tr><td>Very</td><td>X X</td></tr>
<tr><td>Extremely</td><td>X X</td></tr>
</table>

<table>
<tr><th colspan="2">Laws and regulations – health and safety</th></tr>
<tr><th>Importance:</th><th>Indication:</th></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>-</td></tr>
<tr><td>Moderately</td><td>X</td></tr>
<tr><td>Very</td><td>-</td></tr>
<tr><td>Extremely</td><td>X X X</td></tr>
</table>

<table>
<tr><th colspan="2">Access to resources</th></tr>
<tr><th>Importance:</th><th>Indication:</th></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>X</td></tr>
<tr><td>Moderately</td><td>-</td></tr>
<tr><td>Very</td><td>X X</td></tr>
<tr><td>Extremely</td><td>X</td></tr>
</table>

<table>
<tr><th colspan="2">Other legal factors</th></tr>
<tr><th>Importance:</th><th>Indication:</th></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>-</td></tr>
<tr><td>Moderately</td><td>-</td></tr>
<tr><td>Very</td><td>-</td></tr>
<tr><td>Extremely</td><td>-</td></tr>
</table>
</td></tr>
<tr><td>22</td><td>Environmental factors refer to the impact of natural events on a project and a project’s impact on the natural environment. These factors include weather, pollution, climate change, air quality and ventilation, water quality, waste control, raw material, agriculture, geological aspects, noise levels, lighting, health and safety, etc.</td><td>Participants indicated (with an X) the importance of environmental factors as follows:

<table>
<tr><th colspan="2">Weather conditions</th></tr>
<tr><th>Importance:</th><th>Indication:</th></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>-</td></tr>
<tr><td>Moderately</td><td>-</td></tr>
<tr><td>Very</td><td>-</td></tr>
<tr><td>Extremely</td><td>X X X X</td></tr>
</table>
</td></tr>
</table>

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS

	QUESTION	**RESPONSE**
	Please indicate the importance of the following environmental factors relevant to CSP technology as an RE source (please indicate with an X).	

Pollution and waste management	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X X
Extremely	X X

Climate change	
Importance:	*Indication:*
Not at all	-
Slightly	X
Moderately	X X
Very	-
Extremely	X

Water quality and availability	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X
Extremely	X X X

Dust and cleanliness of CSP equipment	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X
Very	X
Extremely	X X

Health and safety in the work place	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X
Very	-
Extremely	X X X

Other environmental factors	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	-
Extremely	-

<table>
<tr><th colspan="3">RESPONSES – SECTION 3:
INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS</th></tr>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td>The responses show that most of the environmental factors are considered very and extremely important when considering their relevance to CSP technology. It should also be noted that, from the responses, weather conditions seem to be the only factor ranked as extremely important, which confirms CSP's dependence on weather conditions and DNI.</td></tr>
<tr><td>23</td><td>Considering operations and maintenance activities (especially mirror and tube cleaning), are there any future improvements that could be made to, e.g., reduce operations and maintenance cost within CSP plants?</td><td>Participants indicated their opinions (with an X) and made the following comments:

<table>
<tr><th>Indication:</th><th>Comment:</th></tr>
<tr><td></td><td></td></tr>
<tr><td>Yes

X X X X</td><td>• Tube replacements are primarily caused by degradation and vacuum losses. New cheaper technologies are emerging for tube repairs, instead of replacing damaged/broken tubes (which is very expensive). A participant indicated that a CSP plant is currently exploring this new technology.
• A participant indicated that a CSP plant is currently doing a Root Cause Analysis for tube and mirror breakages. The findings will assist in reducing future mirror and tube maintenance cost.
• Improved cleaning of mirrors and tubes can assist in reducing maintenance costs, although it requires further R&D on cleaning chemicals to improve the reflectivity of tubes and mirrors.
• Reducing the soiling rate (accumulated dust) of mirrors and tubes can also reduce mirror and tube cleaning costs.</td></tr>
</table></td></tr>
</table>

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS

	QUESTION	**RESPONSE**
		No - | -

The responses indicate that there is potential for further reducing operations and maintenance costs on CSP. The solar field part of CSP is crucial in harnessing the energy from the sun using tubes and mirrors. Participants indicated that addressing tube and mirror breakages will reduce maintenance costs in the future. Reducing dust accumulation in the solar filed will also improve mirror and tube reflectivity, consequently, increasing the ability of mirrors and tubes to absorb a substantial amount of energy from the sun.

24	A **CBA** is the process of comparing projected costs and benefits associated with a project decision to determine whether it is sound to invest in that specific project. CBA considers a project's benefits and costs in monetary terms to determine the best project proposal by tallying up all costs of a project and subtracting that amount from the total projected benefits. With regard to CSP technologies, the total tangible costs of a CSP project include financing, labour, capital investment, insurance, installation, mirror and tube cleaning, fuel, solar field maintenance, power block maintenance, and TES maintenance. The total tangible benefits of CSP plants include revenues received for production, subsidies received from the	Participants indicated (with an X) the importance of relevant costs and benefits as follows: *Tangible costs:*

Labour (employment)	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X
Very	-
Extremely	X X X

Mirror and tube cleaning	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X
Extremely	X X X

Fuel	
Importance:	*Indication:*
Not at all	-

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS

	QUESTION	RESPONSE
	government, and funding from investors or government. Intangible costs mainly include relocation of habitat and lost agricultural activities, and intangible benefits include reduction in gas emissions, improved standard of living, improved health through air quality, and reduced noise when compared to conventional power generation assets. Please indicate the importance of the following costs and benefits relevant to CSP technology as an RE source (please indicate with an X).	

Slightly	-
Moderately	X X X
Very	-
Extremely	X

Solar field maintenance	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X X
Very	X
Extremely	X

Power block maintenance	
Importance:	*Indication:*
Not at all	-
Slightly	X
Moderately	X
Very	X
Extremely	X

TES	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X X
Very	X
Extremely	X

Maintenance (general maintenance)	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X
Very	X X
Extremely	X

Intangible benefits:

Reduction in greenhouse gas emissions	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X
Very	X
Extremely	X X

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS

<table>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td colspan="2">Health and safety benefits (in comparison to other electricity generation methods)</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
X
-
-
X X X</td></tr>
</table>
<table>
<tr><td colspan="2">Reduced noise levels (in comparison to other electricity generation methods)</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
X
X
X
X</td></tr>
</table>
<table>
<tr><td colspan="2">Other costs/benefits</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
-
-</td></tr>
</table>
</td></tr>
<tr><td>25</td><td>Are there any other important aspects/ factors that have not been covered during the interview that you would like to bring to the attention of, or discuss with the interviewer? If so, please list and elaborate on these aspects.</td><td>Participants stated the following as other important aspects/factors regarding CSP plants and/or technology:
Although CSP technology is viable, the major challenge is the location of CSP plants (limited to areas with high DNI). Areas with the required minimum DNI levels are usually arid with water shortages due to little annual rainfall.
The localisation of spares is needed to minimise production losses caused by delayed maintenance resulting from the unavailability of imported spares.
South Africa needs laboratory facilities for tube and mirror testing to ultimately</td></tr>
</table>

RESPONSES – SECTION 3: INTERVIEW QUESTIONNAIRE: PLANT MANAGERS AND OPERATIONS MANAGERS		
	QUESTION	**RESPONSE**
		improve the efficiency of harnessing the sun's energy. • Efficient, new chemical testing is needed to assist with mirror and tube cleaning to ultimately improve mirror reflectivity.

4.3.3.2 Interview questionnaire: Chief Executive Officers and Chief Financial Officers

The responses of the participants to section 3 of the questionnaire are presented in table 4.6 below.

Table 4.6 – Responses from participants – section 3 of questionnaire: Chief Executive Officers and Chief Financial Officers

<table>
<tr><td colspan="3">RESPONSES – SECTION 3:
INTERVIEW QUESTIONNAIRE:
CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS</td></tr>
<tr><td></td><td>QUESTION</td><td>RESPONSE</td></tr>
<tr><td>8</td><td>Political factors refer to factors indicating how and to what extent a government intervenes in or regulates the economy of the country or a certain industry, and other politically related factors.

Please indicate the importance of the following political factors relevant to CSP technology as an RE source (please indicate with an X).</td><td>Participants indicated (with an X) the importance of political factors as follows:

<table>
<tr><td colspan="2">Tax policies/legislation</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
X X
X X</td></tr>
</table>

<table>
<tr><td colspan="2">Labour laws/legislation</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
X
X X
X</td></tr>
</table>

<table>
<tr><td colspan="2">Foreign trade restrictions</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
</table>
</td></tr>
</table>

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE:

CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS

	QUESTION	**RESPONSE**

Not at all	X X
Slightly	X
Moderately	X
Very	-
Extremely	-

Local trade restrictions	
Importance:	*Indication:*
Not at all	X X
Slightly	-
Moderately	X
Very	-
Extremely	X

Import/export duties and tariffs	
Importance:	*Indication:*
Not at all	X
Slightly	-
Moderately	-
Very	X X X
Extremely	-

Environmental policies/legislation	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X
Extremely	X X X

Corruption	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X
Extremely	X X X

Political stability/instability	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	-
Extremely	X X X X

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE:

CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS

<table>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td colspan="2">Other political factors:
Eskom financial instability caused by political interference
(indicated by one participant)</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
-
X</td></tr>
</table>
<table>
<tr><td colspan="2">Other political factors:
Guarantees from the SA government such as subsidies provided to CSP implementation to help reduce the initial capital outlay
(indicated by one participant)</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
-
X</td></tr>
</table>
In brief, the participants' experience indicated that political factors are extremely important and relevant to CSP technology's economic viability. The participants also raised the concern of political interference in RET implementation which causes delays in project completion, resulting in cost overruns.
</td></tr>
<tr><td>9</td><td>Economic factors, in general, refer to factors affecting the fundamental activities of the economy or market, ultimately influencing a country's economic growth and development and how businesses (and related projects) within that country perform.</td><td>
Participants indicated (with an X) the importance of economic factors as follows:
<table>
<tr><td colspan="2">SA's general economic climate and conditions</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
-
X X X X</td></tr>
</table>
</td></tr>
</table>

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE:

CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS

	QUESTION	**RESPONSE**
	Please indicate the importance of the following ***economic factors relevant to CSP technology*** as an RE source (please indicate with an X).	

Availability and condition of goods and services

Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X
Extremely	X X X

Interest rates

Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X
Extremely	X X X

Foreign exchange rates

Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X X X
Extremely	X

Inflation rates

Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X
Very	X
Extremely	X X

Funding and credit availability

Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X
Extremely	X X X

Other economic factors

Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	-

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE:

CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS

<table>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>Extremely</td><td>-</td></tr>
</table>

Besides inflation rate, all the economic factors were ranked very and extremely important. This indicates the significance of economic factors in assessing CSP's economic viability. The country's general economic climate is the only factor that was ranked by all participants as extremely important, demonstrating how critical the country's economic conditions are to CSP development and viability.
</td></tr>
<tr><td>10</td><td>Economic factors, for the determination of the economic viability of investments (e.g., projects), also include (over and above the economic factors mentioned in the previous question (question 12)) a financial analysis of the profitability (or yield/return) of such investments or projects.

Please indicate the importance of using the following financial analysis techniques relevant to CSP technology as an RE source (please indicate with an X).</td><td>Participants indicated (with an X) the importance of financial analysis techniques relevant to CSP technology as follows:

<table>
<tr><td colspan="2">Accounting Rate of Return (ARR)</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>-</td></tr>
<tr><td>Moderately</td><td>-</td></tr>
<tr><td>Very</td><td>X X</td></tr>
<tr><td>Extremely</td><td>X X</td></tr>
</table>

<table>
<tr><td colspan="2">Payback Period (PBP)</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>-</td></tr>
<tr><td>Moderately</td><td>-</td></tr>
<tr><td>Very</td><td>X</td></tr>
<tr><td>Extremely</td><td>X X X</td></tr>
</table>

<table>
<tr><td colspan="2">Discounted Payback Period (DPB)</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>-</td></tr>
<tr><td>Moderately</td><td>X</td></tr>
<tr><td>Very</td><td>-</td></tr>
<tr><td>Extremely</td><td>X X X</td></tr>
</table>

<table>
<tr><td colspan="2">Net Present Value (NPV)</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
</table>
</td></tr>
</table>

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE:

CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS

	QUESTION	**RESPONSE**
		Not at all - Slightly - Moderately - Very X Extremely X X X
		Internal Rate of Return (IRR) *Importance:* / *Indication:* Not at all - Slightly - Moderately - Very X Extremely X X X
		Localised Cost of Energy (LCOE) *Importance:* / *Indication:* Not at all - Slightly - Moderately - Very X Extremely X X X
		Other financial analysis techniques *Importance:* / *Indication:* Not at all - Slightly - Moderately - Very - Extremely -
		The responses clearly indicate that, when assessing the economic viability of CSP technologies, financial analysis techniques are crucial. Interestingly, the LCOE was also ranked as very important and extremely important for CSP.
11	In your opinion, what are the main ***financial risks*** when investing in CSP technology?	The participants indicated the following as financial risks when investing in CSP technology: • CSP projects are highly leveraged with a debt/equity ratio of around 70:30. This

RESPONSES – SECTION 3: INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS		
	QUESTION	**RESPONSE**
		makes it very difficult for shareholders to obtain their ROI in the short term. • The high debt/equity ratio mostly benefits lenders, rather than shareholders. • Underestimation of CSP's operational costs (e.g., running costs). During project development, operational costs are forecasted for the duration of the project lifespan, and participants indicated that these costs are often understated. • An increase of unfavourable weather conditions reduces the efficiency of electricity generation, consequently reducing revenue. • CSP projects are solely dependent on revenues received from Eskom; therefore, a major concern is the potential repercussions should Eskom be liquidated. • The instability of Eskom's grid has a negative impact on the revenues of CSP projects. CSP plants are compensated for every MWh generated and sent to Eskom. The unavailability of the grid implies that CSP plants cannot dispatch available electricity generated. As a result, electricity generated during grid unavailability is wasted/lost revenues. In summary, CSP has been indicated as highly leveraged with a high risk of debt repayment.

RESPONSES – SECTION 3: INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS		
	QUESTION	**RESPONSE**
		Deteriorating weather conditions lead to less production which, in turn, leads to less revenue received from Eskom. Some participants raised concerns of Eskom being liquidated, which would result in the termination of CSP projects due to the absence of revenue from Eskom.
12	In your opinion, what are the main ***financial opportunities*** of investing in CSP technology?	The participants indicated the following as financial opportunities of investing in CSP technology: • Once the initial investment in CSP plants is recovered (and debt paid off), there are high returns for shareholders. • Government support creates financial opportunities through subsidies and funding. • CSP can easily be integrated with PV, increasing electricity generation capacity and reducing operations and maintenance costs, as well as initial capital outlay. • There is a high investment appetite among SA financial institutions to invest in CSP projects. • The possibility of selling electricity to parties other than Eskom has the potential to unlock additional revenue streams. In brief, the participants indicated many financial opportunities for CSP. Government funding was also mentioned as playing a crucial role in reducing CSP costs and attracting investors. This can also add to CSP's economic viability.

RESPONSES – SECTION 3: INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS		
	QUESTION	**RESPONSE**
13	Please list any ***challenges*** that exist with regard to ***obtaining the required finances to fund investment*** in CSP projects.	The participants indicated the following as challenges to obtaining funding for investment in CSP projects: • CSP projects take time to reach financial close due to the high initial capital outlay needed. Financial close is when (i) all the financial requirements for the initial capital outlay have been fulfilled; (ii) PPA has been signed, and (iii) financing conditions have been met to commence with CSP plant construction (Global Infrastructure Hub, 2023). • A minimum of R10 billion is required to invest in a 100 MWh CSP project. This has two major implications: - Identifying investors and securing capital to finance such a large investment take time; and - Sourcing such a large amount of finance necessarily involves several stakeholders. This complicates decision-making and the approval process during the development and operational phase. To sum up, the high initial capital outlay is a major challenge for CSP and leads to some delays in project implementation and financial close.
14	South Africa currently has seven operating CSP plants with a total planned capacity of 600 MWh (of which 500 MWh have reached commercial operation). The	Participants indicated their opinions (with an X) and made the following comments to support their opinion:

RESPONSES – SECTION 3:

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CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS

	QUESTION	**RESPONSE**
	remaining 100 MWh are planned to reach commercial operation later in 2023. Would you recommend ***further investments in CSP plants*** in addition to the existing CSP plants? Please elaborate briefly.	<table><tr><th>Indication:</th><th>Comment:</th></tr><tr><td></td><td></td></tr><tr><td>Yes X X X X</td><td>• CSP has storage capabilities when compared to other RETs like wind and PV. • PV can easily be integrated with CSP and SA has enough land available to develop CSP-PV hybrid systems. • Investors are willing to fund (invest in) CSP projects. • New technology has much longer energy storage capacity (up to 12 hours), making it possible to generate electricity for 24 hours per day (an example is SA's Redstone CSP project).</td></tr><tr><td>No -</td><td>-</td></tr></table> All four participants indicated that they would recommend further investments in CSP due to its storage capabilities when compared to other RETs. They also indicated that CSP can easily be integrated with PV and that South Africa has enough land to develop CSP-PV hybrid systems projects. Investors also seem willing to fund CSP projects, and new projects are creating longer storage hours. They mentioned the Redstone CSP project which will be able to store energy for 12 hours, operating 24 hours a day. In summary, the participants indicated that there is great potential for the future development of

<table>
<tr><th colspan="3">RESPONSES – SECTION 3:
INTERVIEW QUESTIONNAIRE:
CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS</th></tr>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td>CSP over and above what the IRP has projected.</td></tr>
<tr><td>15</td><td>In your view, do you regard PV as a lower cost alternative to CSP, considering the overall benefits of each of these RE sources? Please elaborate and provide reasons supporting your opinion.</td><td>Participants commented as follows:
PV is only cheaper than CSP when energy storage is excluded from CSP. However, when energy storage is included with CSP, CSP is cheaper than PV.
CSP is unique when compared to wind and PV due to its ability to store energy for use after sunset.
In summary, participants do not view PV as a cost alternative to CSP due to CSP’s TES system capabilities, which are not available with PV. Participants consider CSP to be unique when compared to PV and that CSP and PV should be complementary rather than competing technologies. The responses also indicate that CSP’s economic viability goes beyond checking the costs as storage plays a crucial role in evaluating RETs economic viability.</td></tr>
<tr><td>16</td><td>Social factors refer to the social environment of a country and include those factors that influence or are influenced by an investment, e.g., factors such as poverty and unemployment, education and skills, equality, cost of living, cultural trends, demographics, population analytics, family structures, community engagement, acceptance of new technologies, tourist and stakeholder</td><td>Participants indicated (with an X) the importance of social factors as follows:

<table><tr><th colspan="2">Education and skills of available labour force</th></tr><tr><th>Importance:</th><th>Indication:</th></tr><tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
X X
X X</td></tr></table>
<table><tr><th colspan="2">Alleviation of unemployment (in local community)</th></tr><tr><th>Importance:</th><th>Indication:</th></tr></table></td></tr>
</table>

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE:

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	QUESTION	**RESPONSE**
	impact, skilled community, and human life improvement. Please indicate the importance of the following social factors relevant to CSP technology as an RE source (please indicate with an X).	

Not at all	-
Slightly	-
Moderately	-
Very	X X
Extremely	X X

Cost of living and improvement of standard of living	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X
Very	X
Extremely	X X

Community engagement and development	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X
Extremely	X X X

Acceptance of new environmentally green technology	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X X X
Extremely	X

Shareholder impact	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X
Extremely	X X X

Other social factors	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	-
Extremely	-

<table>
<tr><th colspan="3">RESPONSES – SECTION 3:
INTERVIEW QUESTIONNAIRE:
CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS</th></tr>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td>The responses demonstrate that CSP projects play a pivotal role with regard to the socio-economic aspects in the communities where they operate. The responses also indicate that social factors are crucial in determining the economic viability of CSP technologies.</td></tr>
<tr><td>17</td><td>Do you think South Africa has the necessary engineering and operational skills to realise the full potential of CSP technology? Please explain.</td><td>Participants indicated their opinions (with an X) and made the following comments to support their opinion:

<table><tr><th>Indication:</th><th>Comment:</th></tr><tr><td></td><td></td></tr><tr><td>Yes

X X</td><td>• Both participants raised their concern that much effort is still needed within CSP technology to improve the required skills.</td></tr><tr><td>No

X X</td><td>• Participants commented that there is still reliance on overseas skills to assist with the challenges experienced during CSP operations and maintenance.</td></tr></table>
The participants who indicated that there are skills available in SA, added that the main advantage of CSP is that part of the technology still resembles traditional electricity generation technology. Thus, there is still a pool of skills available from Eskom to assist in this regard.</td></tr>
<tr><td>18</td><td>Do CSP plants create permanent employment after construction of the CSP plant? If yes, how many permanent jobs would be / were created by your organisation’s CSP plant?</td><td>Participants indicated their opinions (with an X) and estimated the quantity of permanent jobs created as follows:

<table><tr><th>Indication:</th><th>Estimated permanent jobs created:</th></tr><tr><td></td><td></td></tr><tr><td>Yes</td><td>• CSP plant 1: 100 jobs; and</td></tr></table></td></tr>
</table>

<table>
<tr><th colspan="3">RESPONSES – SECTION 3:
INTERVIEW QUESTIONNAIRE:
CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS</th></tr>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td><table><tr><td>X X X X</td><td>• CSP plant 2: 89 jobs.</td></tr><tr><td>No

-</td><td>-</td></tr></table>
All participants agreed that CSP projects do create permanent employment after construction. The number of employees ranges from a staff complement of 89 to 100 permanent employment during operations and maintenance of the plant.</td></tr>
<tr><td>19</td><td>In your opinion, what are the main benefits of CSP technology for the local community in which it operates? Please elaborate.</td><td>Participants commented the following:
• Most participants indicated that 1% of CSP’s annual revenue is contributed towards community development projects (as stipulated in the PPA).
• Jobs are created in the local community.
• Since CSP is a new technology, employment by CSP plants/projects presents employees the opportunity to acquire new skills.
• One participant commented that, since there is a lack of skills and low education within the communities where CSP plants are located, most of the community development is focused on education and health.

In brief, through the PPAs, CSP projects are contractually bound to contribute to community development. They also employ local communities, bolstering the local economy and enhancing the economic viability of CSP projects.</td></tr>
</table>

<table>
<tr><th colspan="3">RESPONSES – SECTION 3:
INTERVIEW QUESTIONNAIRE:
CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS</th></tr>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td>20</td><td>In your opinion, what are the main benefits of CSP technology in the national community of South Africa? Please elaborate.</td><td>Participants indicated the following benefits and commented the following:
Supplier development.
Contribution to minimising (and ultimately eliminating) electricity shortages.
Skills development of CSP employees and upcoming employees through on-the-job training. CSP plants are also obliged through the PPA to issue bursaries to students.</td></tr>
<tr><td>21</td><td>Technological factors refer to the availability of infrastructure for the necessary support of modern systems, including technological development, availability of technology, cost of technology, innovation, technological flexibility, automation levels, rate of technological changes, government spending on technology, R&D, new technology adoption, etc.

Furthermore, RET factors include intermittency (which is unplanned variations in the power generated by wind or solar due to changes in weather patterns), dispatchability (dispatchable generation is the type of electricity that can be distributed based on the electricity demand; this can be very flexible in terms of load matching and peak matching on a short notice; can also be useful to cover intermittent RE sources when the demand is high), variability (variability is the</td><td>Participants indicated (with an X) the importance of technological factors as follows:

<table>
<tr><th colspan="2">Availability of technology</th></tr>
<tr><th>Importance:</th><th>Indication:</th></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>-</td></tr>
<tr><td>Moderately</td><td>-</td></tr>
<tr><td>Very</td><td>X</td></tr>
<tr><td>Extremely</td><td>X X X</td></tr>
</table>

<table>
<tr><th colspan="2">Cost of technology
(investment in technology)</th></tr>
<tr><th>Importance:</th><th>Indication:</th></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>-</td></tr>
<tr><td>Moderately</td><td>-</td></tr>
<tr><td>Very</td><td>-</td></tr>
<tr><td>Extremely</td><td>X X X X</td></tr>
</table>

<table>
<tr><th colspan="2">Government spending on technology</th></tr>
<tr><th>Importance:</th><th>Indication:</th></tr>
<tr><td>Not at all</td><td>-</td></tr>
<tr><td>Slightly</td><td>-</td></tr>
<tr><td>Moderately</td><td>X</td></tr>
<tr><td>Very</td><td>-</td></tr>
<tr><td>Extremely</td><td>X X X</td></tr>
</table>

<table>
<tr><th colspan="2">R&D</th></tr>
<tr><th>Importance:</th><th>Indication:</th></tr>
<tr><td>Not at all</td><td>-</td></tr>
</table>
</td></tr>
</table>

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INTERVIEW QUESTIONNAIRE:

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	QUESTION	**RESPONSE**
	fluctuating nature of solar resources, which translates into potentially rapid changes in electricity output), scalability (i.e., the deployment of RETs can start on a small scale and grow without the need for a complete replacement of the available infrastructure), and energy storage (the ability of RETs to store energy for use at a later stage). Please indicate the importance of the following technological factors relevant to CSP technology as an RE source (please indicate with an X).	Slightly - Moderately - Very - Extremely X X X X *RETs:* *Intermittency capacity* *Importance:* / *Indication:* Not at all - Slightly - Moderately - Very X X Extremely X X *Dispatchable electricity distribution* *Importance:* / *Indication:* Not at all - Slightly - Moderately - Very X Extremely X X X *Variability in electricity output* *Importance:* / *Indication:* Not at all - Slightly - Moderately - Very X X Extremely X X *Expandability of electricity generation capacity (scalability)* *Importance:* / *Indication:* Not at all - Slightly - Moderately - Very X Extremely X X X *Energy storage capacity (storing energy for later use)* *Importance:* / *Indication:* Not at all - Slightly - Moderately - Very -

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE:

CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS

<table>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>Extremely</td><td>X X X X</td></tr>
</table>
<table>
<tr><td colspan="2">Other technological factors</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
-
-</td></tr>
</table>
In summary, energy storage for CSP continues to be relevant when determining CSP’s economic viability, and all the participants ranked energy storage as extremely important. Participants also indicated that a substantial amount of R&D still needs to be done, and all participants ranked this factor as extremely important. The costs of CSP technology are also essential when evaluating CSP technologies, and all the participants ranked the cost of technology as extremely important.
</td></tr>
<tr><td>22</td><td>Legal factors refer to established rules, regulations, and legislation used by a government to ensure the wellbeing of a country’s economy and the protection of assets and individual rights, e.g., laws and regulations governing tax, employment, licensing, extraction of natural resources, energy management and planning (including grid access), ownership models, access to resources, etc.

Please indicate the importance of the following legal factors relevant to CSP technology as an RE source (please indicate with an X).</td><td>
Participants indicated (with an X) the importance of legal factors as follows:
<table>
<tr><td colspan="2">Laws and regulations (energy planning, management, and grid access)</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
X X
X X</td></tr>
</table>
<table>
<tr><td colspan="2">Access to resources</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
X X X
X</td></tr>
</table>
</td></tr>
</table>

RESPONSES – SECTION 3:

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<table>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td colspan="2">Licencing</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
X X
X X</td></tr>
</table>
<table>
<tr><td colspan="2">Other legal factors</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
-
-</td></tr>
</table>
In summary, legal factors were viewed by participants as relevant and important when considering CSP’s economic viability. Government, through the IRP and PPAs, also contributes to the development of CSP projects.
</td></tr>
<tr><td>23</td><td>Environmental factors refer to the impact of natural events on a project and a project’s impact on the natural environment. These factors include weather, pollution, climate change, air quality and ventilation, water quality, waste control, raw material, agriculture, geological aspects, noise levels, lighting, and health and safety, etc.

Please indicate the importance of the following environmental factors relevant to CSP technology as an RE source (please indicate with an X).</td><td>Participants indicated (with an X) the importance of environmental factors as follows:

<table>
<tr><td colspan="2">Weather conditions</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
-
X X X X</td></tr>
</table>
<table>
<tr><td colspan="2">Pollution and waste management</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
X
X X X</td></tr>
</table>
<table>
<tr><td colspan="2">Climate change</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all</td><td>-</td></tr>
</table>
</td></tr>
</table>

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CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS

	QUESTION	**RESPONSE**

Slightly	-
Moderately	-
Very	X
Extremely	X X X

Water quality and availability	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	-
Extremely	X X X X

Dust and cleanliness of CSP equipment	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	-
Extremely	X X X X

Health and safety in the workplace	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X
Extremely	X X X

Environmental influences (including agricultural influences) of a CSP plant	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X
Extremely	X X X

Site rehabilitation (on closure of the CSP plant)	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X
Very	X
Extremely	X X

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE:

CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS

<table>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td colspan="2">Other environmental factors</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
-
-</td></tr>
</table>

The responses show that most of the environmental factors are very important and extremely important when considering their relevance to CSP technology. It should also be noted that the participants ranked weather conditions, water quality and availability, and dust and cleanliness of CSP equipment as extremely important only</td></tr>
<tr><td>24</td><td>A CBA refer to the process of comparing projected costs and benefits associated with a project decision to determine whether it is sound to invest in that specific project. CBA considers a project’s benefits and costs in monetary terms to determine the best project proposal by tallying up all costs of a project and subtracting that amount from the total projected benefits. With regard to CSP technologies, the total tangible costs of a CSP project include financing, labour, capital investment, insurance, installation, mirror and tube cleanings, fuel, solar field maintenance, power block maintenance, and TES maintenance. The total tangible benefits of CSP plants include revenues received for production, subsidies received from the</td><td>Participants indicated (with an X) the importance of relevant costs and benefits as follows:

Tangible costs:
<table>
<tr><td colspan="2">Finance (capital investment cost)</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
X X
X X</td></tr>
</table>

<table>
<tr><td colspan="2">Installation</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately
Very
Extremely</td><td>-
-
-
X X
X X</td></tr>
</table>

<table>
<tr><td colspan="2">Labour (employment)</td></tr>
<tr><td>Importance:</td><td>Indication:</td></tr>
<tr><td>Not at all
Slightly
Moderately</td><td>-
-
-</td></tr>
</table>
</td></tr>
</table>

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE:

CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS

	QUESTION	**RESPONSE**
	government, and funding from investors or government. Intangible costs mainly include relocation of habitat, lost agricultural activities, and intangible benefits includes reduction in gas emissions, improved standard of living, improved health through air quality, and reduced noise when compared to conventional power generation assets. Please indicate the importance of the following costs and benefits relevant to CSP technology as an RE source (please indicate with an X).	

Very	X X
Extremely	X X

Insurance	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X
Extremely	X X X

Intangible costs:

Relocation of habitat (fauna and flora)	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X X
Very	X
Extremely	X

Lost agricultural activities	
Importance:	*Indication:*
Not at all	X
Slightly	-
Moderately	X X X
Very	-
Extremely	-

Tangible benefits:

Revenue	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	-
Extremely	X X X X

Government subsidies	
Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X
Very	X X
Extremely	X

RESPONSES – SECTION 3:

INTERVIEW QUESTIONNAIRE:

CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS

	QUESTION	**RESPONSE**

Investor funding

Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	-
Extremely	X X X X

Intangible benefits:

Reduction in greenhouse gas emissions

Importance:	*Indication:*
Not at all	X
Slightly	-
Moderately	X
Very	-
Extremely	X X

Improved living standards – local community

Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X
Very	X
Extremely	X X

Improved living standards – national community

Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	X
Very	X
Extremely	X X

Health and safety benefits (in comparison to other electricity generation methods)

Importance:	*Indication:*
Not at all	-
Slightly	-
Moderately	-
Very	X
Extremely	X X X

Reduced noise levels (in comparison to other electricity generation methods)

RESPONSES – SECTION 3: INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS		
	QUESTION	**RESPONSE**
		Importance: / *Indication:* Not at all: X Slightly: - Moderately: X X Very: X Extremely: - *Other costs/benefits indicated* *Importance:* / *Indication:* Not at all: - Slightly: - Moderately: - Very: - Extremely: -

4.3.4 Section 4: Other general aspects

4.3.4.1 Interview questionnaire: Chief Executive Officers and Chief Financial Officers

The responses of the participants to section 4 of the questionnaire are presented in table 4.7 below.

Table 4.7 – Responses from participants – section 4 of questionnaire: Chief Executive Officers and Chief Financial Officers

RESPONSES – SECTION 4: INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS		
	QUESTION	**RESPONSE**
25	In your opinion, what are the **most important** factors **considered by stakeholders** when analysing/considering CSP projects for investment?	Participants indicated the following most important factors considered by stakeholders when analysing/considering CSP projects for investment: • ROI. • Stability of investment (consistency of investments over time). • Stakeholders expect operational results to exceed base case parameters. Base case parameters are the project's

<table>
<tr><th colspan="3">RESPONSES – SECTION 4:
INTERVIEW QUESTIONNAIRE:
CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS</th></tr>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td>expected key performance indicators based on assumptions made at the project development stage (APMG International, 2022)
• Viability of the CSP project.
• CSP's ability to satisfy SA electricity demand.
• The strength of potential shareholders.
• Investment security and the financial position of the project's potential shareholders.
• Revenue of the CSP project.
• The CSP project's health and safety.
• Longevity of the project.

The most dominating factor, as indicated by all the participants, was the significant consideration given to ROI by stakeholders. Two participants expressed concerns about CSP plants' actual performance falling below the initial projections made during project development. For this research, ROI is crucial for assessing the economic viability of CSP plants.</td></tr>
<tr><td>26</td><td>Can CSP output capacity be increased once it has been set at, e.g., 100 MWh? If so, are there any plans to increase the existing capacity of your organisation's CSP plant in the future? Please elaborate.</td><td>Participants indicated their opinions (with an X) and elaborated on future plans to increase capacity as follows:

<table><tr><th>Indication:</th><th>Possibility of increasing electricity generation capacity and opinions</th></tr><tr><td></td><td></td></tr><tr><td>Yes

X X X X</td><td>• Since it is possible to increase CSP output, OEMs always provide an option to enhance the generator to</td></tr></table></td></tr>
</table>

RESPONSES – SECTION 4:

INTERVIEW QUESTIONNAIRE:

CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS

	QUESTION	**RESPONSE**
		provide more output than it was originally designed to generate. • All four participants indicated that their plants have a capacity of 100 MWh (the maximum they can send out to Eskom). This means that the generator can produce more than 100 MWh and the excess generation is used for auxiliary consumption. Auxiliary consumption is the electricity consumed internally for managing the electricity generation technology equipment. • Modifications to an existing plant to increase its output capacity might be more expensive than building a new CSP plant with higher output capacity. • One participant mentioned that the storage capacity of a TES system can also be increased to coincide with the increased output capacity of a CSP plant.
		No - : -
27	Does the CSP plant sell all of its output (MWh) at full capacity to Eskom at both peak and standard production periods? If not, please briefly state the reason/s.	Participants' responses were as follows: *Indication:* : *Sell all output (MWh) at full capacity to Eskom at both peak and standard production periods:* Yes X X X X : • All the participants indicated that the CSP plants are compensated for supply during peak production periods (a higher rate applies during peak periods, hence the reason for

RESPONSES – SECTION 4:

INTERVIEW QUESTIONNAIRE:

CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS

<table>
<tr><th></th><th>QUESTION</th><th>RESPONSE</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td></td><td>splitting supply between peak and standard production periods).
• One participant indicated that the split between peak and standard production periods depends on the PPA with Eskom.</td></tr>
<tr><td>No

-</td><td>-</td></tr>
</table>

The responses from the participants indicate that CSP's ability to continue to generate electricity after sunset has the benefit of being compensated at a higher rate than standard production, which makes CSP more economically viable as an RE source compared to other RETs.
</td></tr>
<tr><td>28</td><td>Are there any future plans to incorporate PV technology with the existing CSP plant? If so, please elaborate briefly on why this is planned.</td><td>
Participants' responses were as follows:

<table>
<tr><td>Indication:</td><td>Planning to incorporate PV technology into the existing CSP plant</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Yes

X X</td><td>• A CSP-PV hybrid system can increase electricity generated and dispatched to Eskom, increasing revenues.
• One of the two participants mentioned that CSP-PV hybrid systems do exist in other countries, specifically referring to a solar park in Dubai under development. This project is expected to generate about 5 400 MWh of electricity (the world's largest CSP project/plant).</td></tr>
<tr><td>No

X X</td><td>• No plans for CSP-PV hybrid system.
• No plans for future CSP-PV hybrid system.</td></tr>
</table>
</td></tr>
</table>

RESPONSES – SECTION 4: INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS AND CHIEF FINANCIAL OFFICERS		
	QUESTION	**RESPONSE**
		The responses indicate that there is great potential for integrating CSP with PV in the future. Not only will this increase output sold, but also increase revenues.
29	Are there any ***other important aspects/ factors*** that have not been covered during the interview that you would like to ***bring to the attention of, or discuss*** with the interviewer? If so, please list and elaborate on these aspects.	One participant stated the following as other important aspects/factors regarding CSP plants and/or technology: • The owners of CSP technology are mostly foreign companies and it takes time for them to transfer skills to the local workforce. The result is that CSP plants receive assistance from the foreign companies for operational and maintenance activities. • Loss of production in CSP plants is attributed to a lack of skills.

4.4 Thematic analysis

Step 1: Familiarising yourself with the data

Step 1 of the thematic analysis was explained in detail in chapter 3 under paragraph 3.4.4 (i) and paragraph 3.4.5. Familiarisation with the data was done through the interviews conducted with the participants, as explained in detail in paragraph 3.4.3. The researcher took notes on the questionnaire template of the responses of the participants. These notes were later transcribed and reread by the researcher to familiarise himself with the collected data. The data were summarised in paragraph 4.3 of chapter 4.

Step 2: Generating initial codes

Saldaña (2013:3) defines a code as “most often a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data”. Clarke and Braun (2013:3) refer to step 2 as coding stage where labels need to be generated to get some crucial features of the data of relevance to the research

question guiding the analysis. Linneberg and Korsgaard (2019:6) defines coding as mostly the process of identifying segments of meaning from the data and also labelling them with a code.

Coding was based on the responses provided by the participants. The identified codes are indicated in table 4.8 below.

Table 4.8 – Coding and identified codes

Questionnaire section	***Question topic***	***Questionnaire participants***	***Coding / Codes***	***Question/s (number/s)***
1: Participant's information	Qualification	PMs & OMs	Qualifications indicated: • PM 1: Master's degree in architectural design • PM 2: Master's degree in business leadership (MBL) • OM 1: Master's degree in industrial process management • OM 2: Bachelor of Technology in chemical engineering	1
		CEOs & CFOs	Qualifications indicated: • CEO 1: Master's in engineering business management, and master's in electrical engineering • CEO 2: Post-graduate qualification in civil engineering technology • CFO 1 and 2: Chartered Accountant (CA (SA))	1
	Main duties & responsibilities	PMs & OMs	Duties and responsibilities indicated: • Management of plant operations and performance (Overseeing plant operations and performance) • Maintenance planning (Maintenance planning) • Coordination of operations (Operations coordination – especially coordination of operational challenges with the project company) • Management of plant compliance (Production management, management of safety compliance, and	2

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			management of environmental activities) • Production management (Production cost management and production efficiency management) • Contractor evaluation (Managing contractor evaluation on site)	
		CEOs & CFOs	Duties and responsibilities indicated: • Overall CSP plant management (Overseeing plant operations and performance) • Contract management (Contract management, especially disputes with Engineering, Procurement and Constructions (EPC) company) • Finance and human resource management (Managing finances, banking, investor relations and human resources) • Reporting to the board of directors (liaising with the board of directors)	2
	Period in current position	PMs & OMs	Periods indicated: • PM 1: 6 months • PM 2: 4 years • OM 1: 3 months • OM 2: 2 years	3
		CEOs & CFOs	Periods indicated: • CEO 1: 7 years • CEO 2: 4 months • CFO 1: 7.4 years • CFO 2: 7 years	3
	Period of employment in energy industry	PMs & OMs	Periods indicated: • PM 1: 19 years • PM 2: 10.5 years • OM 1: 8 years • OM 2: 9 years	4
		CEOs & CFOs	Periods indicated: • CEO 1: 13 years • CEO 2: 35 years • CFO 1: 7.4 years • CFO 2: 10 years	4

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
	Period involved in CSP technology	PMs & OMs	Periods indicated: • PM 1: 6 months • PM 2: 10.5 years • OM 1: 8 years • OM 2: 9 years	5
		CEOs & CFOs	Periods indicated: • CEO 1: 13 years • CEO 2: 4.5 years • CFO 1: 7.4 years • CFO 2: 7 years	5
2: Concentrated Solar Power systems/ technologies (CSP)	Strengths of CSP technology	PMs & OMs	Strengths indicated: • CSP low primary cost using sun as energy source (CSP has low primary costs compared to other traditional electricity generation technology due to its usage of the sun as the source of energy). • CSP uses sun as source of energy, traditional electricity generation methods use coal and gas as source of energy (CSP harnesses energy from the sun, regarded as clean energy unlike traditional electricity generation technology which uses coal and gas). • CSP has low maintenance costs (CSP has lower maintenance costs compared to other electricity generation technology). • CSP generates electricity at night (CSP has the ability to store energy during the day and continue to generate electricity at night). • CSP does not emit harmful gases (CSP's reliance on the sun contributes to combating climate change). • CSP can send electricity to the grid as and when required (CSP is a dispatchable energy, allowing	7

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			production adjustment to meet grid requirements). • CSP creates jobs and improves economic growth (CSP creates jobs and improves economic growth). • CSP becomes more reliable over a longer term (The longer CSP is implemented, the more robust it becomes in terms of its reliability due to experience gained from existing CSP plants). • CSP provides a ROI (CSP plants can operate for 20 to 30 years, allowing investors to obtain their required ROI).	
		CEOs & CFOs	Strengths indicated: • CSP can generate electricity at night (The ability of CSP to store energy during the day to continue to generate electricity after the sunset). • CSP uses less water (compared to traditional electricity generation technologies). • CSP are compensated for generating electricity during high demand times (Compensation for CSP's peak production). • Minimal gases emitted by CSP (Minimal pollution experienced with CSP plants compared to traditional electricity generation technology, and this is good for the environment). • CSP uses the sun as the source of energy, traditional electricity generation technology uses coal and gas as the source of energy	6

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			(CSP plants use RE in comparison to traditional electricity generation which uses coal and gas to generate electricity). • CSP is a proven technology globally (CSP is an internationally proven technology, although it is new to South Africa). • TES makes CSP unique to PV (CSP is unique and advantageous to PV due to CSP's TES capabilities. PV can only generate electricity during the day since it cannot store energy for electricity generation at night, whereas CSP technology can).	
	Weaknesses of CSP technology	PMs & OMs	Weaknesses indicated: • CSP requires large area of land for development (CSP plants require a large area of land for development. Consequently, it is difficult to build in highly populated areas). • CSP relies on DNI which changes with weather patterns (Climate change and consequential change in weather patterns, affects DNI levels). • More spares needed for CSP compared to wind and PV (CSP relies on the availability of a lot of spares to operate in comparison to other RETs like wind and PV). • CSP has high initial capital outlay (Initial capital outlay for CSP is very high. Unlike wind and PV, CSP plants require a traditional turbine generator to generate	7

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			electricity which is used by traditional electricity generation technology. As a result, the power block section of a CSP plant is similar in design than the traditional electricity generation technology). • Suitable areas for CSP plants are normally water scarce areas (CSP plants are located in arid areas to maximise DNI levels. Consequently, CSP plants are normally located in arid areas with less annual rainfall and water scarcity). • Suitable areas for CSP are those areas with high DNI (CSP can only be built in areas where DNI levels are sufficiently high to maintain certain minimum temperatures, enabling the technology to generate electricity efficiently).	
		CEOs & CFOs	Weaknesses indicated: • CSP has high initial capital outlay (CSP has high initial capital outlay compared to wind and PV. A CSP plant needs (i) a solar field to harness energy from the sun, (ii) a salt system (TES) to store energy during the day for electricity generation at night, and (iii) a power block to turn the turbine generator to generate electricity. The equipment is expensive and consequently require a higher initial capital outlay). • CSP requires highly skilled personnel for operations and maintenance (CSP technology is new to	6

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			South Africa and, due to its complex nature, requires highly skilled personnel to operate and maintain it). • CSP plants experience pre-mature failures of tubes and mirrors (there are challenges with the tubes, e.g., maintaining the tubes' vacuum, hydrogen content of the tubes, high operating temperature of the tubes, and cleaning problems with tubes and mirrors due to dust accumulation). • CSP plants take longer to construct (It takes longer to construct CSP plants compared to other RETs, e.g., PV. CSP can be implemented as quickly as within six months). • It is difficult to source CSP spare parts (It is difficult to source CSP technology spare parts, which leads to production losses. Most of the OEMs are based overseas and this causes prolonged lead times for spares delivery).	
	Opportunities of CSP	PMs & OMs	Opportunities indicated: -	-
		CEOs & CFOs	Opportunities indicated: • CSP has the ability to be integrated with PV (PV can easily be integrated with CSP). • CSP's opportunity to manufacture spares locally (Due to skills and spare part scarcity in South Africa, great potential exists for local manufacturing of spare parts and local skill development and training). • Opportunities for skills transfer (Opportunities for skills transfer to	7

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			South Africa from international CSP experts). • CSP research in South Africa is ongoing (CSP research is done in South Africa through the University of Stellenbosch). • CSP has the ability to store energy (CSP has the potential to store the sun's energy during the day for electricity generation during night time. Consequently, electricity can be generated for longer hours than daytime only. This contributes to minimising load shedding). • CSP's opportunity for further development (Although CSP is a new technology in South Africa, it presents opportunities for further development in the country due to high DNI levels providing the required minimum temperature needed by CSP).	
	Threats of CSP	PMs & OMs	Threats indicated: -	-
		CEOs & CFOs	Threats indicated: • Possible PV battery storage development to compete with TES (Risk of the other RETs such as PV battery storage and wind turbines that might be further developed in the future at lower costs compared to CSP). • Eskom's financial instability can lead to non-payment of invoices to CSP plants (Eskom's financial instability, damaged infrastructure, and grid availability. CSP projects rely on Eskom's financial	7

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			instability for revenue and grid availability to supply generated electricity). • CSP plants are very complex to operate (CSP plants are very complex to operate, and currently prolonged production losses are experienced due to skills scarcity). • CSP creates high expectation for jobs among local community (There is high expectation for jobs among local communities where the CSP plants are situated. CSP plants each employ about 90 permanent employees in operations and maintenance, which is much lower than the expectation of the local community).	
	Logistical issues with spare parts	PMs & OMs	Issues indicated and elaborated: • Geographical location of CSP plants makes it difficult to source spares (CSP plants are located far away from industrial areas, and this makes it very difficult to source spares and get them on time). • Inefficient spares ordering system for CSP plants (The spares ordering system is inefficient within the CSP plants). • Shortage of spares due to CSP being a new technology in South Africa (CSP is a new technology in South Africa, while most spares are sourced abroad, consequently causing delays in deliveries). • CSP plants experience delays in operations and maintenance due	6

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			to geographical location (Geographical location, as indicated by one participant, causes delays during operations and maintenance of CSP equipment/plants, but not during construction).	
		CEOs & CFOs	-	-
	Controllable production inefficiencies	PMs & OMs	Inefficiencies indicated : • Production losses experienced due to human error (Human error due to a lack of necessary skills leading to production losses). • Production losses caused by dirty mirrors and tubes (Dirty mirrors and tubes resulting in less energy harnessed from the sun, leading to production losses. In order for the mirrors and tubes to be effective in harnessing energy from the sun, it should always be kept clean). • Reduced production due to poor management of TES (Failure to manage the TES system reduces energy storage capabilities, ultimately leading to production inefficiencies). • Production losses due to lack of skills (Lack of personnel skills leads to the CSP plant losing opportunities to capitalise on good weather conditions). • Production losses due to lack of skills (Turnaround time for addressing breakdown is very slow). • Production losses due to unavailability of spares (Poor preventative	8

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			maintenance due to lack of spares). • Production loss due to lack of skills (Problems in CSP plants are mostly experienced during the first five years of operation). Recommendations • Training and development of personnel (Training and development of personnel). • New cleaning technologies can be applied to mirrors and tubes resulting in improved production (Improved mirror cleanliness, utilising new cleaning technologies and cleaning material). • Improved spares availability can minimise corrective/reactive maintenance resulting in increased production (Improved availability of spares to facilitate timeous preventative maintenance, ultimately avoiding corrective/reactive maintenance. • Eskom needs to improve its grid availability to enable CSP plants to continuously dispatch electricity and minimise revenue losses (Improvement in Eskom's grid stability. Grid stability ensures the availability of Eskom's transmission lines, facilitating the uninterrupted supply of electricity to the grid by CSP plants). • Reduced staff turnover (The shortage of skills results in CSP plants recruiting employees from other CSP plants, leading to a high	

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			number of employees leaving their current jobs to go to other CSP plants).	
		CEOs & CFOs	-	-
	The efficient use of CSP-PV hybrid systems in SA	PMs & OMs	Opinions and elaboration: • Yes - TES can be used for electricity generation at night and PV used for electricity generation during the day (PV can be used during the day while charging the TES system for production of electricity at night, using the CSP plant). - CSP-PV hybrid system increases electricity generated (South Africa's electricity demand is very high. CSP-PV hybrid systems can increase electricity generation capacity to address electricity shortages). - CSP-PV hybrid system reduces reliance on coal and gas by traditional electricity generation technology (CSP-PV hybrid systems in South Africa can reduce reliance on coal and gas by traditional electricity generation technologies, and as a result reduce harmful gas emissions). - CSP-PV hybrid system reduces land usage, leading to less mirrors and tubes used, resulting in reduced LCOE (The CSP-PV hybrid systems	9

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			can also optimise land usage, reducing utilisation of agricultural land used for stock, cattle, and game farming. CSP-PV hybrid systems can also reduce the LCOE and attract CSP investment. CSP-PV hybrid systems reduce the size of the solar field and less usage of mirrors and tubes, reducing operations and maintenance costs). • No -	
		CEOs & CFOs	-	-
3: Determinants of economic viability & PESTLE analysis	Political factors	PMs & OMs	Importance ratings of: • Labour laws / legislation • Local trade restrictions • Environmental policies / legislation • Other indicated factors: - none	10
		CEOs & CFOs	Importance ratings of: • Tax policies / legislation • Labour laws / legislation • Foreign trade restrictions • Local trade restrictions • Import / export duties and tariffs • Environmental policies / legislation • Corruption • Political stability • Other indicated factors: - Eskom instability - Guarantee of government	8
	Economic factors (General)	PMs & OMs	Importance ratings of: • Availability & condition of goods and services • Wages rates • Working hours • Transport • Other indicated factors: -	11

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
		CEOs & CFOs	Importance ratings of: • SA's general economic climate and conditions • Availability & condition of goods and services • Interest rates • Foreign exchange rates • Inflation rates • Funding & credit availability • Other indicated factors: -	9
	Economic factors (Financial analysis techniques)	PMs & OMs	-	
		CEOs & CFOs	Importance ratings of: • Accounting rate of return (ARR) • Payback period (PGP) • Discounted payback period (DPB) • Net present value (NPV) • Internal rate of return (IRR) • Localised cost of energy (LCOE) • Other indicated financial analysis techniques: -	10
	Economic factors (Other)	PMs & OMs	Recommendation of further investment in CSP plants and elaboration: • Yes - CSP plants increase electricity capacity, minimising the impact of load shedding (CSP increases the availability of electricity in South Africa while the country is currently struggling with load shedding). - CSP also responds to the high South African demand for electricity (South Africa needs additional electricity generation capacity to supply for the high demand). - The high DNI in the Northern Cape is suitable for CSP	12

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			development (The Northern Cape is a perfect location for electricity generation by CSP due to the area's high DNI levels, meeting the minimum requirements of CSP plants which ultimately optimises the efficiency of CSP plant electricity generation). - CSP-PV hybrid system will reduce cost per kWh. (The opportunity to integrate PV with CSP in future will maximise electricity generation and reduce cost per kWh). - CSP depending on the TES hours, can generate electricity for 24 hours a day (Traditional electricity generation technology (e.g., coal and gas) can generate electricity 24 hours a day, while wind turbines can generate electricity whenever sufficient air movement (wind) is available. Furthermore, CSP can generate electricity for 24 hours depending on TES capabilities). - Further CSP development will reduce initial capital outlay (CSP provides great opportunity for cost reduction on initial capital outlay. CSP takes longer to construct (up to three years) compared to PV	

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			(e.g., can be implemented as quickly as six months). The more CSP gets developed, the more experience is gained, and this can reduce construction duration. As a result the initial capital outlay will be reduced). • No	
			View and opinion of PV as lower cost alternative to CSP: • PV is cheaper on small-scale electricity generation and CSP is cheaper on large-scale electricity generation (PV is only cheaper when generating electricity on a smaller scale. However, with large scale electricity generation, CSP is more cost efficient than PV). • CSP with TES is cheaper than PV (A participant has indicated that, when a TES system is incorporated into CSP enabling electricity generation at night, CSP becomes cheaper than PV). • CSP has more benefits than PV when considering TES (Although small-scale PV electricity generation is cheaper than CSP, the benefits of CSP's daytime energy storage capabilities need to be considered). • CSP has more advantages than PV (CSP has more advantages than PV and are compensated for peak production	14

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			due to the TES system). • ROI for CSP takes some time when compared to PV (The ROI might be favouring PV in the short term, whereas CSP provides long-term ROI).	
			Cost drivers of operations and maintenance of CSP plants Operations cost drivers: • Number of employees. • Material and consumable usage. • Cleaning of the solar field. • Insurance. • HTF costs. • Quantity of chemicals used. • Data monitoring and operating system costs Maintenance cost drivers: • Spare part usage. • Solar field. • TES system. • Power block. • Cleaning of the solar field.	13
		CEOs & CFOs	Financial risks indicated: • It is difficult for shareholders to get their ROI (CSP projects are highly leveraged with debt/equity ratio at around 70:30. This makes it very difficult for shareholders to obtain their ROI). • CSP projects have a high debt/equity ratio (The high debt/equity ratio mostly benefits lenders, rather than shareholders). • CSP's operational/ running costs are normally under-estimated during project development (Underestimation of CSP's operational costs, e.g., running costs. During project	11

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			development, operational costs are forecasted for the duration of the project's lifespan and participants indicated that these costs are often understated). • Unfavourable weather conditions negatively impact DNI, resulting in production and revenue losses (The increase in unfavourable weather conditions reduces the efficiency of electricity generation, in turn, reducing revenue). • CSP solely depends on revenues received from Eskom (CSP projects are solely dependent on income from Eskom, therefore, a major concern is the influence in the event of Eskom being liquidated). • Grid unavailability reduces energy sent out, resulting in revenue losses (The instability of Eskom's grid also has a negative effect on CSP projects' income. CSP plants are compensated for every MWh generated and sent to Eskom. The unavailability of the grid implies that CSP plants cannot dispatch available electricity generated. As a result, electricity generated when the grid is not available is wasted and not compensated, leading to lost revenues).	
			Financial opportunities indicated: • There are high returns for shareholders once the initial capital outlay is recovered (Once the initial investment in	12

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			CSP plants is recovered and debt paid off there are high returns for shareholders). • CSP needs support from the government through subsidies and funding (Government support creates financial opportunities through subsidies and funding). • CSP-PV hybrid system can reduce running and initial capital outlay costs (CSP can easily be integrated with PV, increasing electricity generation capacity and reducing operations, maintenance costs and initial capital outlay). • South African financial institutions also support CSP development (There is a high investment appetite among South African financial institutions to invest in CSP plants/projects) • Electricity sales to other customers other than Eskom can also create additional revenues for CSPs (The possibility of selling electricity to other parties than Eskom has the potential to unlock additional revenue streams)	
			Challenges in obtaining required finance: • CSP projects experience financial close delays (CSP projects take time to reach financial close due to the high initial capital outlay needed. Financial close is when (i) all the financial requirements for the initial capital outlay	13

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			have been fulfilled, (ii) PPA has been signed and (iii) financing conditions have been met to commence with CSP plant construction). • CSP projects require high initial capital outlay (A minimum of R10 billion is required to invest in a 100 MWh CSP project. This has two major implications: (i) Identifying investors and securing capital to finance such a large investment take time; and (ii) Sourcing such a large amount of financing necessarily involves several stakeholders. This complicates decision-making and the approval process during the development and operational phases).	
			Recommendations of further investment in CSP plants and elaboration • Yes - CSP has TES system and wind and PV does not have TES system (CSP has storage capabilities when compared to other RETs like wind and PV). - Investors are willing to fund CSP projects (Investors are willing to fund or invest in CSP projects). - CSP plants are capable of generating electricity for 24 hours a day (New technology has much longer energy storage capacity, allowing it to generate electricity	14

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			for 24 hours per day). • No -	
			View and opinion on PV as lower cost alternative to CSP: • CSP is cheaper than PV when TES is included and expensive when TES is excluded (Most participants indicated that PV is only cheaper than CSP when energy storage is excluded from CSP. However, when energy storage is included with CSP, CSP is cheaper than PV). • CSP can store energy to be used after sunset (CSP is unique when compared to wind and PV due to its ability to store energy for use after the sunset).	15
	Social factors (General)	PMs & OMs	Importance ratings of: • Education and skills of available labour force. • Alleviation of unemployment (in local community). • Cost of living and improvement of standard of living. • Community engagement. • Stakeholder impact. • Other indicated factors: -	15
		CEOs & CFOs	Importance ratings of: • Education and skills of available labour force. • Alleviation of unemployment (in local community). • Cost of living and improvement of standard of living. • Community engagement and development. • Acceptance of new environmentally green technology. • Stakeholder impact. • Other indicated factors:	16

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			-	
	Social factors (Other)	PMs & OMs	View and opinion on SA having the necessary engineering and operational skills to realise the full potential of CSP technology. • Yes - CSP plants get most of their skills locally from Eskom (Eskom is a valuable source for supplying CSP plants with employees who have the required skills). - CSP plants are struggling to meet the remuneration and benefits demands of available skills (South Africa does have the labour force with the required skills, while the challenge currently is employee' remuneration and benefits). - CSP plants are located in areas where there is a shortage of skills since most skills are available in industrial areas (Since CSP plants are located in remote areas, employees with the necessary skills are only available in industrial areas). - It is easy for the labour force to adapt to CSP plants because they have similar features than the power block with traditional electricity generation technology (Part of the CSP plant, i.e., the power block, is similar to traditional	16

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			electricity generating assets. This makes it easy for the labour force to adapt to the entire CSP technology). - South Africa's existing CSP plants can be used for further skills development (South Africa has currently enough CSP plants for further skills development). • No - Shortage of engineering and operational skills due to CSP technology being new in South Africa (Since CSP is still new technology in South Africa, a lot of training by educational institutions in CSP technology is needed).	
			Permanent employment created by CSP plants? • Yes - CSP plant 1 : 100 jobs - CSP plant 2: 89 jobs • No -	17
			Percentage local skilled labour vs foreign skilled labour operating and maintaining the CSP plant: • CSP plant 1 - 100% local skilled labour • CSP plant 2 - 80% local skilled labour - 20% foreign skilled labour	18
		CEOs & CFOs	View and opinion on SA having the necessary engineering and operational skills to	17

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*

			realise the full potential of CSP technology:
			• Yes
			  - But a lot still needs to be done to improve skills (Both participants have raised concerns that a lot still needs to be done within CSP technology to improve the required skills).
			• No
			  - South African CSPs still rely on foreign skills (Participants commented that there is still reliance on overseas skills to assist with the challenges experienced during CSP operations and maintenance).	

			Permanent employment created by CSP plants?
			• Yes
			  - CSP plant 1: 100 jobs
			  - CSP plant 2: 89 jobs
			• No
			-
				18

			Benefits of CSP technology to the local community: • 1% CSP revenue is allocated for community development projects (Most participants indicated that 1% of CSP's annual revenue is contributed towards community development projects (as stipulated in the PPA). • CSP plants create jobs in communities where they operate (Local job creation). • New skills are acquired from CSP technology (Since CSP is a new technology, employment by CSP plants/projects	19

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			presents employees the opportunity to acquire new skills). • The 1% revenue allocation to community development is focused on education and health (One participant commented that, due to the lack of skills and low education levels among the communities where CSP plants are located, most of the community development is focused on education and health).	
			Benefits of CSP technology to SA's national community: • Development of suppliers (Supplier development). • CSP minimises electricity shortages (Contributing to minimising and, ultimately, eliminating electricity shortages). • On-the-job training at CSP plants improves skills of the labour force (Skills development of CSP employees and new employees through on-the-job training. CSP plants are also obliged through the PPA to issue bursaries to students).	20
	Technological factors (general)	PMs & OMs	Importance ratings of: • Availability of technology. • Cost of technology (investment in technology). • Maintenance cost. • Maintenance frequency. • Technological flexibility and adaptability. • Level of automation.	19

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			Importance ratings of renewable energy technology: • Intermittency capability. • Dispatchable electricity distribution. • Variability in electricity output. • Expandability of electricity generation capacity (scalability). • Energy storage capacity (storing energy for later use). • Other indicated factors: -	
		CEOs & CFOs	Importance ratings of: • Availability of technology. • Cost of technology (investment in technology). • Government spending on technology. • Research and development. Importance ratings of renewable energy technology: • Intermittency capability. • Dispatchable electricity distribution. • Variability in electricity output. • Expandability of electricity generation capacity (scalability). • Energy storage capacity (storing energy for later use). • Other indicated factors: -	21
	Technological factors (general)	PMs & OMs	Benefits of incorporating TES with a CSP plant: • CSP with TES can continue to generate electricity after sunset (A TES system enables a CSP plant to continue generating electricity when there is no sun). • CSP with TES improves reliability of CSP technology (A	20

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			TES system improves dispatchability and reliability of the CSP plant). • CSP with TES is able to meet demand changes (A TES system enables a CSP plant to meet the variable and dynamic electricity demand). • TES system reduces gas emissions, positively benefiting the environment (A TES system has environmental benefits. It minimises the need for using fossil fuels for electricity generation, reduces gas emissions, and consequently combats climate change). • TES system provides grid flexibility by providing electricity as and when required by the national grid (A TES system provides grid flexibility). • CSP with TES can generate electricity within timeframes when there is high demand for electricity (A TES system enables CSP plants to generate electricity after sunset and this timeframe includes peak production. e.g., peak production is a period where demand for electricity is very high as a result, electricity generated by CSP plants is compensated at a higher rate than normal production and, consequently, contributes 80% of CSP revenue generated).	
		CEOs & CFOs	-	-
	Legal factors	PMs & OMs	Importance ratings of: • Laws and regulations – operational.	21

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			• Laws and regulations – health and safety. • Access to resources. • Other indicated factors: -	
		CEOs & CFOs	Importance ratings of: • Law and regulations (energy planning, management, and grid access). • Access to resources. • Licencing. • Other indicated factors: -	22
	Environmental factors (General)	PMs & OMs	Importance ratings of: • Weather conditions. • Pollution & waste management. • Climate change. • Water quality & availability. • Dust and cleanliness of CSP equipment. • Health and safety in the work place. • Other indicated factors: -	22
		CEOs & CFOs	Importance ratings of: • Weather conditions. • Pollution & waste management. • Climate change. • Water quality & availability. • Dust and cleanliness of CSP equipment. • Health and safety in the work place. • Environmental influences (including agricultural influences) of a CSP plant. • Site rehabilitation (on closure of the CSP plant). • Other indicated factors: -	23
	Environmental factors (Other)	PMs & OMs	Recommended future improvements of operations and maintenance activities within CSP plants: • Yes - Improvement in prolonged lifespan for tubes can reduce operations and maintenance	23

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			costs (Tube replacements are primarily caused by degradation and vacuum losses. New, cheaper technologies are emerging for tube repairs, instead of replacing damaged / broken tubes, which is very expensive. A participant indicated that a CSP plant currently explores this new technology). - Reduced breakages of mirrors and tubes in turn reduces maintenance costs (A participant indicated that a CSP plant is currently doing a Root Cause Analysis for tube and mirror breakages. The findings will assist in reducing future mirror and tube maintenance cost). - New cleaning strategies for mirrors and tubes will improve reflectivity and, as a result, improve productivity and reduce maintenance costs (Improved cleaning of mirrors and tubes can also assist in reducing maintenance cost, although it requires further R&D on cleaning chemicals to improve reflectivity of tubes and mirrors). - Reducing accumulated dust in the solar field can reduce mirror and tube cleaning costs	

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			(Reducing the soiling rate, also known as accumulated dust of mirrors and tubes, can also reduce mirror and tube cleaning cost). • No -	
		CEOs & CFOs	-	-
	Cost-benefit analysis (CBA)	PMs & OMs	Importance ratings of tangible costs: • Labour (employment). • Mirror cleaning. • Fuel. • Solar field maintenance. • Power block maintenance. • TES. • General maintenance. Importance ratings of intangible benefits: • Reduction in greenhouse gas emissions. • Health and safety benefits (in comparison to other electricity generation methods). • Reduced noise levels (in comparison to other electricity generation methods). • Other indicated factors: -	24
		CEOs & CFOs	Importance ratings of tangible costs: • Finance (capital investment cost). • Installation. • Labour (employment). • Insurance. Importance ratings of intangible costs: • Relocation of habitat (fauna and flora). • Lost agricultural activities. Importance ratings of tangible benefits: • Revenue.	24

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			• Government subsidies. • Investor funding. Importance ratings of intangible benefits: • Reduction in greenhouse gas emissions. • Improved living standards – local community. • Improved living standards – national community. • Health and safety benefits (in comparison to other electricity generation methods). • Reduced noise levels (in comparison to other electricity generation methods). • Other indicated factors: -	
4. Other general aspects	Most important factors considered by stakeholders in analysing/considering CSP projects for investment	CEOs & CFOs	Factors indicated: • ROI (ROI). • Consistency of ROI (Stability of the investment/consistency of investment over time). • Stakeholders expect actual operational results to be higher than projected results (Stakeholders expect operational results to exceed base case parameters. Base case parameters are the project's expected performance based on assumptions made at project development stage). • CSP project's total revenues should be able to cover total costs (Viability of the CSP project). • CSP plants should be able to positively contribute to meeting South Africa's electricity demand (CSP's ability to satisfy South African electricity demand).	25

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			• Stakeholders rely on the positive contribution of shareholders to the CSP project (The strength of potential shareholders). • Stakeholders rely on a sustainable investment and a strong balance sheet for the CSP's project company (Investment security and the financial position of the project's potential shareholders). • Stakeholders consider sustainable revenues received from Eskom for the CSP projects (Revenue of the CSP project). • Stakeholders consider health and safety of CSP labour force (The CSP project's health and safety). • Consideration of the long-term sustainability of the project (Longevity of the project).	
	CSP plant's plans to increase its output capacity in the future	CEOs & CFOs	View and elaboration: • Yes - The OEM can increase CSP's output (Since it is possible to increase CSP output, OEMs always provide an option to enhance the generator to provide more output than it was originally designed to generate). - CSP plant 1 and CSP plant 2 are currently generating electricity in excess of 100 MWh. The excess is for internal use to run the plant's equipment (All four participants indicated that their plants have a	26

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			capacity of 100 MWh (the maximum they can send out to Eskom. This means that the generator can produce more than 100 MWh; the excess generation is used for auxiliary consumption. Auxiliary consumption is the electricity consumed for managing the electricity generation technology equipment). - Existing plant modifications might be more expensive than constructing a new CSP plant (Modifications to an existing plant to increase its output capacity might be more expensive than building a CSP plant from scratch with a higher output capacity). - Increase storage hours of the TES can increase output (One participant mentioned that the storage capacity of a TES system can be increased to coincide with the increased output capacity of a CSP plant). • No -	
	CSP plant selling all of its output at full capacity to Eskom	CEOs & CFOs	View and elaboration: • Yes - CSP plants receive higher revenues for electricity generated during high demand times, referred to as peak production, when compared to lower demand, referred to as standard	27

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			production (All the participants indicated that the supplier is compensated for supply during peak production periods – a higher rate for peak periods, hence the reason for splitting supply between peak and standard production periods). - The rate paid by Eskom on peak and standard production depends on the PPA (One participant indicated that the split between peak and standard production periods depends on the supplier's PPA with Eskom).	
	CSP plant's plans to incorporate PV technology with the existing CSP plant in the future	CEOs & CFOs	View and elaboration: • Yes - CSP-PV hybrid system increases the electricity generated (CSP-PV hybrid system can increase electricity generated and dispatched to Eskom, which increases revenue). - CSP-PV hybrid system increases electricity generated (One participant mentioned that CSP-PV hybrid systems do exist in other countries, e.g., a solar park in Dubai under development that will generate about 5 400 MWh of electricity, the largest global CSP project/plant). • No - No plans for CSP-PV hybrid system.	28

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
			- No plans for future CSP-PV hybrid system.	
Closing question	Any additional aspects not covered in questionnaires that participants wanted to add/discuss with researcher	PMs & OMs	Aspects/factors mentioned/discussed: • CSP technology is only viable in areas with high DNI (CSP technology is viable technology, but the major challenge is the location of the CSP plants (due to its dependence on and its location limited to areas with high minimum required DNI levels). Areas having the required minimum DNI levels are usually arid with water shortages due to little annual rainfall). • Manufacturing of CSP spares locally can reduce expected time of delivery and minimise production losses (Localisation of spares is needed to minimise production losses caused by delayed maintenance resulting from the unavailability of imported spares). • R&D is still needed on how to prolong tube and mirror lifespan (South Africa needs laboratory facilities for tube and mirror testing, to ultimately improve the efficiency of harnessing the sun's energy). • New cleaning strategies through chemical testing will improve energy harnessing from the sun, resulting in improved production (Efficient new chemical testing to assist with mirror and tube cleaning aimed to ultimately improve mirror reflectivity).	25

Questionnaire section	*Question topic*	*Questionnaire participants*	*Coding / Codes*	*Question/s (number/s)*
		CEOs & CFOs	Aspects/factors mentioned/discussed: • CSP owners are mostly foreign companies, resulting in delayed skills transference to the South African labour force (The owners of CSP technology are mostly foreign companies and it takes time for them to transfer skills to the local workforce. This means that CSP plants are getting assistance from the foreign companies for operational and maintenance activities). • Lack of CSP skills by local labour force results in production losses (Loss of production in CSP plants is also contributed to lack of skills).	29

Step 3: Searching for themes

To address this study's primary objective, which is to evaluate the economic viability of CSP as an RE source using a CBA, four pre-existing themes were identified. As explained in chapter 3 under paragraph 3.4.5, a deductive thematic analysis was applied to identify the themes. A theoretical framework was used to structure the questionnaires into sections keeping the themes in mind. The four themes were (i) Participants' experience, duties, and responsibilities, (ii) CSP's Strength, Weaknesses, Opportunities, and Threats (SWOT analysis), (iii) Determinants of economic viability and PESTLE analysis, and (iv) The future development of CSP technology.

Step 4: Reviewing themes

Step 4 involved reviewing the themes identified in step 3. The main purpose of this step was to ensure that the themes were relevant to the research question, which is whether CSP could be economically viable as an RE source in SA. In step 4 the researcher reflected on the themes to determine whether they could still be linked back to the original data gathered. In this way, the researcher found that the four themes indeed were relevant to the study's primary objective.

Step 5: Defining and naming themes

Step 5 involved the mapping of the codes (generated in step 2) to the four themes already identified in step 3. This is illustrated in table 4.9 below.

Table 4.9 – Identified themes from identified codes

Theme	***Questionnaire section***	***Section Questions' topic/s***	***Question timeframe/ focus***	***Questionnaire participants***	***Question/s (number/s)***
Participants' experience, duties & responsibilities	1: Participant's information	Participant's experience, duties, and responsibilities	-	PMs & OMs	1 to 5
			-	CEOs & CFOs	1 to 5
CSP SWOT analysis	2: Concentrated Solar Power systems/ technologies (CSP)	Strengths & weaknesses	Operational	PMs & OMs	6 to 9
			Strategic	CEOs & CFOs	6
		Opportunities & threats	Operational	PMs & OMs	-
			Strategic	CEOs & CFOs	7
Determinants of economic viability & PESTLE analysis	3: Determinants of economic viability & PESTLE analysis	Political factors	Operational	PMs & OMs	10
			Strategic	CEOs & CFOs	8
		Economic factors	Operational	PMs & OMs	11 to 14
			Strategic	CEOs & CFOs	9 to 5
		Social factors	Operational	PMs & OMs	15 to 18
			Strategic	CEOs & CFOs	16 to 20
		Technological factors	Operational	PMs & OMs	19 & 20
			Strategic	CEOs & CFOs	21
		Legal factors	Operational	PMs & OMs	21
			Strategic	CEOs & CFOs	22
		Environmental factors	Operational	PMs & OMs	22 & 23
			Strategic	CEOs & CFOs	22
		Cost-benefit analysis (CBA)	Operational	PMs & OMs	24
			Strategic	CEOs & CFOs	24
The future development of CSP technology	***4:*** *Other general aspects*	-	Operational	PMs & OMs	-
			Strategic	CEOs & CFOs	25 to 28
Closing question	***Closing question***	Any additional aspects not covered in questionnaires that participants wanted to add/	Operational	PMs & OMs	25
			Strategic	CEOs & CFOs	29

		discuss with researcher			

Step 6: Producing the report

In step 6, the final stage of the analysis, the researcher has to write up the report to give a concise, coherent, logical, non-repetitive, and interesting account of the story as portrayed by the data within and across the themes. The fourth secondary objective of this study is to evaluate the economic viability of CSP as an RE source, draw conclusions, and make recommendations based on the literature review and the empirical findings. For the purposes of this study, step 6 forms part of chapter 5.

4.5 Summary

Chapter 4 addressed the third secondary objective of the study by providing a detailed description, explanation, and analysis of the research and its findings drawn from the interviews. The interviews were conducted with eight participants selected from two 100 MWh CSP plants in the Northern Cape. The chapter discussed how the data were collected from the eight participants through the semi-structured interviews, i.e., the structure of the interviews and the questionnaires used to conduct the interviews.

The chapter also provided the responses from the participants. The responses to each question were followed by a summary of the information gathered and linked to the research objectives of this study. This was followed by the thematic analysis of the data using the six-step approach by Braun and Clarke (2006:13). The last step (step 6) will be covered in chapter 5.

5. CHAPTER 5: RESEARCH RESULTS, ANALYSIS, AND DISCUSSIONS

5.1 Introduction

Chapter 5 addresses the fourth secondary objective of this research, which is to evaluate the economic viability of CSP as an RE source, draw conclusions, and make recommendations, all based on the literature review and the empirical research findings.

The primary objective of this study was to evaluate the economic viability of CSP as an RE source, using a cost-benefit analysis. The primary objective was supported by the following secondary objectives:

- The first secondary objective was to conduct a literature review to obtain a comprehensive understanding of the economic viability and suitability (especially in an SA context) of CSP. To achieve this, all relevant available material (from textbooks, journals, previous research and publications from the SA government) were consulted to identify, analyse, and evaluate all relevant quantitative and qualitative factors/information (chapter 2).
- The second secondary objective was to design an empirical study to enable the collection of sufficient, relevant, and trustworthy data to determine whether CSP (in an SA context) could be considered a viable RE source, considering all relevant factors (chapter 3).
- The third secondary objective was to describe, explain, and analyse the research findings to achieve the second secondary objective. The research findings were described and explained in chapter 4.
- The fourth secondary objective was to evaluate the economic viability of CSP as an RE source, draw conclusions, and make recommendations based on the literature review and the empirical research findings (chapter 5).

Chapter 5 commences with the conclusions drawn from the participants' responses, the literature review using a PESTLE analysis, and the empirical study using a PESTLE as well as a SWOT analysis. Thereafter, the chapter presents a CBA, followed by conclusions and recommendations derived from the CBA. The last two paragraphs of chapter 5 provide the limitations of this research and a final summary.

5.2 Conclusions drawn from the participants' responses

5.2.1 Plant and operations managers' experience and qualifications

The first plant manager had a master's degree in architectural design, while the second had a master's degree in business leadership (MBL) and a Bachelor of Technology degree in electrical

engineering. The first operations manager had a master's degree in industrial process management, and the second had a Bachelor of Technology degree in chemical engineering.

The average experience in the (i) current position for all four participants, as indicated in table 5.1 below, was 1.69 years; (ii) the average experience in the energy industry for all four participants was 11.63 years; and (iii) the average experience in CSP for all participants was 7.00 years.

As indicated in table 5.1, three participants had a minimum of eight years' experience in CSP, and one participant had six months' experience. However, the latter participant had 19 years' experience within the energy industry. The researcher considered the qualifications and experience of the participants sufficient to provide valid and trustworthy information for the study.

Table 5.1 – Summary of plant and operations managers' experience

Participants	Position	Experience in current position (years)	Experience in energy industry (years)	Experience in CSP (years)
1	Plant manager	0.50	19.00	0.50
2	Plant manager	4.00	10.50	10.50
3	Operations manager	0.25	8.00	8.00
4	Operations manager	2.00	9.00	9.00
	Total years	***6.75***	***46.50***	***28.00***
	Longest experience	4.00	19.00	10.50
	Shortest experience	0.25	8.00	0.50
	Average experience	1.69	11.63	7.00

5.2.2 CEOs' and CFOs' experience and qualifications

The first CEO had a master's degree in engineering business management, as well as a master's degree in electrical engineering. The second CEO had a post-graduate qualification in civil engineering technology. The two CFOs were Chartered Accountants (CA (SA)).

The average experience in the (i) current position for all four participants, as indicated in table 5.2 below, was 5.43 years; (ii) the average experience in the energy industry for all four participants was 16.35 years; and (iii) the average experience in CSP for all participants was 7.98 years.

Table 5.2 shows that all four participants had more than four years' experience in CSP. Their qualifications and experience were considered sufficient to provide valid and trustworthy information for the study.

Table 5.2 – Summary of CEOs' and CFOs' experience

Participants	Position	Experience in current position (years)	Experience in energy industry (years)	Experience in CSP (years)
1	CEO	7.00	13.00	13.00
2	CEO	0.33	35.00	4.50
3	CFO	7.40	7.40	7.40
4	CFO	7.00	10.00	7.00
	Total years	***21.73***	***65.40***	***31.90***
	Longest experience	7.40	35.00	7.40
	Shortest experience	0.33	7.40	4.50
	Average experience	5.43	16.35	7.98

5.3 Conclusions from the literature review

As mentioned above, the first secondary objective of the study was to conduct a literature review to obtain a comprehensive understanding of the economic viability and suitability (especially in an SA context) of CSP.

From the literature review (paragraph 2.3 specifically) it is clear that a distinction should be made between financial viability and economic viability. The purpose of financial viability is to determine whether a project is expected to generate adequate income (cash inflow) to recover financial cost (cash outflows) without external support. Economic viability's purpose, on the other hand, is wider than that of financial feasibility. Economic viability's purpose (particularly from a governmental perspective) goes beyond financial evaluating only. To be economically viable, a project should prove to be economically feasible, innovative, and sustainable by focussing on three dimensions of the project, i.e., (i) the country's entire economy, (ii) the welfare of the country's citizens, and (iii) the environmental impact. From this point of departure (paragraph 2.3), the literature review further suggests that a PESTLE analysis should be incorporated into an evaluation of (and consequently determining) the economic viability of CSP projects since a PESTLE analysis provides a framework analysis of macro factors when deploying CSP technology (European Union, 2020:6), facilitating a strategic understanding of (and consequently the impact on) the wider environment (Casan *et al.*, 2021:5, CIPD, 2021).

Consequently, evaluating the economic viability of CSP as RE source, can be done using a Cost-benefit analysis, incorporating a PESTLE analysis and a SWOT analysis. A Cost-benefit analysis focuses on the costs and benefits (financial and non-financial) which is supplemented by the PESTLE and SWOT analyses' strategic focus.

The following paragraphs (5.3.1, 5.3.2 and 5.3.3) draw conclusions from the literature review on PETSLE, Cost-benefit, and SWOT analyses.

5.3.1 PESTLE analysis

5.3.1.1 Political factors

From the literature review, the following conclusions can be drawn regarding political factors that (may) influence the economic viability of CSP as RE source:

The SA government's commitment, policies and programmes being implemented are crucial political factors determining the economic viability of CSP as RE source (DE, 2019b:36).

- Policy stability

  Transition from fossil fuels to RE sources is a political struggle and cannot be effective without confronting and destabilising dominant systems of energy power. While political factors are the main drivers of policy formulation and contribute substantially to RE investment considerations, policy stability is crucial for any country, representing the main reason why long-term energy targets (as pledged in the Paris Agreement) are not met – even on a global scale (Ndlovu & Telekdarie, 2020:189).

  Although the SA government has formulated policies and programmes to address the energy crisis through the IRP (MSSRF, 2017:12), the SA government's regulatory framework became a risk for SA in terms of enforcing and accelerating RE projects.

- Exclusion of CSP from the IRP beyond 2030

  Currently, energy experts have raised their concerns about CSP's exclusion from the IRP beyond 2030. The 600 MWh allocated to CSP through the existing IRP document until 2030 is insufficient, especially considering South Africa's CSP potential due to the abundance of DNI in the Northern Cape.

  Furthermore, CSP relies on attractive and efficient government policies to ensure a balanced approach when allocating RETs in the IRP document to effectively address SA's existing energy crisis and future energy needs.

- Revision of the IRP and role misalignment

  Although the SA government is committed to continuously revise the IRP document, this process occurs at a slower pace than anticipated (and necessary). One important revision that has been made is the increase in the generating license threshold from 1 MWh to

100 MWh (IPP projects generating electricity up to 100 MWh do not require a license to do so). This change signals the political will from the SA government to accelerate the implementation of RET projects. However, SA's energy experts remain concerned about the lack of role clarification and alignment between the newly established electricity ministry, the Department of Public Enterprises, and the Department of Energy.

- Electricity generation licenses/licencing

  Currently, the threshold for private entities to generate electricity without required licenses is 100 MWh (DE, 2021:6). This is a key political factor determining (and limiting) the economic viability of CSP as RE source, limiting the full potential of CSP to be utilised in SA due to the time-consuming application process to obtain electricity generating licenses

5.3.1.2 Economic factors

Governments play a crucial role in economic factors through policy formulation and implementation as well as supporting business activities (IMF, 2017:3). More specifically, macro-economic factors withing the economic environment influence the private sector (as well as the SA government) to support and invest in the development of CSP projects (Lennox *et al*., 2019:3). These two aspects are especially important since Investors rely heavily on economic factor analysis to be able to make informed investment decisions to yield optimum returns (StockMaster, 2022).

From the literature review, the following conclusions can be drawn regarding economic factors that (may) influence the economic viability of CSP as RE source:

- Economic growth

  The literature review has indicated that following main economic factors impact a country's development (Srivastav, 2023, Tanner, 2021):

  - Availability of natural resources

    Availability of natural resources for CSP (specifically the suitability of SA's climate and weather conditions (i.e., high and sufficient DNI radiation levels), does not hamper economic growth as far as the implementation and utilisation of CSP as RE source is concerned.

    Availability of natural resources may also be classified as a technological factor (technological factors are discussed below in paragraph 5.3.1.4).

- Adequate power and energy resources

  SA's existing energy (electricity) shortage and Eskom's ongoing financial struggle and inefficiency hamper SA's economic growth. Political factors also affect the SA government's ability to provide fair access to energy (Burke & Stephens, 2017:2).

  Adequate power and energy resources is also classified as a technological factor (technological factors are discussed below in paragraph 5.3.1.4).

- Adequate technological resources (and technological advancement)

  CSP technology per se, does not hamper economic growth, although the limited locally available CSP and related spare parts negatively influence the efficiency of CSP plants and technology.

  Adequate technological resources (and technological advancement) are discussed in paragraph 5.3.1.4 below).

- Capital accumulation (availability)

  Although the literature review revealed that CSP technology is indeed cost effective (when implemented at a larger scale), but this requires a huge initial capital outlay and, as a result, becomes risky for investors. Globally, government subsidies for CSP developments have proven to be the best way to attract private investment.

  Studies from the literature review also indicates that the LCOE, IRR, and NPV of CSP projects improve for government subsidised CSP projects (when compared to unsubsidised CSP projects). (Capital investment appraisal techniques are discussed below). Furthermore, compensation for the incorporation of TES into CSP enhances the competitiveness of CSP technology.

  In conclusion: apart from the fact that the availability of capital is crucial for investment, it is evident that government subsidies for CSP development is necessary to attract private investors in CSP plants, promising improved financial performance.

During the 2021 COP conference, SA secured about R131 billion in pledges by the European Union, France, Germany, and the United States of America to assist SA's transitioning process from electricity generation from primarily coal to using RETs.

- Sufficient human resources (available labour force)

  Sufficient human resources (available labour force) with regards to CSP development, implementation, and operation, does not hamper economic growth,

  Sufficient human resources (available labour force) are classified as a social factor (social factors are discussed below in paragraph 5.3.1.3).

- Adequate and relevant education levels and training

  Adequate and relevant education levels and training per se, does not hamper economic growth. However, the existing limited locally available and relevantly qualified (and/or trained) labour in CSP and related technology negatively influence the economic viability of CSP as RE source.

  Adequate technological resources (and technological advancement) is discussed in paragraph 5.3.1.4 below).

- Interest rates and inflation

  In general, high interest rates and inflation discourage investors from investment since it decreases the probability of earning reasonable returns on investments (Lennox *et al*., 2019:19). This would also be the case with investment in CSP projects.

- Capital investment appraisal techniques

  Although traditional capital investment appraisal techniques (Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PBP), and Accounting Rate of Return (ARR)) are used for the evaluation of CSP projects, many investors prefer to use the Levelised Cost of Electricity/Energy (LCOE) as primary indicator to make CSP (and other power generating technologies/methods) investment decisions. In addition to capital investment appraisal techniques, investors utilise cost-benefit analysis.

The literature review indicates that CSP projects' yield positive net present values (NPVs) and favourable payback periods (PBPs) ranging from 7.5 to 17.6 years (which are below the life expectancy of CSP plants). The average IRR of CSP plants/projects has increased to above the global IRR benchmark of 10%. According to IRENA (2023), CSP plants/projects' average LCOE values also decreased from 2010 (USD0.380/kWh) to 2023 (year to date: USD 0.118/kWh) – a decrease of 68.9%.

These abovementioned calculated capital investment appraisal techniques' results favour the economic viability of CSP as RE source.

5.3.1.3 Social factors

An energy transition will have an impact on social factors. The following conclusions can be drawn from the literature review regarding social factors that (may) influence the economic viability of CSP as RE source:

- Human welfare and quality of life

  SA's existing energy crisis with the consequential impact of loadshedding, impacts quality of life to a certain extend. Generating additional electricity, and ultimately sufficient electricity to sustainably satisfy demand in the long-term, will increase SA citizens' welfare and quality of life. CSP and related technology can greatly contribute towards a sustainable electricity supply in the long-term.

- Employment

  SA's existing energy crisis with the consequential impact of loadshedding, does not only negatively impact the economy and hampers economic growth, but it also negatively impacts employment when labourers/employees lose their jobs (e.g., businesses scaling down activities and/or closing down due to the severe impact of the energy crisis).

  Development and deployment of RE technologies can contribute greatly towards addressing SA's energy crisis, consequently stimulating general economic growth which would consequently create jobs (elevating unemployment). In addition to this general economic growth and job creation, development, and deployment of RE technologies in itself, will create jobs.

- Expertise, qualifications, skills, and training

  Currently, some RE technologies (particularly CSP and related technologies) are new in SA. Consequently, SA's labour force currently lacks the relevant expertise, qualifications,

and skills to support CSP and related technologies. Therefore, particularly CSP expertise are obtained internationally to support the development and operation of CSP plants. Skills shortages in the operation and maintenance of CSP plants have also been identified as a major challenge within the SA context, potentially leading to electricity generation (production) losses.

SA needs to provide relevant and sufficient training and development opportunities to the local labour force to improve their existing skills and to acquire new skills and qualifications. Equipping the local labour force with relevant skills, qualifications and ultimately expertise, will improve the economic viability of CSP as RE source by (i) providing local skilled and qualified labour force and expertise, while this will (ii) decrease cost of employment (and ultimately operational cost).

- Community development and upliftment

  CSP plants are typically situated in regions having high DNI, which are, in SA, coincidently in remote rural areas. These areas are home to previously disadvantaged communities. CSP project companies are compelled to contribute 1% of its revenue to community development. Consequently, the local economy is stimulated, benefitting both the community in several ways, e.g., promoting equality, job creation, reducing poverty levels, and providing electricity to previously disadvantaged communities not having access to electricity before.

  Over and above the contribution to community development, another 1% of revenue must be channelled towards black-owned enterprise development, having its own benefits.

  Furthermore, CSP project companies are required to have 8% of its shares held in community trusts. Being a shareholder in the CSP companies, community trusts receive dividends (as any other shareholder). These dividends are then used by community trusts to predominantly finance community centres and provide bursaries to local community members.

All of the above factors will positively contribute towards the economic viability of CSP as RE source.

5.3.1.4 Technological factors

Since CSP is a new technology being implemented in SA, technology and related matters will have an impact on technological factors. The following conclusions can be drawn from the literature review regarding technological factors that (may) influence the economic viability of CSP as RE source:

- Availability of RE resources

  DNI is CSP technology's primary (renewable) resource. SA's atmospheric conditions, especially in certain regions, have more than adequate high DNI levels being required by CSP technology / CSP plants for efficient operation. The Northern Cape has been identified as one of these suitable areas, having the highest DNI levels in SA.

- CSP's ability to incorporate TES systems/technology

  TES technology incorporated into CSP technology provides CSP plant with the ability to continue with electricity generation after sunset and during unfavourable atmospheric conditions when DNI levels are lower than optimal, or even too low to capture the sun's energy. Fully charged, large TES systems can support CSP's electricity generation for days, enabling CSP plants to dispatch electricity to the grid, as and when required. Therefore, incorporating TES into CSP solves the problem of mismatch between solar energy supply (availability) due to unfavourable atmospheric conditions, and electricity demand.

  Furthermore, the ability to continue with electricity generation after sunset and during unfavourable atmospheric conditions when DNI levels are lower than optimal, or even too low to capture the sun's energy, also increases CSP's electricity generation capacity through the availability of additional electricity generation hours. Consequently, higher revenue and profit can be generated due to increased electricity generation capacity.

  The possibility to incorporate TES into CSP, distinguishes CSP from other RE technologies (e.g., wind and PV) since TES equipped CSP plants can provide dispatchable electricity (see dispatchability below in the next bullet point) to the grid, ultimately stabilising the grid and electricity supply.

  Since TES incorporation into CSP plants distinguishes CSP from other RE technologies, this technological factor can also be identified as a strength under a SWOT analysis.

- Characteristics of CSP and related technology

  CSP and related technologies' characteristics have been discussed in chapter 2, paragraph 2.4.4 (ii):

- Energy storage capability

  CSP's energy storage capability (storing the sun's heat energy during daytime) enables electricity generation after sunset (by utilising the heat energy being stored during daytime) until the stored energy is depleted. Storage capacity of CSP plants varies from one plant, depending on the installed storage capacity of a particular CSP plant. Other RE technologies lack this capability. Furthermore, this energy storage capability of CSP greatly favours CSP's electricity generation efficiency above other RE technologies.

  CSP's energy storage capability consequently provides CSP with a competitive advantage above other RE technologies.

- Intermittency

  When TES is incorporated as additional feature into CSP, TES provides CSP with a solution to other RE technologies' intermittency problems (e.g., PV) (Suarez, 2021b).

  As for energy storage capability (discussed above), the option to incorporate TES into CSP to improve its energy storage capability provides CSP with a competitive advantage above other RE technologies.

- Dispatchability

  RE technologies other than CSP have dispatchability challenges (Potts & Walwyn, 2020:4, Energy Centre, 2018:6). CSP has a competitive advantage over PV due to CSP's ability to flexibly dispatch electricity on a large scale – even when there is no DNI (after sunset) or during low DNI (e.g., overcast weather).

  As for energy storage capability and intermittency (discussed above), CSP's ability to supply dispatchable electricity to the grid, provides CSP with a competitive advantage above other RE technologies.

- Variability

  Due to solar resources' variability in electricity supply as a consequence of atmospheric conditions (i.e., overcast weather), solar resources rely on grid

flexibility to accommodate this variability (IRENA, 2019:8). When assessing the economic viability of RE technologies, grid integrity (the grid's ability to cope with variability) is of vital importance when choosing different types of RE technologies to provide a balanced energy mix. A balanced energy mix (the mix of different RE technologies in the overall electricity generation network), should balance electricity supply, minimising variability.

Consequently, it is important for the SA government to provide sufficient support (funding), encouraging investors to invest in different RE technologies to obtain a balanced energy mix.

- Scalability

Emerging RE technology projects are often developed on a small scale due to uncertainties about the project's success. These uncertainties are primarily caused by investors' still considering CSP as a new technology in comparison to other matured RE technologies such as wind and PV. The high initial capital layout/investment required for investment in CSP plants, intensify investors' uncertainties about the project's success.

Once the project proves to be successful, these small-scale projects' capacities are increased (scaled up) to be more profitable. If scalability is not built into a small-scale project's initial design, expansion of such small-scale project to increase capacity could be very difficult and extremely costly. Not providing for scalability in a small-scale project's initial design, could therefore negatively influence the economic viability of RE technologies (including CSP technology).

The following technological factors provides CSP with a competitive advantage above other RE technologies: (i) availability of RE resources, (ii) TES technology incorporated into CSP technology, (iii) energy storage capability, (iv) intermittency, and (v) dispatchability.

However, the technological factors, variability, and scalability, could negatively influence the economic viability of RE technologies (including CSP technology) if not managed effectively.

5.3.1.5 Legal factors

The following conclusions can be drawn from the literature review regarding legal factors that (may) influence the economic viability of CSP as RE source:

- Regulated electricity sector

  Currently, SA's electricity sector is highly regulated, with Eskom (an SoE) the only authorised buyer of electricity being generated by IPPs. IPPs have requested the SA government to deregulate SA's electricity market to enable them to sell electricity to Eskom and any other entities.

  The overall purpose of regulating SA's electricity sector consists of the following three aims: (i) ensuring equal distribution of electricity throughput SA, preventing unfair unequal electricity distribution, (ii) ensuring a balanced energy mix, rather than a profit-driven energy mix determined by private investors, (iii) ensuring alignment of RE projects with commitments made in the Paris agreement; especially reaching net-zero carbon emissions by 2050. These three aims can also be regarded as advantages of regulating SA's electricity sector.

  Disadvantages of regulating SA's energy sector includes the following: (i) since electricity is supplied to a single buyer (i.e., Eskom) and electricity prices are regulated by NERSA, results in uncompetitive, higher electricity prices. These higher electricity prices negatively influence electricity's affordability – especially for previously disadvantaged communities, (ii) the current ERA grants too much power to the Minister of Energy, resulting in political interference with regards to type of RE technology to be implemented, causing unnecessary delays in the implementation of RE technologies and political pressure.

- Licencing to generate electricity

  The objective of electricity generation licencing is to ensure efficient, effective, sustainable, and orderly development and operation of electricity generation facilities within SA (NERSA, 2020). To obtain an electricity generation license, minimum regulatory requirements should be met by the applicant, e.g., the applicant should be part of the IRP plan, and will be located in an area in an area where connection to the grid would be possible.

  Initially, an electricity generation license was required by an electricity generating facility when more than 1 MWh (i.e., 1MW per hour) was generated. This threshold of 1 MWh has been increased to the existing maximum electricity generation capacity of 100 MWh (i.e., 100MW per hour) before an electricity generation license is required. According to NERSA, generation licenses should take around 120 days to be issued (excluding

provision for time to connect the electricity generating facility to the grid). However, IPPs complain that it takes longer than 120 days to obtain an electricity generation license.

From the above two factors, it is clear that SA's stringent electricity regulations is the major contributor to the current electricity challenges. The single buyer model is currently not working for South Africa and there is a need to allow IPPs to be given permission to sell electricity to private customers and not only Eskom. By increasing the threshold on electricity generation licenses, this is an indication that the SA government acknowledges the existing electricity crisis and wants to accelerate RE development.

5.3.1.6 Environmental factors

The following conclusions can be drawn from the literature review regarding environmental factors that (may) influence the economic viability of CSP as RE source:

- Greenhouse gas emission

  The emission of greenhouse gasses (GHGs) into the atmosphere by electricity generation facilities, is the main cause of climate change and its consequential problems (United Nations, 2015:6). The primary objective of the Paris Agreement is to minimise climate change and its detrimental consequences (United Nations, 2015:6). To reach this primary objective, the Paris Agreement employs the following two secondary objectives. Firstly, it is expected of countries who has commitment to the Paris Agreement to foster climate resilience (i.e., coping with and managing the negative impact of climate change and prevention of this negative impact becoming worse), and to limit its GHG emissions to the lowest possible level by implementing RE technology for electricity generation. Secondly, the Paris Agreement channels finances (funding) towards countries with low GHG gas emissions and development of climate resilience (United Nations, 2015:3).

  Since countries have to align their GHG emissions and the usage of RE technologies for electricity generation to the Paris Agreement, GHG emission levels should be considered when evaluating the economic viability of RE projects (Steenkamp & Naudé, 2018:71).

- Water consumption

  CSP technology uses either a wet cooling, or a dry cooling system for cooling purposes, both using water. CSP technology equipped with a wet cooling system, uses far less water than traditional electricity generation methods. Furthermore, although CSP technology equipped with a dry cooling system uses some water, CSP's water consumption is further

reduced by 80% when it is equipped with a dry colling system instead of a wet cooling system.

All attempts should be made to avoid contamination of both ground and surface water.

- Land occupation and usage

  Non-agricultural land should be efficiently used for CSP plants. Usage of agricultural land used for food production, should ultimately be avoided.

- Fauna and flora

  Construction and operation of RE technologies should ultimately not pose any threat to indigenous vegetation and wildlife.

  Environmentalists have raised concerns about bird mortality at CSP plants due to birds colliding with CSP's mirrors, mistaking the mirrors for water. However, recent research has indicated that, over time, birds become used to the mirrors, causing initial mortality rates to drop.

- Location – geographical considerations

  Geographic location plays a vital role in evaluating the economic viability of CSP as RE source, due to the following:

  - Available grid connection

    Selecting a location having the required DNI levels for CSP to be optimally efficient, can be challenging since such a suitable location may be remote in an area not having access to the grid for a connection between the grid and the CSP plant (Union of Concerned Scientists, 2017).

    However, this do not pose a problem in SA since the identified suitable areas having the required high DNI levels in the Northern Cape, do have access to the existing grid for a connection between the grid and the CSP plant. The economic viability of CSP as RE source is therefore not influenced by the unavailability of grid connections due to location.

  - Siting

Siting refers to the identification of a suitable area to position the CSP plant, as well as the negotiations to obtain the area, drafting and signing of contract/s, obtaining required licences and/or permits, and establishing relationships with the local community (Union of Concerned Scientists, 2017). Siting can be an administrative burden, can easily increase related costs beyond anticipated levels, and cause project delays (Union of Concerned Scientists, 2017).

None of the environmental factors should negatively influence the economic viability of CSP as RE source.

In fact, CSP's low GHG emission level and low water consumption (especially when equipped with a dry cooling system), favours CSP's economic viability. Furthermore, if SA adheres to the Paris Agreement's primary objective, SA can attract possible funding for investment in CSP as RE source which will greatly favour the economic viability of CSP as RE source.

Land occupation and usage, fauna and flora, and location factors should not influence the economic viability of CSP as RE source if they are carefully considered during development and optimally managed during the operation of CSP plants.

5.3.2 Cost-benefit analysis

The following conclusions can be drawn from the literature review regarding aspects of a Cost-benefit analysis that (may) influence the economic viability of CSP as RE source:

- Initial capital layout

  The main concern about CSP plants is the required initial capital investment which is very high in comparison to other RE technology projects (e.g., wind and PV). Higher investment consequently incurs higher financing costs. Higher financing costs will, as a result, negatively impact CSP's positive net economic contribution to society. On the other hand, CSP plants' benefits completely outweigh its costs, possibly leaving room to absorb increased financing costs.

  However, required investment in CSP plants has drastically declined over the past years. Actual investment in the KaXu Solar One project amounted to USD891 million (operations commenced during 2015), while budgeted investment in the Redstone project amounts to USD210 million (operations planned to commence towards the end of 2023). This decrease in CSP's investment cost is very encouraging for investors, while challenging

the decision of the SA government not to invest in additional projects once the Redstone project is completed.

- Costs

  The operations and maintenance cost of CSP plants are currently ranging between USD20/MWh and USD40/MWh, consisting of insurance costs, annual operational costs (ranging from 0.5% to 1% of the initial capital outlay, excluding maintenance costs), and maintenance costs (primarily represented by mirror cleaning cost and mirror replacement cost) (Reuters Events, 2018).

- Benefits

  CSP plants' primary benefit is the possibility to generation additional revenue when TES systems are incorporated into CSP plants. Another major benefit of CSP plants is CSP's ability to enhance grid stability by dispatching generated electricity to the grid as and when required. Another benefit of CSP plants is CSP's capability to provide varying temperature heat for industrial processes and water purification activities (which can be used in CSP plants itself) (Zhou *et al*., 2019:1), is yet another benefit of CSP plants.

  As emphasised by Fatima *et al*. (2021:1), extensive research has indicated that RE technologies do indeed (i) minimise the depletion of non-renewable energy resources (e.g., coal), (ii) ensures sustainable electricity generation and supply, and (iii) substantially reduce GHG emissions.

- Cost-benefit analysis results – costs vs benefits

  CSP plants' benefits outweigh its costs, especially when considering combatting climate change and SA's commitment to the Paris Agreement (implying the SA government's willingness to change from traditional (outdated) non-renewable resources to renewable energy (RE) sources as basis for electricity generation (Renaud *et al*., 2020:24)).

Considering the above conclusions, the most important to take note of is the fact that CSP plants' benefits outweigh its costs, especially when considering combatting climate change and SA's commitment to the Paris Agreement. This favours the economic viability of CSP as RE source.

5.3.3 SWOT analysis

The following conclusions can be drawn from the literature review regarding a SWOT analysis that (may) influence the economic viability of CSP as RE source:

5.3.3.1 Strengths

- CSP's ability to incorporate TES systems/technology

  TES technology incorporated into CSP technology has been identified as a technological factor in the PESTLE analysis (discussed in detail in paragraph 5.3.1.4). Since TES incorporation into CSP plants provides CSP with a competitive advantage above other RE technologies, it can also be identified as a strength of CSP technologies, favouring the economic viability of CSP as RE source.

- CSP's energy storage capability

  CSP's energy storage capability ability has been identified as a technological factor in the PESTLE analysis (discussed in detail in paragraph 5.3.1.4). Since CSP's energy storage capability is unique to CSP it also provides CSP with a competitive advantage above other RE technologies and can also be identified as a strength of CSP technologies, favouring the economic viability of CSP as RE source.

- CSP's intermittency capability with TES incorporated into CSP

  CSP's intermittency capability with TES incorporated into CSP has been identified as a technological factor in the PESTLE analysis (discussed in detail in paragraph 5.3.1.4). Since CSP's intermittency capability with TES incorporated into CSP provides a solution to other RE technologies' intermittency problems (e.g., PV), it can also be identified as a strength of CSP technologies, favouring the economic viability of CSP as RE source.

- CSP's dispatchability characteristic

  CSP's dispatchability has been identified as a technological factor in the PESTLE analysis (discussed in detail in paragraph 5.3.1.4). CSP's dispatchability overcome other RE technologies' dispatchability challenges, it can also be identified as a strength of CSP technologies, favouring the economic viability of CSP as RE source.

- CSP's low water consumption

  CSP's water consumption has been identified as an environmental factor in the PESTLE analysis (discussed in detail in paragraph 5.3.1.6). CSP's low water consumption can also

be identified as a strength of CSP technologies, favouring the economic viability of CSP as RE source.

5.3.3.2 Weaknesses

- Limited expertise, qualified labourers, and skills, and training

  Expertise, qualification, and training is also identified as a social factor in the PESTLE analysis (discussed in paragraph 5.3.1.3) but can also be identified as a weakness of CSP technologies.

  SA's labour force currently lacks the relevant expertise, qualifications, and skills to support CSP and related technologies. Therefore, particularly CSP expertise, are obtained internationally to support the development and operation of CSP plants. Skills shortages in the operation and maintenance of CSP plants have also been identified as a major challenge within the SA context, potentially leading to electricity generation (production) losses.

  Sourcing experts and labour having the required specialised skills from abroad, increase SCP operational cost which could negatively influence CSP's economic viability.

5.3.3.3 Opportunities

- CSP's ability to incorporate TES systems/technology

  TES technology incorporated into CSP technology has been identified as a technological factor in the PESTLE analysis (discussed in detail in paragraph 5.3.1.4) as well as a strength of SCP technologies in the SWOT analysis (paragraph 5.3.3.1). Since TES incorporation into CSP plants provides CSP with a competitive advantage above other RE technologies, it can also be identified as an opportunity for CSP plants not having TES systems incorporated, to incorporate TES systems to increase electricity generation (production) and income to favour its financial performance.

5.3.3.4 Threats

- Exclusion of CSP from the IRP beyond 2030

  The exclusion of CSP from the IRP beyond 2030 is also identified as a political factor but can also be identified as a threat to the future implementation and long-tern viability of CSP technology (exclusion of CSP technologies from the IRP beyond 2030 has been discussed in paragraph 5.3.1.1).

- Lack in government support of CSP technology

  CSP technology has not yet matured in SA, while alternative RE technologies (i.e., wind and PV) have matured. Consequently, the SA government does not support CSP technology by means of grants and subsidies. Therefore, potential investors in CSP plants are likely to opt for investment in alternative RE technologies.

5.4 Conclusions from the empirical study

5.4.1 PESTLE analysis

5.4.1.1 Political factors

The participants were asked to rank the following political factors that may have an influence on the economic viability of CSP as RE source, according to his/her order of importance: (i) labour laws and legislation; (ii) local trade restrictions; (iii) environmental policies/legislation; (iv) tax policies and legislation; (v) foreign trade restrictions; (vi) import and export duties and tariffs; (vii) corruption; (viii) political instability; (ix) Eskom financial instability; and (x) guarantees from the SA government.

Table 5.3 below indicates the average percentage of participants that have chosen a specific level of importance in ranking the abovementioned political factors.

Political factors indicated as extremely and very important, include tax policies and legislation, corruption, political instability, Eskom's financial instability, and guarantees from government.

Table 5.3 – Summary of results for political factors

Importance	Political
Extremely important	46%
Very important	24%
Moderately important	11%
Slightly important	7%
Not at all important	13%
TOTAL	**100%**

The following conclusions can be drawn from the empirical study regarding the political factors indicated as extremely and very important that (may) influence the economic viability of CSP as RE source:

- Corruption

  Corruption may not directly influence the economic viability of CSP as RE source but may have a negative impact on the SA government's available funding for CSP projects, the fair allocation of available funding, as well as delays in related administrative processes and procedures.

- Political instability

  Political instability may not directly influence the economic viability of CSP as RE source but may have a negative impact on SA's economy (e.g., the weakening rand causing increases in the cost of imported SCP spare parts and the cost to obtain CSP foreign expertise to support the development and operation of CSP plants). The extent of these cost increases will ultimately determine the severity of its impact on the economic viability of CSP as RE source.

- Guarantees from government

  Guarantees from government refers to financial support (e.g., grants, subsidies, etc.) to assist and ultimately encourage investment in CSP technologies and plants. This may negatively influence the economic viability of CSP as RE source since potential investors in CSP plants are likely to opt for investment in alternative RE technologies. (Lack in government support of CSP technology is identified as a threat to CSP technologies, discussed in paragraph 5.3.3.4).

5.4.1.2 Economic factors

The participants were asked to rank the following economic factors that may have an influence on the economic viability of CSP as RE source, according to his/her order of importance: (i) availability and condition of goods and services; (ii) wage rates; (iii) working hours; (iv) transport; (v) SA's general economic climate and conditions; (vi) interest rates; (vii) foreign exchange rates; (viii) inflation rates; (ix) funding and credit availability; (x) ARR; (xi) PBP; (xii) DPBP; (xiii) NPV; (xiv) IRR; and (xv) LCOE.

Table 5.4 below indicates the average percentage of participants that have chosen a specific level of importance in ranking the abovementioned economic factors.

Economic factors indicated as extremely and very important include transport, SA's general economic climate and conditions, interest rates, foreign exchange rates, funding and credit availability, PBP, DPBP, NPV, IRR, and LCOE.

Table 5.4 – Summary of results for economic factors

Importance	Economic
Extremely important	59%
Very important	28%
Moderately important	11%
Slightly important	2%
Not at all important	0%
TOTAL	**100%**

The following conclusions can be drawn from the empirical study regarding the economic factors indicated as extremely and very important that (may) influence the economic viability of CSP as RE source:

- SA's general economic climate and conditions

  SA's general economic climate and conditions directly links to SA's unstable and struggling economy, having detrimental consequences which will influence the economic viability of CSP as RE source.

  A consequence of an unstable and struggling economy is the weakening rand, causing increases in the cost of imported SCP spare parts and the cost to obtain CSP foreign expertise to support the development and operation of CSP plants. The extent of these cost increases will ultimately determine the severity of its impact on the economic viability of CSP as RE source.

  An unstable and struggling economy may hamper investment by potential, but cautious investors.

  Another consequence of an unstable and struggling economy is increased interest rates, leading to increased financing costs and quite possibly, increased inflation. The extent of the increase in interest rates will ultimately determine the severity of its impact on the economic viability of CSP as RE source.

- Interest rates

  Interest rates is discussed at the previous bullet point as a consequence of an unstable and struggling economy.

- Foreign exchange rates

  Foreign exchange rates are discussed at the first bullet point as a consequence of an unstable and struggling economy.

- Funding and credit availability

  Funding refers to the availability of financial support (e.g., grants, subsidies, etc.) from the SA government to assist and ultimately encourage investment in CSP technologies and plants. This may negatively influence the economic viability of CSP as RE source since potential investors in CSP plants are likely to opt for investment in alternative RE technologies. (Lack in government support of CSP technology is identified as a threat to CSP technologies, discussed in paragraph 5.3.3.4).

  Availability of credit itself, may not influence the economic viability of CSP as RE source. However, high interest rates may hamper the availability of credit at acceptable interest rates.

  Both funding and the availability of credit, may delay investment activities until funding and/or credit is obtained.

- PBP, DPBP, NPV, IRR, and LCOE

  Capital investment appraisal techniques are discussed as an economic factor under the heading *Capital investment appraisal techniques* in paragraph 5.3.1.2.

  Interesting though, is that the literature review indicates that many investors prefer to use LCOE as primary indicator to make CSP (and other power generating technologies/methods) investment decisions, while the empirical study indicates the contrary within SA.

5.4.1.3 Social factors

The participants were asked to rank the following social factors that may have an influence on the economic viability of CSP as RE source, according to his/her order of importance: (i) education and skills of labour force; (ii) alleviation of unemployment in the local community; (iii) cost of living and improvement of standard of living; (iv) community engagement and development; (v) acceptance of new environmentally green technology; and (vi) stakeholder impact.

Table 5.5 below indicates the average percentage of participants that have chosen a specific level of importance in ranking the abovementioned social factors.

Social factors indicated as extremely and very important, include education and skills of labour force, community engagement, and acceptance of new environmentally green technology.

Table 5.5 – Summary of results for social factors

Importance	Social
Extremely important	52%
Very important	32%
Moderately important	14%
Slightly important	2%
Not at all important	0%
TOTAL	**100%**

The following conclusions can be drawn from the empirical study regarding the social factors indicated as extremely and very important that (may) influence the economic viability of CSP as RE source:

- Education and skills of labour force

  The indication of education and skills of the labour as being extremely or very important by the participants, is an indication that the empirical study coincide with the literature review's conclusions.

  Education and skills of the labour force relevant to CSP technologies are discussed as a social factor in a PESTLE analysis under the heading *Expertise, qualifications, skills, and training* in paragraph 5.3.1.3

- Community engagement

  The indication of community engagement as being extremely or very important by the participants, is an indication that the empirical study coincide with the literature review's conclusions.

  Community engagement relevant to CSP technologies are discussed as a social factor in a PESTLE analysis under the heading *Community development and upliftment* in paragraph 5.3.1.3.

5.4.1.4 Technological factors

The participants were asked to rank the following technological factors that may have an influence on the economic viability of CSP as RE source, according to his/her order of importance: (i) availability of technology; (ii) cost of technology; (iii) maintenance cost; (iv) frequency of maintenance; (v) technological flexibility and adaptability; (vi) level of automation; (vii) intermittence capacity; (viii) dispatchable electricity distribution; (ix) variability in electricity output; (x) expandability of electricity generation capacity; (xi) energy storage capacity; (xii) government spending on technology; and (xiii) research and development cost.

Table 5.6 below indicates the average percentage of participants that have chosen a specific level of importance in ranking the abovementioned technological factors.

Technological factors indicated as extremely and very important, include energy storage, cost of technology, availability of technology, and research and development cost.

Table 5.6 – Summary of results for technological factors

Importance	Technological
Extremely important	60%
Very important	20%
Moderately important	19%
Slightly important	1%
Not at all important	0%
TOTAL	**100%**

The following conclusions can be drawn from the empirical study regarding the technological factors indicated as extremely and very important that (may) influence the economic viability of CSP as RE source:

- Energy storage

  The indication of energy storage as being extremely or very important by the participants, is an indication that the empirical study coincide with the literature review's conclusions.

  Community engagement relevant to CSP technologies are discussed as a social factor in a PESTLE analysis under the heading *Energy storage capability* in paragraph 5.3.1.4.

- Cost of technology

  The indication of the cost of technology as being extremely or very important by the participants, is an indication that the empirical study coincide with the literature review's conclusions regarding cost of technology. However, cost of technology has been discussed as *Initial capital layout* under Cost benefit analysis in paragraph 5.3.2.

- Availability of technology

  Availability of technology refers to the availability of CSP technology in SA. CSP and related technologies are available in SA, although it is predominantly imported to SA.

  The indication of the availability of CSP and related technologies as being extremely or very important by the participants, is an indication that importing CSP and related technologies poses some difficulties and/or stumble blocks, e.g., (i) cumbersome administrative work (e.g., obtaining import permits (if necessary) and customs and excise related tasks and processes to be followed), (ii) long wating time for technology to be transported from the country of origin to SA, (iii) possible unforeseen delays during the import process, possibly causing interruptions in electricity generation (production), leading to loss income and forfeiting profit.

5.4.1.5 Legal factors

The participants were asked to rank the following legal factors that may have an influence on the economic viability of CSP as RE source, according to his/her order of importance: (i) laws and regulations (operational); (ii) laws and regulations (health and safety); (iii) access to resources; (iv) laws and regulations (energy planning, management, and grid access); and (v) licensing.

Table 5.7 below indicates the average percentage of participants that have chosen a specific level of importance in ranking the abovementioned legal factors.

Legal factors indicated as extremely and very important, include licensing, laws and regulations (operational), and laws and regulations (energy planning, management, and grid access).

Table 5.7 – Summary of results for legal factors

Importance	Legal
Extremely important	46%
Very important	46%
Moderately important	4%
Slightly important	4%
Not at all important	0%
TOTAL	**100%**

The following conclusions can be drawn from the empirical study regarding the legal factors indicated as extremely and very important that (may) influence the economic viability of CSP as RE source:

- Licensing

  The indication of licencing as being extremely or very important by the participants, is an indication that the empirical study coincide with the literature review's conclusions regarding issues to obtain electricity generation licenses.

  Licensing has been discussed under the heading *Licencing to generate electricity* as a legal factor in a PESTLE analysis in paragraph 5.3.1.5.

- Laws and regulations (operational) & Laws and regulations (energy planning, management, and grid access)

  Laws and regulations (operational) & Laws and regulations (energy planning, management, and grid access), per se, do not influence the economic viability of CSP as RE source, although it may be cumbersome and possible time consuming to implement or incorporate physical measures in a CSP plant's infrastructure to ensure compliance. However, implementing or incorporating physical measures to ensure compliance, may have a once-off cost implication which should not have a major negative impact on the economic viability of CSP as RE source.

5.4.1.6 Environmental factors

The participants were asked to rank the following environmental factors that may have an influence on the economic viability of CSP as RE source, according to his/her order of importance: (i) weather conditions; (ii) pollution and waste management; (iii) water quality and availability; (iv) dust and cleanliness of CSP equipment; (v) health and safety in the workplace; and (vi) environmental influences (including agricultural influences).

Table 5.8 below indicates the average percentage of participants that have chosen a specific level of importance in ranking the abovementioned environmental factors.

Environmental factors indicated as extremely and very important, include weather conditions, pollution and waste management, water quality and availability, and environmental influences (including agricultural influences).

Table 5.8 – Summary of results for environmental factors

Importance	Environmental
Extremely important	73%
Very important	13%
Moderately important	13%
Slightly important	2%
Not at all important	0%
TOTAL	**100%**

The following conclusions can be drawn from the empirical study regarding the environmental factors indicated as extremely and very important that (may) influence the economic viability of CSP as RE source:

- Weather conditions

  Weather conditions specifically refer to the influence of overcast weather on the efficiency of electricity generation during overcast weather, and possibly the interruption of electricity generation during periods of prolonged overcast weather (also referred to as unfavourable atmospheric conditions).

  The indication of weather conditions as being extremely or very important by the participants, is an indication that the empirical study coincide with the literature review's conclusions regarding weather conditions.

Weather conditions have been discussed under three headings, (i) *Availability of RE resources*, (ii) *CSP's ability to incorporate TES systems/technology*, and *Energy storage capability* as a technological factor in a PESTLE analysis in paragraph 5.3.15.

Unfavourable atmospheric conditions (overcast weather) will only influence CSP plants where TES systems/technology is not integrated into the CSP plant. Unfavourable atmospheric conditions (overcast weather) will negatively influence such plants electricity generation efficiency during overcast weather, and possibly interrupt electricity generation during periods of prolonged overcast weather.

- Pollution and waste management

The indication of pollution and waste management as being extremely or very important by the participants, is an indication that pollution and waste management is important and should be efficiently managed. However, it should not have a negative impact on the economic viability of CSP as RE source. Such cost should form part of SCP plants' operation and maintenance costs and efficiently managed throughout the CSP plants' operation.

- Water quality and availability

The indication of water quality and availability as being extremely or very important by the participants, is an indication that it is important for efficient operation of CSP plants. Water quality can be managed by purifying available water to meet quality standards. Availability of water having the required quality, should be considered when determining CSP plants' location. If an alternative location could not be identified, and the CSP plant needs to be located in a water scare area, proper planning should be done to ensure that quality water could be made available.

CSP technology uses either a wet cooling, or a dry cooling system for cooling purposes, both using water. However, CSP technology equipped with a wet cooling system, uses far less water than traditional electricity generation methods. CSP technology with a dry cooling system uses some water, while water consumption is further reduced by 80% when it is equipped with a dry colling system instead of a wet cooling system. CSP's water consumption is fairly low in comparison to traditional electricity generation methods, which should limit incurred transport costs deliver quality water to CSP plants from sources. Therefore, these transport costs could negatively influence the economic viability of CSP

as RE source, although its impact could be low (depending from the distance between water sources and CSP plants.

- Environmental influences (including agricultural influences)

  Environmental influences (including agricultural influences) should not influence the economic viability of CSP as RE source if it is carefully considered during development and optimally managed during the operation of CSP plants.

5.4.2 SWOT analysis

5.4.2.1 Strenghts

Because they utilise the sun as a source of energy, CSP plants have both low primary costs and maintenance costs compared to conventional power generation technologies. CSP has the additional ability to store energy during the day and continue electricity production at night, distinguishing it from wind and PV technologies. Wind and PV can only generate electricity when there is the required wind speed and sun, respectively.

Furthermore, CSP's usage of the sun as source of energy positively contributes to combating climate change and can generate dispatchable energy through its TES, allowing generation adjustments to meet grid requirements. CSP technology creates jobs within communities where it operates, thereby benefiting disadvantaged communities. The compensation of CSP's peak production adds a unique aspect when compared to other RETs such as wind and PV.

5.4.2.2 Weaknesses

CSP plants require large areas of land, of which some might be used for stock, cattle, and game farming. Frequent changes in weather patterns can affect CSP production by reducing the amount of energy harnessed from the sun, causing delays in charging the TES system during the day. CSP technology is still new to South Africa and most of the spare parts are still being sourced from overseas. This leads to prolonged expected time of arrival and, in turn, production losses.

CSP projects require high initial capital outlay. This results in delays in reaching financial close and prolonged construction periods. CSP plants are mostly constructed in arid regions with less rainfall and water shortages. Water shortages lead to production losses and, consequently, revenue losses. To operate and maintain CSP, specialised skills are required, some of which are still imported from overseas. The premature breakages of tubes and mirrors increase the replacement costs and reduce the amount of energy harnessed in the solar field, again leading

to lower production. CSP plants can take as long as three years to construct, whereas PV plants can be built in six months.

5.4.2.3 Opportunities

CSP plants can easily be integrated with PV and result in reduced initial capital outlay. Great potential still exists for the local manufacturing of spare parts, development, and training of local skills (including skills transfer from foreign experts). With sufficient R&D, there is significant potential to enhance TES systems, extending their storage capacity to accommodate longer hours.

5.4.2.4 Threats

There is a high likelihood that RETs such as wind and PV could undergo faster developed than CSP technologies, resulting in the abandonment of CSP by investors. Currently, wind and PV are more mature technologies compared to CSP. In addition, there is a legal constraint, as all IPP companies are limited to selling electricity exclusively to Eskom, which is high risk in case of Eskom defaulting on payments. Eskom currently faces challenges of financial instability and relies on government bailouts.

CSP plants are considerably more complex to operate compared to wind and PV, leading to production and revenue losses. Despite high expectations for job creation from local communities, a 100 MWh CSP plant typically employs only about 100 permanent employees.

5.4.3 Cost-benefit analysis

Based on the empirical findings, the participants indicated that the TES system offers more benefits compared to other RET technologies like wind and PV. Information gathered from the participants showed that, although wind and PV appear to be cheaper than CSP initially, once the TES system is considered, CSP becomes a more attractive investment than the other RET projects.

Participants also raised concerns about the high CSP initial capital outlay, which is line with findings from the literature review. To reduce the initial capital outlay, participants explained that they conduct a Root Cause Analysis to determine the main cause of high tube and mirror breakages.

5.5 Determining the economic viability of CSP as an RE source (using a cost-benefit and SWOT analysis) – an overview

5.5.1 Cost-benefit analysis

5.5.1.1 Costs of CSP plants

CSP plants are divided into three sections: the power block, the solar field, and the TES system. The initial capital outlay of CSP plants comprises the solar field, which carries the bulk of costs at 58%, followed by the power block at 30%, and the TES system at 12% (NREL, 2023). The initial capital outlay of Redstone, under construction in the Northern Cape, was projected at R11.6 billion. According to NREL's (2023) cost breakdown split, this would typically consist of R6.7 billion allocated to the solar field, R3.5 billion allocated to the power block, and R1.4 billion allocated to the TES system (Acwa Power, 2021). The average initial capital outlay for CSP plants worldwide, measured in USD/per kWh, has significantly reduced from 2010 to 2022 (Hernández *et al.*, 2015), as indicated in figure 5.1 below. Figure 5.1 shows that, in 2010, the costs for a CSP plant were USD10 082/kWh, which dropped significantly by 60% to USD4 274/kWh (Hernández *et al.*, 2015).

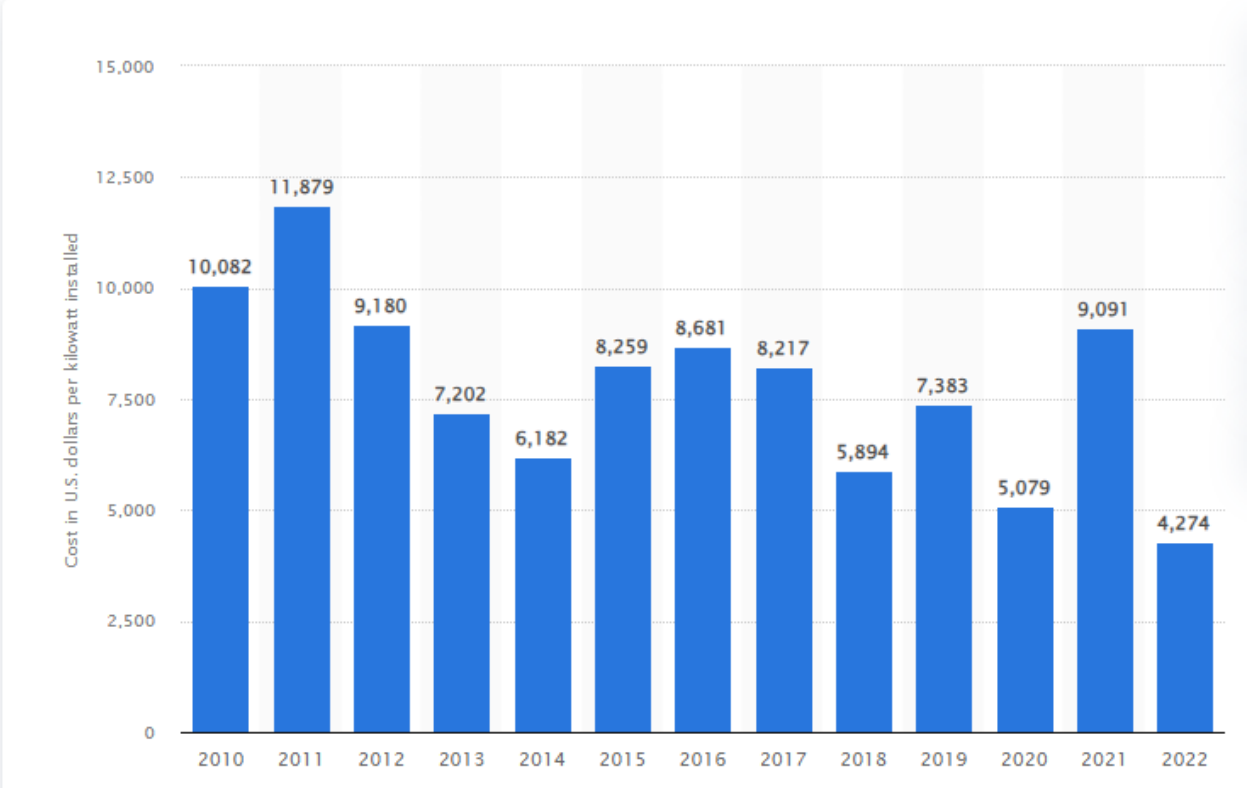

Figure 5.1: Worldwide average initial capital outlay in USD/per kWh for CSP plants

Source: Hernández (2015)

The operations and maintenance costs of a CSP plant represent the total expenditures required to operate and maintain a CSP plant over its lifetime. These costs consist of fixed costs and variable costs. Fixed costs include administrative fees, administrative labour, insurance, land lease payments, legal fees, operating labour, property taxes, site security, project management, and other taxes. Variable costs include project management, general maintenance, scheduled maintenance of technical plant life, unscheduled maintenance of technical plant life, mirror washing, transformer maintenance, power block maintenance, solar field maintenance, water usage, and electricity usage (NREL, 2023).

For CSP plants still in operation, the operations and maintenance costs range from USD0.2/kWh to USD0.04/kWh, which is about 18% to 20% of the LCOE (HelioSCSP, 2023). LCOE costs for CSP plants have declined over the years, showing a 69% decrease from 2010 to 2022 as illustrated in figure 5.2 below (IRENA, 2023). The 69% decrease is derived from the LCOE values of CSP plants, as illustrated in figure 5.2, which shows LCOE of USD0.380/kWh in 2010 and USD 0.118/kWh in 2022 (IRENA, 2023).

	Total Installed costs (2022 USD/kW)			Capacity factor (%)			Levelised cost of electricity (2022 USD/kWh)		
	2010	2022	Percent change	2010	2022	Percent change	2010	2022	Percent change
Bioenergy	2 904	2 162	-26%	72	72	1%	0.082	0.061	-25%
Geothermal	2 904	3 478	20%	87	85	-2%	0.053	0.056	6%
Hydropower	1 407	2 881	105%	44	46	4%	0.042	0.061	47%
Solar PV	5 124	876	-83%	14	17	23%	0.445	0.049	-89%
CSP	10 082	4 274	-58%	30	36	19%	0.380	0.118	-69%
Onshore wind	2 179	1 274	-42%	27	37	35%	0.107	0.033	-69%
Offshore wind	5 217	3 461	-34%	38	42	10%	0.197	0.081	-59%

Figure 5.2: Total installed cost, capacity factor and LCOE trends by technology, 2010 and 2022

Source: IRENA (2023:15)

CSP projects have demonstrated positive NPV in cases where government provides support in the form of grants or subsidies. Positive NPV suggests that the projected earnings generated by a CSP plant exceed the anticipated costs. SPT has demonstrated high NPV due to its ability to generate high temperatures, resulting in increased production compared to the matured CSP technology known as PTC.

Studies conducted by Yang *et al*. (2018:1-9), Shafiee *et al*. (2020:1-17) and Yasin and Draidi (2020:253-264) found that the PBP for CSP projects range from 7.5 years up to 17.6 years. Investors have raised concerns that the PBP for CSP is too long, but as more CSP projects are developed, the PBP is expected to continue to decline. The primary contributor to the high PBP is the decrease in CSP deployment between 2010 and 2017. However, with accelerated deployment in the future, there is potential for the PBP to decrease (Craig, 2018:22). According to IRENA (2023:22), the deployment of CSP plants remains significantly low compared to other RET technologies. Only 0.1 GWh was added in 2022, while the global cumulative standing was at 6.5 GWh at the end of 2022 (IRENA, 2023:21). The cumulative global capacity of CSP was 161 times smaller than the capacity of solar PV installed at the end of 2022 (IRENA, 2023:41).

CSP plants are currently surpassing the 10% global average IRR, which serves a benchmark for RE projects (Snieckus, 2020). A study conducted by Yang *et al*. (2018:1-9) demonstrated IRR for CSP projects ranging from 6.5% to 20%. In essence, this indicates that CSP plants are profitable; thus, the returns are capable of covering the cost of capital.

5.5.1.2 Benefits of CSP plants

In an SA context, a two-tiered costing system is used, wherein CSP plants are compensated for peak production at a rate 2.7 times higher than standard production. For example, the production of 1 000 MWh for standard production and 1 000 MWh for peak production will be equivalent to 3 700 MWh (1 000 MWh standard production and 2 700 MWh peak production). The 2 700 MWh peak production is calculated as follows: 1 000 MWh multiplied by 2.7.

This two-tiered system makes CSP plants an attractive investment due to the high revenues generated. According to the IPP Office (2023:18), 1% of annual revenue generated by CSP plants is allocated to social development, another 1% to black-owned enterprises, and 8% shareholding allocated to the local community.

According to DLR (2021:32), a CSP plant is estimated to create about 2 000 direct and indirect jobs during construction and 100 permanent jobs thereafter for the operations and maintenance of the plant. The creation of these jobs positively contributes to addressing the high unemployment rate in South Africa, which stood at 31.9% in the third quarter of 2023 (Stats SA, 2023).

CSP also offers environmental and health benefits. The environmental benefits include the reduction of GHG when moving from fossil fuel power generation technologies to CSP, contributing to a decrease in natural disasters caused by global warming. The health benefits arise from the reduction of respiratory diseases caused by air pollution.

CSP as an RE source also positively contributes to the SA target of net-zero carbon emissions by 2050 as per the Paris Agreement. For example, Kaxu Solar One, a 100 MWh CSP plant completed in 2015, will offset 315 000 tons of GHG emissions per annum, while Redstone is projected to offset 440 000 tons of GHG emissions.

5.5.1.3 Cost-benefit analysis – summary

Table 5.9 – Cost-benefit analysis – summary

Cost benefit analysis – summary	
Costs	***Benefits***
• Initial capital outlay (Redstone projects is estimated at R11.6 Billion) • Operations and maintenance costs ranges from USD0.2/kWh to USD0.04/kWh	• Global Internal Rate of Return is 10% • At peak production, CSP yields higher revenue in comparison with standard production • CSP yields positive Net Present Values • Local community development (1% of revenue is allocated to social development in local community). • Enterprise development (1% of revenue is allocated to black-owned enterprises) • Job creation (100 permanent jobs created during operations and maintenance) • Job creation (2 000 temporary jobs created during construction) • Offsetting GHG's (e.g., the 100 MWh Redstone CSP plant currently under construction will offset an estimated 440 000 tons of GHG per annum). • Reduction in water consumption (CSP's dry cooling methods consume 80% less water than traditional electricity generation methods).

5.5.2 SWOT analysis

The following strengths, weaknesses, opportunities, and threats were identified for CSP projects – see table 5.10 below.

Table 5.10 – SWOT analysis for CSP technology

Strengths	**Weaknesses**
• CSP is dispatchable compared to other RET technologies like wind and PV. • CSP provides grid electricity when needed, whether during the day or night. • Once built, the operational costs are very low, resulting in competitive electricity pricing. • The high temperatures generated by PTC results in increase production and, consequently, improved revenue. • The LCOE for CSP projects has been consistently decreasing over the years. • CSP with TES provides ancillary services. (Ancillary services are services that electricity operators need to guarantee a reliable electricity system such as voltage support and balancing of reserves.)	• High water consumption. • CSP plants are currently not effective in low DNI areas. • Complex technology to operate. • High risk of unavailability of spare parts. • CSP plants require a large area of land to operate. • CSP plants can attract animals with its light, and the heat can be fatal for some species. • The molten salt used in TES can freeze in low temperatures and decompose in high temperatures.
Opportunities	**Threats**
• Dry cooling can drastically reduce water consumption. • With technological advancements in energy enhancement, CSP is expected to gradually become effective in low DNI areas. • Research in increasing TES storage hours has the potential to make CSP plants more competitive compared to wind and PV technologies.	• The slowing down of CSP deployment results in delayed reduction of costs. • Delayed reduction of costs in CSP leads to investors turning their interest to PV. • More research is currently being done on battery storage for PV and this is likely to further reduce CSP deployment. • As breakthroughs continue in other RETs, CSP runs the risk of becoming obsolete.

• CSP presents significant opportunities for electricity export, given its ability to generate electricity that exceeds local demand. • Additional policy support to CSP can further reduce costs.	

5.6 Conclusions from the cost-benefit analysis

5.6.1 Costs of CSP plants – conclusion

Although the initial capital outlay of CSP plants remains high, these costs continue to decrease over time, resulting in the reduction of PBP for investors. Ongoing R&D efforts are focused on improving the costs of mirrors and tubes used in the solar field. This would ultimately lead to a reduction in initial capital outlay, as the solar field, for example, carries most of the costs of CSP plants. The deployment of CSP plants is occurring at a slow pace; yet, operations and maintenance costs continue to decline, contributing to increased returns for investors. While PV is still leading in the high reduction of LCOE, CSP and wind come a close second, sharing the same percentage reduction over the years. Nevertheless, CSP projects continue to demonstrate positive NPV, which means that their total present value of cash inflows over the project's lifetime exceeds total present value of cash outflow. The IRR for CSP projects currently meets the 10% global average percentage, making CSP more economically viable as an RE source. This favourable IRR is attractive for investors, resulting in more net cash being generated by CSP projects.

5.6.2 Benefits of CSP plants – conclusion

The compensation of peak production in the SA two-tiered system makes CSP projects economically viable and attractive to investors. The conclusion can be drawn that, through the PPA's enforcement between CSP projects and Eskom, CSP brings improvement in (i) social development; (ii) black-owned enterprises; and (iii) the local community in which it operate. CSP also creates both permanent and temporary employment which assists in lowering the country's unemployment rate. CSP plants provide health and environmental benefits to society by contributing to GHG emission reduction and, thus, to less pollution and a decline in respiratory diseases. CSP also positively contributes to the SA commitment to the Paris Agreement of net-zero carbon emissions by 2050.

In evaluating the economic viability of CSP systems as an RE source using a cost-benefit analysis, the conclusion is that CSP plants are economically viable as renewable energy source within an SA context. CSP systems positively contribute to (i) resolving the current electricity crisis in the country; (ii) the local economic and social development of communities; and (iii) local supplier development. CSP projects have positive environmental benefits over and above the local community benefits.

5.7 Conclusion on the economic viability of CSP as alternative RE source in a South African context

South Africa is faced with electricity shortages, and, at the same time, the country is transitioning through the JET from fossil fuel electricity generation technologies to RETs. The JET is in line with the SA government's commitment to the Paris Agreement which aims at net-zero carbon emissions by 2050. The Paris Agreement also seeks to limit the increase in the global average temperature to well below 2 degrees Celsius, with efforts to further constrain it to 1.5 degrees Celsius. South Africa, with 104 billion square metres of suitable area, has the potential of around 11 000 TWh of electricity generation from CSP technology (Duvenhage *et al.*, 2020:1), while the utilisation of CSP technology will contribute towards the aims/objectives of the Paris Agreement.

From the literature review and the empirical study, it can be concluded that CSP is indeed economically viable as an alternative RE source in an SA context and that the benefits of CSP outweigh the costs. CSP with TES is economically attractive for deployment at a larger scale and, as a result, it can add more electricity to the grid, consequently, contributing towards combating (and ultimately eliminating) SA's electricity shortages and ongoing struggle with loadshedding. When considering wind, PV, and CSP technologies, CSP is the only RET that can store energy for later use, which can positively contribute to the country's JET. The longer operational hours of TES imply that CSP can generate electricity for 24 hours a day, similar to fossil fuel power generation technologies, resulting in a smooth transition. The continuous electricity generation for 24 hours a day allows CSP to address the dispatchability risk faced by RETs.

5.8 Recommendations for improving the economic viability of CSP as an RE source

5.8.1 Cost-benefit analysis – recommendations

5.8.1.1 Costs of CSP plants

- Research, including a route-cause analysis should be conducted on the premature mirror and tube breakages to determine the main cause of breakages. As a result, a possible reduction in mirror and tuber replacement cost could be obtained, while this could ultimately decrease the LCOE of CSP projects.

- Further reduction in capital outlay will not only attract more investors but will also shorten the PBP. This will yield earlier returns for investors than currently the situation.

- Eskom should consider upgrading the electricity infrastructure to ensure that CSP plants in remote areas are able to send electricity generation.

- Alternative materials for heating up the HTF in the TES system should be explored to minimise the risk of molten salt freezing during low temperatures and decomposing in high temperatures.

5.8.1.2 Benefits of CSP plants

- New CSP projects should consider prioritising the incorporation of PTC technology in CSP due to PTC's ability to achieve high temperatures. This will lead to increased production (power generation), higher revenue, and improved returns for investors.

- The SA government should continue to support CSP deployment through grants, subsidies, and the two-tiered pricing system which compensates the TES system. Delays in CSP deployment not only have a negative impact on CSP costs, but also on CSP's maturity levels compared to those of wind and PV technologies.

5.8.2 PESTLE analysis – recommendations

5.8.2.1 Political factors

- 7Policy stability

  The SA government should revisit the ERA and revise the powers vested in the Department of Energy minister for choosing electricity generation technologies through ministerial determinations. The review process should consider aligning the roles and responsibilities between the newly established electricity ministry, the public enterprise ministry, the energy ministry and the environmental affairs ministry. Alignment of roles and responsibilities within ministries will ensure that there is no biasness when selecting RE projects and this will ensure a balanced approach to South Africa's energy mix. A balanced approach will avoid unnecessary exclusion of CSP projects in the IRP document resulting to minimised loadshedding that the country currently experiences.

5.8.2.2 Economic factors

- Acceleration of CSP implementation

  The SA government should drive the acceleration of CSP deployment by allocating additional CSP projects above the 600 MWh already designated in the IRP up to 2030. A faster deployment of CSP will speed up the reduction of LCOE in the coming years and improves economic viability of CSP as RE source.

- Local production of CSP spare parts

  The DTI should promote local production of CSP spare parts, currently being imported. This will not only reduce replacement costs but will also improve electricity generation (production) efficiency and increased electricity supply since plant and/or equipment breakdowns will be repaired faster with locally available, instead of imported spare parts. Improved electricity generation (production) and supply will also lead to increased revenue and consequently an improved return for investors. All of these mentioned aspects will, ultimately, improve CSP's economic viability.

5.8.2.3 Social factors

- Job creation and job expectancy

  In order to ensure that there is no high job expectation from communities than what CSP plants are capable of, the SA government through the IPP office should run an awareness campaign to local communities to ensure that expectations are aligned with what CSP plants can provide to communities. Alignment of communities to CSP projects will enhance understanding and improve CSP's acceptance by communities consequently improving CSP's economic viability as a RE source.

5.8.2.4 Technological factors

- Dry cooling vs wet cooling systems

  New CSP development should consider using dry cooling instead of wet cooling systems to reduce water usage and, consequently, operations and maintenance costs. The reduction in operations and maintenance costs will also improve the technology's LCOE and enabling CSP technology to easily compete with wind and PV.

- Identification and exploration of alternative materials for heating up the HTF in the TES system Dry cooling vs wet cooling systems.

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  Alternative materials should be identified and explored for heating up the HTF in the TES system minimise the risk of molten salt freezing during low temperatures and decomposing in high temperatures. Alternative materials will also increase the TES storage system resulting to uninterrupted electricity generation after the sunset consequently leading to increased production and less maintenance costs.

5.8.2.5 Legal factors

- Licencing and selling regulations.

  Through structural reforms, the SA government should ease licensing and selling regulations to open the electricity market. Opening the market means that IPP's should have options to sell electricity generated to other entities other than Eskom alone. Opening the market will further create competition and reduce electricity prices and resulting to attracting investment in CSP projects. Attraction of investors to CSP will improve CSP economic viability.

5.8.2.5 Environmental factors

- Net-zero carbon emissions

  In order to ensure that SA meets global targets of net-zero carbon emissions by 2050, the IRP timelines for projects implementation should be adhered to. Consideration should be made on deploying more CSP projects in the Northern Cape province due to high DNI availability. The more CSP plants deployed, the lesser emissions experienced resulting to lesser climate change effects.

5.8.3 SWOT analysis – recommendations

5.8.3.1 Strengths

- TES incorporated into CSP

  More research should continue to be conducted on TES system hours. Increased storage hours enable CSP technologies to generate electricity 24 hours a day and creates potential to use excess energy generated for other industrial heating requirements.

Excess heat generated by CSP will provide a competitive advantage to wind and PV resulting to improved economic viability for CSP.

5.8.3.2 Weaknesses

- CSP's LCOE

The LCOE for CSP projects is still high when compared to wind and PV and this requires the SA government to increase incentives/subsidies to CSP projects to attract more investment. The increase in incentives/subsidies will accelerate CSP's maturity and reduce LCOE in the future.

5.8.3.3 Opportunities

- TES incorporation into CSP

CSP with TES have the opportunity to replace traditional power generation technologies due to the ability to provide baseload power but requires additional allocation of MWhs in the IRP. By allocation additional MWh in the IRP, this will enable CSP to mature quicker than projected and make CSP projects more economically viable as RE source.

5.8.3.4 Threats

- Policy stability

Renewable energy transition from fossil fuels has been identified by Burke and Stephens (2017:3) as a political struggle and cannot be effective without confronting and destabilising dominant systems of energy power.

- Future battery storage rendering TES obsolete.
  In order to minimise the potential threat of future battery storage to compete or render TES obsolete, CSP project implementation should be accelerated by the SA government and possibly integrate CSP with PV to ensure that the two technologies complement each other rather than competing against each other. Complementary projects will ensure increased capacity and create opportunities to use excess energy for other heating requirements by other industries.

5.9 Limitations of the research

The limitations of the study are as follow:

- The CSP industry in South Africa is still in its infancy and the researcher encountered restrictions when gathering costs and benefits. As a result, the researcher had to rely mostly on global CSP costs. Other limitations pertained to obtaining specific costs and benefits of CSP plants based in South Africa, and the researcher found only a few local and global research papers to rely on.

- The preferred method of evaluating CSP projects by investors is the LCOE which generalises costs across all electricity generating technologies. However, this approach overlooks the benefits of TES, potentially overstating costs. Moreover, the LCOE focuses only on costs and does not take into account revenues. Thus, the researcher had to consider other capital investment appraising methods such as NPV, IRR, and PBP.

- The intangible benefits of CSP plants cannot be easily quantified, and the researcher had to rely mostly on estimated GHG emission reductions. For instance, there are health and environmental benefits brought by GHG emission reduction, but assigning a rand value to these benefits remains a challenge.

- The intangible costs of CSP plants are also difficult to quantify. Although CSP plants do not emit harmful quantities of GHGs, the literature argues that there might be hidden costs related to the production of materials. For example, the process of manufacturing mirrors and tubes might be emitting harmful quantities of GHG. This study did not investigate the cost impact caused by manufacturers of CSP materials, as it fell outside the purview of the research.

- This study applied non-probability sampling to select the participants based on their accessibility. This means that the researcher decided what information needed to be gathered and identified individuals who were willing and able to provide the information by virtue of their knowledge and experience. This method of sampling makes it difficult to generalise perceptions gathered from participants and could be viewed as biased.

- Of the eight participants interviewed, only one participant was interviewed face to face, while the other seven preferred electronic interviews via Teams, Zoom, and Google Meet. Face-to-face interviews provide researchers with increased interaction with participants, enabling the use of verbal and non-verbal cues to gather more comprehensive data. The preference of electronic interviews might have been triggered by the fact that the interviews were conducted in 2023, following the Covid-19 outbreak. Limitations on contact and face-to-face meetings during this period may have influenced this preference.

- Because it is a new technology, CSP is difficult to compare with other RETs such as PV. Also, the LCOE formula used by investors to evaluate electricity generating technologies does not take into account the storage benefits provided by CSP. NPV, IRR, PBP, and CBA formulas were designed to evaluate shorter- to medium-term projects, but the lifespan of CSP plants ranges from 20 to 30 years.

5.10 Summary

This study's problem statement refers to the fact that South Africa is facing an unprecedented electricity crisis and that the bulk of the country's energy comes from non-renewable energy. Currently, investors favour PV over CSP because of its quicker returns and shorter construction duration. However, this study found that CSP technology is more viable due to its ability to store energy for use after sunset. Further CSP development is recommended by the study, highlighting CSP's ability to add to baseload power throughout the day. This study concludes that, in an SA context, CSP is economically viable as an RE source, especially due to its ability to store energy for use after sunset.

The recommendations made by this study address the problem statement and will (i) contribute to alleviating the energy crisis faced by South Africa, and (ii) assist SA in achieving its net-zero carbon emission by 2050 as per the Paris Agreement.

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APPENDIX 1: Approval Letter

[Researcher address line 1]
[Researcher address line 2]
[Postal code]
[Researcher telephone number]
[Researcher e-mail address]

[Company Name]
[Address line 1]
[Address line 2]
[Postal code]
[Date]

Dear Sir/Madam

RE: Permission to conduct research at [PLANT NAME] of [ORGANISATION NAME]

My Name is Velly Ngomane, and I am currently studying towards a master's degree in Management Accountancy at North-West University, South Africa, and I am conducting research as part of this degree.

The research topic is "*Evaluating the economic viability of Concentrated Solar Power (CSP) systems as renewable energy source*". The topic is mostly inspired by the current electricity challenges faced by South Africa and looking at the slow pace of rolling out CSP technology for electricity generation. The latter has a huge potential in the South African energy mix.

South Africa's existing energy crisis: due to Eskom's inability to provide sustainable and sufficient electricity to the grid, results in regular disruptive (usually unplanned and/or short at notice) load shedding. This has already led, since load shedding commenced in late 2007, to numerous dire consequences, e.g.: hampered economic growth, negative impact on the outlook of the country as an investment destination, decreasing international competitiveness, a rise in unemployment figures and the resultant alleviation of poverty due to deteriorating economic productivity.

The research question this study aims to answer, is whether CSP could be economically viable as a RE source in South Africa and the primary objective for the study is to "evaluate the economic viability of CSP as a RE source, using a Cost-benefit analysis".

The research will entail collecting data (by means of interviews) from your organisation's senior employees (i.e.: the Chief Executive Officer (CEO), Chief Financial Officer (CFO), Plant Manager,

as well as the Operations Manager). If they agree to be interviewed, the interviews will be conducted on a one-on-one face-to-face basis with the researcher. These interviews will take about an hour and will be conducted in your working area or site, or any place suitable for the participants and the researcher. Where not possible, the interviews will be conducted via electronic communication suitable for the participants and the researcher such as Zoom, Microsoft Teams and Skype. Participant's responses will also be audio recorded. All information provided, or opinions stated during the interview will be treated as confidential and used for the purposes of this study.

Participants will be required to give their written consent to be interviewed by the researcher before the interview is scheduled. Participant's responses will be treated with the necessary confidentially. Therefore, participants' identities (both their names and the name of the organisation) will be kept anonymous. Anonymity will be maintained throughout the research, research results and/or research publications.

The research participants will not be advantaged or disadvantaged in any way. They will be reassured that they can withdraw from the interview at any time without any penalty. When a participant withdraws during an interview, any information already provided during the interview up to the point of withdrawal, will be disregarded for the purposes of this study. There are no foreseeable risks in participating in this study, and the participants will not be paid for this study.

I therefore request permission, in writing, to conduct my research at [Plant Name] of your organisation. The permission letter should be on your organisation's letterhead, signed and dated, and specifically referring to myself by name and the title of my study.

Please note that the questionnaires will be sent/e-mailed to the participants once they have given consent to be interviewed at least one week before the interview is scheduled with the participants. A letter of consent template will be sent to all participants for formal consent to be granted by them.

I have also attached a proposed draft approval letter which should be on your letterhead for the response with regards to this approval letter request and you are welcome to contact me for any clarity needed.

Yours Faithfully

Mr VB Ngomane

Primary Researcher

North-West University

Tel: 072 535 1924

E-mail: vbngomane@gmail.com

Mr FJ Bibbey

Study Supervisor

North-West University

Frans.Bibbey@nwu.ac.za

APPENDIX 2: Approval Response Letter Template

[*COMPANY LETTERHEARD]*

[Address line 1]
[Address line 2]
[Postal code]
[Tel: ……]
[E-mail: ……..]
DATE: /date /month/2022]

Mr VB NGOMANE
Primary Researcher
North-West University
Tel: 072 535 1924
E-mail: vbngomane@gmail.com

Dear Mr Ngomane

RE: Permission to conduct research interviews at [ORGANISATION NAME]

I refer to your letter seeking permission to conduct research at [PLANT NAME] of [ORGANISATION NAME].

This letter serves as permission being granted to you: Mr VB Ngomane (i) to conduct interviews at [PLANT NAME] of [ORGANISATION NAME] with the Chief Executive Officer, Chief Financial Officer, Plant Manager, and the Operations Manager; and (ii) that information gathered during the interview may be used for the purposes of the research titled *"Evaluating the economic viability of Concentrated Solar Power (CSP) systems as renewable energy source"* only.

The participants are welcome to arrange the requested one-hour interviews during working hours at our working area or site or any area suitable for the participants and the researcher. The researcher, Mr VB Ngomane, is welcome to conduct the interviews by means of any other electronic communication, suitable to both the interviewer and the participant (interviewee).

Yours Sincerely

…… ……

(*Signature*) (Date)

…… (*Name and Position/Occupation in the Company)*

APPENDIX 3: Letters of consent to all research participants

[Researcher address line 1]
[Researcher address line 2]
[Postal code]
[Researcher telephone number]
[Researcher e-mail address]

[Plant name]
[Company Name]
[Address line 1]
[Address line 2]
[Postal code]
[Date]

Dear Participant

RE: INVITATION TO PARTICIPATE IN A MASTER'S DEGREE RESEARCH PROJECT

Title of Research: Evaluating the economic viability of Concentrated Solar Power systems as renewable energy source

My name is Velly Ngomane. I am currently enrolled for a master's degree at the North-West University of South Africa and is conducting research as part of this degree. This research concerns evaluating the economic viability of Concentrated Solar Power systems as renewable energy source in South Africa.

You are hereby kindly invited to take part in an interview as part of the empirical study of the aforementioned master's degree since I am interested in your invaluable experiences, opinions, and perceptions about Concentrated Solar Power systems in general, the suitability thereof as renewable energy source, as well as the economic viability of Concentrated Solar Power systems in the South African environment and conditions. Please note that approval for the research in your organisation has already been granted by your management. The questionnaires will be sent/e-mailed to you once consent has been granted at least one week before the interview is scheduled.

If you are willing to contribute towards this study by participating in an interview, and consequently contribute towards research, please take note of the following:

- All participants / interviewees will remain ANONYMOUS during and after the study has been completed.
- NO PERSONAL INFORMATION will be REQUIRED or recorded during the interview, and NO PERSONAL INFORMATION will be DISCLOSED to any third parties at any time during, or after the study has been completed. All personal information will be CONFIDENTIAL.
- Opinions and perceptions (and/or any information) provided during the interview, will be used solely for research purposes of this study; and
- Participating in this study / agreeing to be interviewed pose NO RISKS whatsoever; if you become aware of any risk, you are welcome to raise your concerns to the respective officials.

If you choose to participate in an interview, take note of the following:

- Participation is COMPLETELY VOLUNTARY.
- You can WITHDRAW from the interview AT ANY TIME *without any penalisation*.
- By PARTICIPATING IN THE INTERVIEW, you give CONSENT that your opinions and perceptions (and/or and any information) provided during the interview, may be used solely for research purposes of this study.

Please answer all questions as accurately and honestly as possible. The duration of the interview will be between 45 minutes to an hour. On completion of all interviews, the researcher will analyse and summarise the data, without any association with your identity, but with a general opinion regarding the energy industry (specifically, Concentrated Solar Power systems). In this way your contribution to the research will be beneficial to enhance understanding of the Concentrated Solar Power systems and its economic viability within a South African context.

You are also welcomed to contact any of the undersigned parties for any queries that you might have.

If you are willing to be interviewed, please sign the consent form on the following page and e-mail a scanned copy to the primary researcher, VB Ngomane at the indicated e-mail address on the consent form.

Yours Faithfully

Mr VB Ngomane
Primary Researcher
North-West University
(072) 535 1924
vbngomane@gmail.com

Mr FJ Bibbey
Research Supervisor
North-West University
Frans.Bibbey@nwu.ac.za

CONSENT FORM to participate in an interview for the research project as indicated below.

Please fill out the consent form and e-mail a scanned copy thereof to the primary researcher, Mr VB Ngomane at the following e-mail address: vbngomane@gmail.com

I _____ (Name of participant or representative), hereby give my permission to be interviewed for the research project titled *Evaluating the economic viability of Concentrated Solar Power systems as renewable energy source*. I hereby also give you permission for the interview to be audio recorded and understand that I will remain anonymous and that all information I provide, or opinions stated during the interview will be treated as confidential and used for the purposes of this study.

_____	_____	_____
Signature	**Place**	**Date**

APPENDIX 4: Interview questionnaire: Chief Executive Officers & Chief Financial Officers

INTERVIEW QUESTIONS ON EVALUATING THE ECONOMIC VIABILITY OF CONCENTRATED SOLAR POWER SYSTEMS AS A RENEWABLE ENERGY SOURCE

to the

CHIEF EXECUTIVE OFFICERS and the CHIEF FINANCIAL OFFICERS

The purpose of this interview is to gather data that will be used in evaluating the economic viability of CSP as a renewable energy source, using a Cost-Benefit Analysis.

INTRODUCTION

Access to energy is at the heart of development and if not effectively implemented, it has a huge impact on people's health, education, food security, gender equality, livelihoods, and poverty (The World Bank, 2018). Energy is also a lifeblood of modern living and an enabler for economic growth and stability (DE, 2019a:2). As alluded by Van der Nest (2015), for an effective and efficient development, South Africa needs a reliable and available infrastructure providing utility services.

South Africa needs to have a more balanced approach when choosing the type of electricity generating technology to use through its Integrated Resource Plan (IRP). Looking at the IRP document, CSP has not been given the attention it deserves considering its potential and the benefits it can offer to South Africa. That is the reason why this research is based on looking at CSP's economic viability using a Cost-benefit analysis approach.

This interview is conducted to get opinions and perspectives about CSP in general, the suitability thereof as a Renewable Energy (RE) source, as well as its economic viability in the South African environment and conditions.

This interview forms part of the empirical research of a mini-dissertation entitled "*Evaluating the economic viability of Concentrated Solar Power systems as renewable energy source*." This mini-dissertation is in partial fulfilment for an M Com (Management Accountancy) degree at the Potchefstroom Campus of the North-West University. This research is conducted for academic purposes under supervision of Mr FJ Bibbey (e-mail: frans.bibbey@nwu.ac.za).

Should the interviewee have any questions at any time after the interview, the researcher can be contacted at the following email address or cell phone number: vbngomane@gmail.com or 072 535 1024.

Please note that (i) participation is anonymous (a participant's identity will not be made available); (ii) participating in the interview is voluntary and that participants can withdraw at any stage during

the interview if they prefer to; (iii) all information provided will be treated as confidential; (iv) data gathered will only be used for the purpose of this research; (v) this research is conducted following the ethical guidelines of the North-West University.

INTERVIEW QUESTIONNAIRE: CHIEF EXECUTIVE OFFICERS & CHIEF FINANCIAL OFFICERS

SECTION 1: Participant's information

Interviewee's position: ☐ CFO ☐ CEO

1. What are your formal qualifications after school?

……

2. Please describe your main duties and responsibilities in your current position (other than the normal duties and responsibilities as Chief Executive Officer (CEO) or as Chief Financial Officer (CFO).

……

……

……

3. For how long have you been in your current position?

……

4. How long have you been employed in the energy industry?

.....

5. How long have you been employed or involved in Concentrate Solar Power (CSP) technology?

.....

SECTION 2: Concentrated Solar Power Systems/technologies (CSP)

6. What would you regard as the ***strengths and weaknesses*** associated with the implementation of CSP technology?
Strengths:

……...

……...

……...

……...

……...

……...

Weaknesses:

……...

……...

……...

……...

……...

……...

7. What would you regard as the ***opportunities and threats*** associated with the implementation of CSP technology?

Opportunities:

……...

……...

……...

……...

……...

……...

Threats:

……...

……...

……...

……...

……...

……...

SECTION 3: Determinants of economic viability & PESTLE analysis

A PESTLE analysis is a strategic framework used to evaluate the business environment in which organisations operate. In the context of this study, it is used to evaluate the economic viability of CSP projects as a renewable energy source, ultimately being part of a Cost-benefit analysis.

A PESTLE analysis is an acronym that stands for Political, Economic, Social, Technological, Legal and Environmental factors. PESTLE analysis plays a crucial role in strategic planning and assessment of project viability, while assisting in project prioritisation and providing consistency in strategic analysis.

All questions in this section addresses a PESTLE analysis and Cost-benefit analysis.

8. **Political factors** include factors indicating how and to what extent a government intervenes with or regulates the economy of the country or a certain industry and other politically related factors.

   Please indicate the importance of the following political factors relevant to CSP technology as a renewable energy source (please indicate with an X).

Political factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Tax policies / legislation					

Political factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Labour laws / legislation					
Foreign trade restrictions					
Local trade restrictions					
Import / export duties and tariffs					
Environmental policies / legislation					
Corruption					
Political stability or instability					
Other factors that you would like to add:					
(a)					
(b)					
(c)					
(d)					

9. Economic factors, in general, are factors affecting or influencing fundamental activities of the economy or market, ultimately influencing a country's economic growth and development and how businesses (and related projects) within that country perform.

Please indicate the importance of the following economic factors relevant to CSP technology as a renewable energy source (please indicate with an X).

Economic factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
SA's general economic climate and conditions					
Availability & condition of goods and services					
Interest rates					
Foreign exchange rates					

Economic factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Inflation rates					
Funding & Credit availability					
Other factors that you would like to add:					
(a)					
(b)					
(c)					
(d)					

10. **Economic factors**, for the determination of the economic viability of investments (e.g., projects), also include (over and above the economic factors mentioned in the previous question (question 12)) a financial analysis of the profitability (or yield/return) of such investments or projects.

    Please indicate the importance of using the following ***financial analysis techniques*** relevant to CSP technology as a renewable energy source (please indicate with an X).

Economic factors – Financial analysis techniques	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Accounting rate of return (ARR)					
Payback period (PBP)					
Discounted Payback period (DPB)					
Net present value (NPV)					
Internal rate of return (IRR)					
Levelised cost of energy (LCOE)					

Economic factors – Financial analysis techniques	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Other financial analysis techniques that you would like to add:					
(a)					
(b)					
(c)					
(d)					

11. In your opinion, what are the main ***financial risks*** when investing in CSP technology?

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12. In your opinion, what are the main ***financial opportunities*** of investing in CSP technology?

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13. Please list any ***challenges*** that exist with regards to ***obtaining the required finances*** to fund investment in CSP projects.

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14. South Africa currently has seven operating CSP plants with a total planned capacity of 600 megawatt hours (of which 500-megawatt hours has reached commercial operation) while the remaining 100-megawatt hours are planned to reach commercial operation later in 2023. Would you recommend ***further investments in CSP plants*** in addition to the existing CSP plants? Please briefly elaborate.

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15. In your own view, do you regard ***PV as a lower cost alternative to CSP***, considering the overall benefits of each of these renewable energy sources? Please elaborate and provide reasons supporting your opinion.

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16. **Social factors** analyse the social environment of a country and assesses these factors influencing or being influenced by an investment.

Please indicate the importance of the following social factors relevant to CSP technology as a renewable energy source (please indicate with an X).

Social factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Education and skills of available labour force					
Alleviation of Unemployment (in local community)					
Cost of living and improvement of standard of living					
Community engagement and development					
Acceptance of new environmentally green technology					
Stakeholder impact					
Other factors that you would like to add:					
(a)					
(b)					
(c)					
(d)					

17. Do you think South Africa has the necessary ***engineering and operational skills*** to realise the full potential of CSP technology? Please explain.

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18. Do CSP plants create ***permanent employment*** after construction of the CSP plant? If yes, how many permanent jobs would be / were created by your organisation's CSP plant?

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19. In your opinion, what are the main ***benefits of CSP technology in the local community*** in which it operates? Please elaborate.

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20. In your opinion, what are the main ***benefits of CSP technology in the national community*** of South Africa? Please elaborate.

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21. **Technological factors** include the availability of infrastructure and technology for the necessary support of modern systems.

Furthermore, Renewable Energy technological factors further includes intermittency (which is unplanned variations in the power generated by wind or solar due to changes in weather patterns), dispatchability (dispatchable generation is the type of electricity that can be distributed based on the electricity demand, and they can be very flexible in terms of load matching and peak matching within a short notice and can also be useful to cover intermittent RE sources when the demand is high), variability (variability is the fluctuating nature of solar resources, which translates into potentially rapid changes in electricity output), scalability (deployment of renewable energy technologies on a small scale and growing it without the need for a complete major replacement of the available infrastructure), and energy storage (the ability of renewable energy technologies to store energy for use at a later stage).

Please indicate the importance of the following technological factors relevant to CSP technology as a renewable energy source (please indicate with an X).

Technological factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Availability of technology					
Cost of technology (investment in technology)					
Government spending on technology					
Research and development					
Renewable energy technologies:					
Intermittency capability					
Dispatchable electricity distribution					
Variability in electricity output					
expandability of electricity generation capacity (Scalability)					
Energy storage capacity (storing energy for later use)					
Other factors that you would like to add:					
(a)					
(b)					
(c)					
(d)					

22. Legal factors are established rules, regulations, and legislation used by a government to ensure the wellbeing of a country's economy, protection of assets and individual rights.

Please indicate the importance of the following legal factors relevant to CSP technology as a renewable energy source (please indicate with an X).

Legal factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Laws and regulations (energy planning, management, and grid access)					
Access to resources					
Licencing					
Other factors that you would like to add:					
(a)					
(b)					
(c)					
(d)					

23. Environmental factors involve the impact of natural events on a project and a project's impact on the natural environment.

Please indicate the importance of the following environmental factors relevant to CSP technology as a renewable energy source (please indicate with an X).

Environmental factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Weather conditions					
Pollution & waste management					
Climate change					
Water quality & availability					
Dust and cleanliness of CSP equipment					
Health and safety in the working place					
Environmental influences (including agricultural influences) of a CSP plant					
Site rehabilitation (on closure of the CSP plant)					
Other factors that you would like to add:					
(a)					
(b)					
(c)					
(d)					

24. A **Cost-benefit analysis (CBA)** is the process of comparing projected costs and benefits (tangible and intangible) associated with a project decision to determine whether it is sound to invest in that specific project. CBA involves considering a project's benefits and costs valued in monetary terms to determining the best project proposal by tallying up all costs of a project and subtracting that amount from the total projected benefits.

Please indicate the importance of the following costs and benefits relevant to CSP technology as a renewable energy source (please indicate with an X).

Cost or benefit	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Tangible costs					
Finance cost (capital investment cost)					
Installation cost					
Labour (employment) cost					
Insurance cost					
Intangible costs					
Relocation of habitat (fauna and flora)					
Lost agricultural activities					
Tangible benefits					
Revenue					
Government subsidies					
Investor funding					
Intangible benefits					
Reduction in greenhouse gas emissions					
Improved living standards – local community					
Improved living standards – national community					
Health and safety benefits (in comparison to other electricity generation methods)					
Reduced noise levels (in comparison to other electricity generation methods)					
Other costs / benefits that you would like to add:					
(a)					
(b)					
(c)					
(d)					

SECTION 4: Other General aspects

25. In your opinion, what are the ***most important factors*** being ***considered by stakeholders*** when analysing/considering CSP projects for investment?

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26. ***Can CSP output capacity be increased*** once it's set at e.g., 100 MWh? If so, are there any plans to increase the existing capacity of your organisation's CSP plant in the future? Please elaborate.

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27. Does the CSP plant ***sell all of its output (MWh) at full capacity*** to Eskom at both peak and standard production periods? If not, please briefly state the reason/s.

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28. Are there any ***future plans to incorporate PV technology*** with the existing CSP plant? If so, please briefly elaborate on why it is planned?

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29. Are there any ***other important aspects/factors*** that have not been covered during the interview which you would like to ***bring to the attention of, or discuss*** with the interviewer? If so, please list and elaborate on these aspects.

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I would like to thank you for participating in this research and questionnaire, it is much appreciated.

APPENDIX 5: Interview questionnaire: Plant Managers and Operations Managers

INTERVIEW QUESTIONS ON EVALUATING THE ECONOMIC VIABILITY OF CONCENTRATED SOLAR POWER SYSTEMS AS A RENEWABLE ENERGY SOURCE

to the

PLANT MANAGERS and OPERATIONS MANAGERS

The purpose of the interview is to gather data that will be used in evaluating the economic viability of CSP as a renewable energy source, using a Cost-benefit analysis.

INTRODUCTION

Access to energy is at the heart of development and if not effectively implemented, it has a huge impact on people's health, education, food security, gender equality, livelihoods, and poverty (The World Bank, 2018). Energy is also a lifeblood of modern living and an enabler for economic growth and stability (DE, 2019a:2). As alluded by Van der Nest (2015), for an effective and efficient development, South Africa needs a reliable and available infrastructure providing utility services.

South Africa needs to have a more balanced approach when choosing the type of electricity generating technology to use through its Integrated Resource Plan (IRP). Looking at the IRP document, CSP has not been given the attention it deserves considering its potential and the benefits it can offer to South Africa. That is the reason this research is based on looking at CSP's economic viability using a Cost-benefit analysis approach.

The interviews will be conducted to get opinions and perspective about CSP in general, the suitability thereof as a Renewable Energy (RE) source, as well as its economic viability in the South African environment and conditions.

This interview schedule forms part of a mini-dissertation entitled "*Evaluating the economic viability of Concentrated Solar Power systems as renewable energy source*." The researcher is writing a mini-dissertation in partial fulfilment for the M Com (Management Accountancy) degree at the Potchefstroom Campus of the North-West University. The research is conducted for academic purposes under supervision of Mr FJ Bibbey (e-mail: frans.bibbey@nwu.ac.za).

The Interviewee can contact the researcher any time after the interview has been conducted through email: vbngomane@gmail.com or Mobile contact: 072 535 1024 and the interview

questionnaire will be sent to all participants beforehand so that they can familiarise themselves with.

Please note that any information provided will be treated as confidential and this participation is voluntary. Participants can also withdraw at any stage during the interview. All the data gathered will only be used for the purpose of this research and all participant's identity will be kept anonymous. The research is conducted following the ethical guidelines of the North-West University.

INTERVIEW QUESTIONNAIRE: PLANT MANAGERS & OPERATIONS MANAGERS

SECTION 1: Participant's information

Interviewee's position: ☐ Plant Manager ☐ Operations Manager

1. What are your formal qualifications after school?

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2. Please describe your main duties and responsibilities in your current position (other than the normal duties and responsibilities as Plant Manager or as Operations Manager).

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3. For how long have you been in your current position?

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4. How long have you been employed in the Energy Industry?

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5. How long have you been employed or involved in Concentrate Solar Power (CSP) technology?

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SECTION 2: Concentrated Solar Power Systems/technologies (CSP)

6. Do you experience any logistical issues with regards to imported CSP spare parts? If so, please elaborate.

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7. What would you regard as the ***strengths and weaknesses*** associated with the implementation and operation of CSP technology?

Strengths:

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Weaknesses:

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8. Please state any ***controllable production inefficiencies*** being experienced to date in your organisation's CSP plant and briefly indicate what can be done in the future to eliminate these inefficiencies?

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9. Some countries around the world are already using a ***CSP-PV hybrid systems to optimise CSP's strengths*** to storing energy to be used when there is no sun. Do you think South Africa can also efficiently use CSP-PV hybrid systems? Please elaborate.

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SECTION 3: Determinants of economic viability & PESTLE analysis

A PESTLE analysis is a strategic framework used to evaluate the business environment in which organisations operate. In the context of this study, it is used to evaluate the economic viability of CSP projects as a renewable energy source, ultimately being part of a Cost-benefit analysis.

A PESTLE analysis is an acronym that stands for Political, Economic, Social, Technological, Legal and Environmental factors. PESTLE analysis plays a crucial role in strategic planning and assessment of project viability, while assisting in project prioritisation and providing consistency in strategic analysis.

All questions in this section addresses a PESTLE analysis and Cost-benefit analysis.

10. **Political factors** include factors indicating how and to what extent a government intervenes with or regulates the economy of the country or a certain industry and other politically related factors.

    Please indicate the importance of the following political factors relevant to CSP technology as a renewable energy source (please indicate with an X).

Political factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Labour laws / legislation					
Local trade restrictions					
Environmental policies / legislation					
Other factors that you would like to add:					
(a)					
(b)					
(c)					
(d)					

11. **Economic factors**, in general, are factors affecting or influencing fundamental activities of the economy or market, ultimately influencing a country's economic growth and development and how businesses (and related projects) within that country perform.

    Please indicate the importance of the following economic factors relevant to CSP technology as a renewable energy source (please indicate with an X).

Economic factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Availability & condition of goods and services					
Wage rates					
Working hours					
Transport					
Other factors that you would like to add:					
(a)					
(b)					
(c)					
(d)					

12. South Africa currently has seven operating CSP plants with a total planned capacity of 600 megawatt hours (of which 500-megawatt hours has reached commercial operation) while the remaining 100-megawatt hours are planned to reach commercial operation later in 2023. Would you recommend ***further investments in CSP plants*** in addition to the existing CSP plants? Please briefly elaborate.

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13. In your opinion, what are the main ***cost drivers of the operation and maintenance cost*** of CSP plants?

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14. In your own view, do you regard ***PV as a lower cost alternative to CSP***, considering the overall benefits of each of these renewable energy sources? Please elaborate and provide reasons supporting your opinion.

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15. **Social factors** analyse the social environment of a country and assesses these factors influencing or being influenced by an investment.

    Please indicate the importance of the following social factors relevant to CSP technology as a renewable energy source (please indicate with an X).

Social factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Education and skills of labour force (available to CSP)					
Alleviation of Unemployment (in local community)					
Cost of living and improvement of standard of living					
Community engagement					
Stakeholder impact					
Other factors that you would like to add:					

Social factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
(a)					
(b)					
(c)					
(d)					

16. Do you think South Africa has the necessary ***engineering and operational skills*** to realise the full potential of CSP technology? Please explain.

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17. Do CSP plants create long term ***permanent employment*** after construction of the CSP plant? If yes, how many permanent jobs would be / were created by your organisation's CSP plant?

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18. Is this CSP project currently using local skilled labourers to operate and maintain the CSP plant? If so, what ***percentage of the total skilled labourers involved in the CSP project*** are ***local skilled labourers*** (in comparison to foreign skilled labourers)?

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19. **Technological factors** include the availability of infrastructure and technology for the necessary support of modern systems.

    Furthermore, Renewable Energy technological factors further includes intermittency (which is unplanned variations in the power generated by wind or solar due to changes in weather patterns), dispatchability (dispatchable generation is the type of electricity that can be distributed based on the electricity demand, and they can be very flexible in terms of load matching and peak matching within a short notice and can also be useful to cover intermittent RE sources when the demand is high), variability (variability is the fluctuating nature of solar resources, which translates into potentially rapid changes in electricity output), scalability (Scalability means that the deployment of RET's can start on a small scale and also grow without the need for a complete major replacement of the available infrastructure) and energy storage (the ability of Renewable Energy technologies to store energy for use at a later stage).

    Please indicate the importance of the following technological factors relevant to CSP technology as a renewable energy source (please indicate with an X).

Technological factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Availability of technology					

Technological factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Cost of technology (investment in technology)					
Maintenance cost					
Frequency of maintenance					
Technological flexibility and adaptability					
Level of automation					
Renewable energy technologies:					
Intermittency capability					
Dispatchable electricity distribution					
Variability in electricity output					
expandability of electricity generation capacity (Scalability)					
Energy storage capacity (storing energy for later use)					
Other factors you would like to add:					
(a)					
(b)					
(c)					
(d)					

20. A ***CSP plant can incorporate Thermal Energy Storage (TES)***, which stores energy either in a form of sensible heat or as latent heat (for example, using molten salt), which enables these plants to continue to generate electricity whenever needed, day or night. Are there any benefits of Thermal Energy Storage system for CSP? Please elaborate.

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21. **Legal factors** are established rules, regulations, and legislation used by a government to ensure the wellbeing of a country's economy, protection of assets and individual rights.

    Please indicate the importance of the following legal factors relevant to CSP technology as a renewable energy source (please indicate with an X).

Legal factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Laws and regulations – operational					
Laws and regulations – health and safety					
Access to resources					
Other factors you would like to add:					
(a)					
(b)					
(c)					
(d)					

22. **Environmental factors** involve the impact of natural events on a project and a project's impact on the natural environment.

    Please indicate the importance of the following environmental factors relevant to CSP technology as a renewable energy source (please indicate with an X).

Environmental factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Weather conditions					
Pollution & wate management					

Environmental factor	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Climate change					
Water quality & availability					
Dust and cleanliness of CSP equipment					
Health and safety in the working place					
Other factors that you would like to add:					
(a)					
(b)					
(c)					
(d)					

23. Considering ***operations and maintenance activities*** (especially mirror and tube cleaning), are there any ***future improvements*** that could be made to, e.g., reduce operations and maintenance costs within CSP plants?

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24. A **Cost-benefit analysis (CBA)** is the process of comparing projected costs and benefits (tangible and intangible) associated with a project decision to determine whether it is sound to invest in that specific project. CBA involves considering a project's benefits and costs valued in monetary terms to determining the best project proposal by tallying up all costs of a project and subtracting that amount from the total projected benefits.

Please indicate the importance of the following costs and benefits relevant to CSP technology as a renewable energy source (please indicate with an X).

Cost or benefit	***Importance***				
	Not at all	***Slightly***	***Moderately***	***Very***	***Extremely***
	1	2	3	4	5
Tangible costs					
Labour (employment) cost					
Mirror and tube cleaning cost					
Fuel cost					
Solar field maintenance cost					
Power block maintenance cost					
Thermal Energy System (TES) costs					
Maintenance cost (general maintenance)					
Intangible benefits					
Reduction in greenhouse gas emissions					
Health and safety benefits (in comparison to other electricity generation methods)					
Reduced noise levels (in comparison to other electricity generation methods)					
Other costs / benefits that you would like to add:					
(a)					
(b)					
(c)					
(d)					

25. Are there any ***other important aspects/factors*** that have not been covered during the interview which you would like to ***bring to the attention of, or discuss*** with the interviewer? If so, please list and elaborate on these aspects.

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I would like to thank you for participating in this research and questionnaire, it is much appreciated.

APPENDIX 6: THEMATIC ANALYSIS OF INTERVIEW QUESTIONS

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: CHIEF EXECUTIVE OFFICERS & CHIEF FINANCIAL OFFICERS**		
QUESTION		***REASON***
	SECTION 1: Participant's information	
1	What are your formal qualifications after school?	The question was posed to determine whether the research participants have technical/financial/management qualifications. This will give the researcher an idea of what type of and quality of responses to expect from the participants.
2	Please describe your main duties and responsibilities in your current position.	This will give the researcher a better understanding of what to expect regarding the responses from the participants and to compare these duties and responsibilities with another participant in another CSP plant in a similar position.
3	How long have you been in your current position?	To determine the experience of the participants based on their current position.
4	How long have you been employed in the energy industry?	To determine the overall experience of the participants within the energy industry. The researcher wants to also establish whether the participants worked on electricity generating technologies other than CSP.
5	How long have you been employed or involved in CSP technology?	To determine relevant experience on CSP and whether the participant had worked on CSP plants other than their current employment.
	SECTION 2: Concentrated Solar Power systems/technologies (CSP)	
6	What would you regard as the ***strengths and weaknesses*** associated with the implementation of CSP technology?	This question will give the researcher guidance on the internal advantages and disadvantages of CSP technology.

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: CHIEF EXECUTIVE OFFICERS & CHIEF FINANCIAL OFFICERS**		
QUESTION		***REASON***
7	What would you regard as the ***opportunities and threats*** associated with the implementation of CSP technology?	This question will give the researcher guidance on the external advantages and disadvantages of CSP technology.
	SECTION 3: Determinants of economic viability & PESTLE analysis	
	SECTION 3.1: Political factors	
8	**Political factors** include factors indicating how and to what extent a government intervenes in or regulates the economy of the country or a certain industry, and other politically related factors. Please indicate the importance of the following political factors relevant to CSP technology as an RE source (please indicate with an X).	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial in the assessment of CSP's economic viability. Participants can also add relevant factors that the researcher might have missed in the literature review. This question will assist the researcher in gaining a better understanding of the main factors, as well as the less important factors, contributing to CSP's economic viability.
	SECTION 3.2: Economic factors	
9	**Economic factors**, in general, are factors affecting the fundamental activities of the economy or market, ultimately influencing a country's economic growth and development and how businesses (and related projects) within that country perform. Please indicate the importance of the following economic factors relevant to CSP technology as an RE source (please indicate with an X).	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial in the assessment of CSP's economic viability. Participants can also add relevant factors that the researcher might have missed in the literature review. This question will assist the researcher in gaining a better understanding of the main factors, as well as the less important factors, contributing to CSP's economic viability.

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: CHIEF EXECUTIVE OFFICERS & CHIEF FINANCIAL OFFICERS**		
QUESTION		***REASON***
10	**Economic factors**, for the determination of the economic viability of investments (e.g., projects), also include (over and above the economic factors mentioned in the previous question (question 12)) a financial analysis of the profitability (or yield/return) of such investments or projects. Please indicate the importance of using the following ***financial analysis techniques*** relevant to CSP technology as an RE source (please indicate with an X).	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial in the assessment of CSP's economic viability. Participants can also add relevant factors that the researcher might have missed in the literature review. This question will assist the researcher in gaining a better understanding of the main factors, as well as the less important factors, contributing to CSP's economic viability.
11	In your opinion, what are the main ***financial risks*** when investing in CSP technology?	The financial risks identified will assist the researcher in the CBA exercise.
12	In your opinion, what are the main ***financial opportunities*** of investing in CSP technology?	This question aims to find out whether there are any financial opportunities on CSP technologies which can add to the economic viability of CSP technology.
13	Please list any ***challenges*** that exist with regard to ***obtaining the required finances*** to fund investment in CSP projects.	The main objective of this question is to establish any funding constraints for CSP investments.
14	South Africa currently has seven operating CSP plants with a total planned capacity of 600 MWh (of which 500 MWh have reached commercial operation). The remaining 100 MWh are planned to reach commercial operation later in 2023. Would you recommend ***further investments in***	This question aims to establish whether the participants would give CSP an opportunity for future investment after the Redstone project, which is the last CSP plant to be developed from the IRP.

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: CHIEF EXECUTIVE OFFICERS & CHIEF FINANCIAL OFFICERS**		
QUESTION		***REASON***
	CSP plants in addition to the existing CSP plants? Please elaborate briefly.	
15	In your view, do you regard ***PV as a lower cost alternative to CSP***, considering the overall benefits of each of these RE sources? Please elaborate and provide reasons supporting your opinion.	The researcher aims to determine whether PV is cheaper than CSP. This question will also assist the researcher in determining whether PV is an alternative to CSP based on costs for both technologies.
	SECTION 3.3: Social factors	
16	**Social factors** analyse the social environment of a country and assesses these factors influencing or being influenced by an investment. Please indicate the importance of the following social factors relevant to CSP technology as an RE source (please indicate with an X).	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial in the assessment of CSP's economic viability. Participants can also add relevant factors that the researcher might have missed in the literature review. This question will assist the researcher in gaining a better understanding of the main factors, as well as the less important factors, contributing to CSP's economic viability.
17	Do you think South Africa has the necessary engineering and operational skills to realise the full potential of CSP technology and why do you think so?	Researcher wants to establish whether SA is in an advantageous position to construct, operate and maintain CSP plants locally or whether these skills need to be imported.
18	Do CSP plants create ***permanent employment*** after construction of the CSP plant? If yes, how many permanent jobs would be / were created by your organisation's CSP plant?	The researcher wants to determine the economic contributions of CSP plants with regard to employment and whether these are also sustainable by creating permanent employment.
19	In your own opinion, what are the main benefits of CSP technology for the local	This is part of assessing the economic contribution of CSP technologies in the communities where they operate.

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: CHIEF EXECUTIVE OFFICERS & CHIEF FINANCIAL OFFICERS**		
QUESTION		***REASON***
	community in which it operates? Please elaborate.	
20	In your opinion, what are the main ***benefits of CSP technology in the national community*** of South Africa? Please elaborate.	This is part of assessing the economic contribution of CSP technologies at the national level.
	SECTION 3.4: Technological factors	
21	**Technological factors** include the availability of infrastructure and technology for the necessary support of modern systems. Furthermore, RET factors include intermittency (which is unplanned variations in the power generated by wind or solar due to changes in weather patterns), dispatchability (dispatchable generation is the type of electricity that can be distributed based on the electricity demand; this can be very flexible in terms of load matching and peak matching on a short notice; can also be useful to cover intermittent RE sources when the demand is high), variability (variability is the fluctuating nature of solar resources, which translates into potentially rapid changes in electricity output), scalability (i.e., the deployment of RETs can start on a small scale and grow without the need for a complete replacement of the available infrastructure), and energy storage (the	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial in the assessment of CSP's economic viability. Participants can also add relevant factors that the researcher might have missed in the literature review. This question will assist the researcher in gaining a better understanding of the main factors, as well as the less important factors, contributing to CSP's economic viability.

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: CHIEF EXECUTIVE OFFICERS & CHIEF FINANCIAL OFFICERS**		
QUESTION		***REASON***
	ability of RETs to store energy for use at a later stage). Please indicate the importance of the following technological factors relevant to CSP technology as an RE source (please indicate with an X).	
	SECTION 3.5: Legal factors	
22	**Legal factors** are established rules, regulations, and legislation used by a government to ensure the wellbeing of a country's economy and the protection of assets and individual rights. Please indicate the importance of the following legal factors relevant to CSP technology as an RE source (please indicate with an X).	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial in the assessment of CSP's economic viability.
	SECTION 3.6: Environmental factors	
23	**Environmental factors** involve the impact of natural events on a project and a project's impact on the natural environment. Please indicate the importance of the following environmental factors relevant to CSP technology as an RE source (please indicate with an X).	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial in the assessment of CSP's economic viability.
24	A **CBA** is the process of comparing projected costs and benefits associated with a project decision to determine	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: CHIEF EXECUTIVE OFFICERS & CHIEF FINANCIAL OFFICERS**		
QUESTION		***REASON***
	whether it is sound to invest in that specific project. CBA considers a project's benefits and costs in monetary terms to determine the best project proposal by tallying up all costs of a project and subtracting that amount from the total projected benefits. Please indicate the importance of the following costs and benefits relevant to CSP technology as an RE source (please indicate with an X).	in the assessment of CSP's economic viability. Participants can also add relevant factors that the researcher might have missed in the literature review. This question will assist the researcher in gaining a better understanding of the main factors, as well as the less important factors, contributing to CSP's economic viability.
	SECTION 5: Other general aspects	
25	In your opinion, what are the ***most important factors considered by stakeholders*** when analysing/considering CSP projects for investment?	This question will assist the researcher in identifying the factors considered by stakeholders before investing in CSP technologies. This will provide important insight into CSP technologies and assist the researcher in determining CSP's economic viability.
26	Can CSP output capacity be increased once it has been set at, e.g., 100 MWh? If so, are there any plans to increase the existing capacity of your organisation's CSP plant in the future? Please elaborate.	This question will assist the researcher in determining whether there are additional features in the CSP project that could increase production capacity in response to Eskom's requirements as per the PPA.
27	Does the CSP plant sell all of its output (MWh) at full capacity to Eskom at both peak and standard production periods? If not, please briefly state the reason/s.	This question wants to ascertain whether CSP plants experience production idling due to contractual obligations that specify set times for standard and peak production.
28	Are there any future plans to incorporate PV technology with the existing CSP plant? If so, please elaborate briefly on why this is planned.	This question will help the researcher determine whether there is potential technological synergies between CSP and PV.
29	Are there any ***other important aspects/ factors*** that have not been covered during	The question will assist the researcher in finding other relevant information from the participants

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: CHIEF EXECUTIVE OFFICERS & CHIEF FINANCIAL OFFICERS**		
QUESTION		***REASON***
	the interview that you would like to ***bring to the attention of, or discuss*** with the interviewer? If so, please list and elaborate on these aspects.	which might have not been covered in all the questions asked to the CEOs and CFOs.

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: PLANT MANAGERS & OPERATIONS MANAGERS**		
QUESTION		***REASON***
1	What are your formal qualifications after school?	The question was posed to determine whether the research participants have technical/financial/management qualifications. This will give the researcher an idea of what responses to expect from the participants.
2	Please describe your main duties and responsibilities in your current position.	This will give the researcher a better understanding of what to expect regarding the responses from the participants and to compare these duties and responsibilities with another participant in another CSP plant in a similar position.
3	How long have you been in your current position?	To determine the experience of the participants based on their current position.
4	How long have you been employed in the energy industry?	To determine the overall experience of the participants within the energy industry. The researcher wants to also establish whether the participants worked on electricity generating technologies other than CSP.
5	How long have you been employed or involved in CSP technology?	To determine relevant experience on CSP and whether the participant had worked on CSP plants other than their current employment.
	SECTION 2: Concentrated Solar Power systems/technologies (CSP)	
6	Do you experience any logistical issues with regard to imported CSP spare parts? Please elaborate	This question is to assess any localisation of spares for CSP projects. This question will also assist in finding out whether CSP spares are readily available and whether this has an impact on production.
7	What would you regard as the strengths and weaknesses of CSP technology?	This will help the researcher gain insight on the technical benefits and challenges when it

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: PLANT MANAGERS & OPERATIONS MANAGERS**		
QUESTION		***REASON***
		comes to the actual operations and maintenance of CSP plants.
8	Please state any ***controllable production inefficiencies*** experienced to date in your organisation's CSP plant and briefly indicate what can be done in the future to eliminate these inefficiencies. Please share any uncontrollable production losses caused by CSP technology based on the nature of its design and do you think EPC can do a lot to improve design of CSP plants	This question's objective is to obtain the exact main contributors to production inefficiencies.
9	Some countries around the world are already using a CSP-PV hybrid systems to optimise CSP's strength to storing energy to be used when there is no sun. Do you think South Africa can also efficiently use CSP-PV hybrid systems? Please elaborate.	The researcher wants to establish whether there are any pipelined projects for a CSP-PV hybrid systems. This will give the researcher an idea of what the relationship between CSP and PV can be when they are integrated rather than competing against each other.
	SECTION 3: Determinants of economic viability & PESTLE analysis	
	SECTION 3.1: Political factors	
10	**Political factors** include factors indicating how and to what extent a government intervenes in or regulates the economy of the country or a certain industry, and other politically related factors. Please indicate the importance of the following political factors relevant to CSP technology as an RE source (please indicate with an X).	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial in the assessment of CSP's economic viability. Participants can also add relevant factors that the researcher might have missed in the literature review. This question will assist the researcher in gaining a better understanding of the main factors, as well as the less important factors, contributing to CSP's economic viability.

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: PLANT MANAGERS & OPERATIONS MANAGERS**		
QUESTION		***REASON***
	SECTION 3.2: Economic factors	
11	**Economic factors**, in general, are factors affecting the fundamental activities of the economy or market, ultimately influencing a country's economic growth and development and how businesses (and related projects) within that country perform. Please indicate the importance of the following economic factors relevant to CSP technology as an RE source (please indicate with an X).	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial in the assessment of CSP's economic viability. Participants can also add relevant factors that the researcher might have missed in the literature review. This question will assist the researcher in gaining a better understanding of the main factors, as well as the less important factors, contributing to CSP's economic viability.
12	South Africa currently has seven operating CSP plants with a total planned capacity of 600 MWh (of which 500 MWh have reached commercial operation). The remaining 100 MWh are planned to reach commercial operation later in 2023. Would you recommend further investments in CSP over and above the existing CSP plants? Please elaborate briefly.	This question will give the researcher an overview of whether CSP might be re-considered for inclusion in the government's Integrated Resource Plan beyond 2030.
13	In your opinion, what are the main ***drivers of the operation and maintenance costs*** of CSP plants?	This will assist the researcher in finding out whether there is potential for reducing CSP costs to improve the LCOE.
14	In your own view, do you regard ***PV as a lower cost alternative to CSP***, considering the overall benefits of each of these RE sources? Please elaborate and provide reasons supporting your opinion.	This question aims to provide more understanding (over and above the literature review) of why investors prefer PV over CSP. The participants currently work at a CSP plant and might provide more insight. The researcher also wants to establish the importance of considering aspects other than

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: PLANT MANAGERS & OPERATIONS MANAGERS**		
QUESTION		***REASON***
		the capital outlay when choosing these technologies.
	SECTION 3.3: Social factors	
15	**Social factors** analyse the social environment of a country and assesses these factors influencing or being influenced by an investment. Please indicate the importance of the following social factors relevant to CSP technology as an RE source (please indicate with an X).	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial in the assessment of CSP's economic viability. Participants can also add relevant factors that the researcher might have missed in the literature review. This question will assist the researcher in gaining a better understanding of the main factors, as well as the less important factors, contributing to CSP's economic viability.
16	Do you think South Africa has the necessary engineering and operational skills to realise the full potential of CSP technology? Please explain.	Since CSP technology is new to the country, this question will give the researcher an overview of whether SA has the necessary operational and maintenance skills for this technology. The responses will add value to the researcher's assessment of CSP's economic viability.
17	Do CSP plants create ***permanent employment*** after construction of the CSP plant? If yes, how many permanent jobs would be / were created by your organisation's CSP plant?	The researcher wants to determine the economic contributions of CSP plants with regard to employment and whether these are also sustainable by creating permanent employment.
18	Is this CSP project currently using local skilled labourers to operate and maintain the CSP plant? If so, what ***percentage of the total skilled labourers involved in the CSP project*** are ***local skilled labourers*** (in comparison to foreign skilled labourers)?	This question is linked to question 17, but the main objective here is to determine whether CSP plants also use foreign skills and to what extent when compared to local resources.

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: PLANT MANAGERS & OPERATIONS MANAGERS**		
QUESTION		***REASON***
	SECTION 3.4: Technological factors	
19	**Technological factors** include the availability of infrastructure and technology for the necessary support of modern systems. Furthermore, RET factors include intermittency (which is unplanned variations in the power generated by wind or solar due to changes in weather patterns), dispatchability (dispatchable generation is the type of electricity that can be distributed based on the electricity demand; this can be very flexible in terms of load matching and peak matching on short notice; can also be useful to cover intermittent RE sources when the demand is high), variability (variability is the fluctuating nature of solar resources, which translates into potentially rapid changes in electricity output), scalability (i.e., the deployment of RETs can start on a small scale and grow without the need for a complete replacement of the available infrastructure), and energy storage (the ability of RETs to store energy for use at a later stage). Please indicate the importance of the following technological factors relevant to CSP technology as an RE source (please indicate with an X).	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial in the assessment of CSP's economic viability. Participants can also add relevant factors that the researcher might have missed in the literature review. This question will assist the researcher in gaining a better understanding of the main factors, as well as the less important factors, contributing to CSP's economic viability.

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: PLANT MANAGERS & OPERATIONS MANAGERS**		
QUESTION		***REASON***
20	A CSP plant can incorporate Thermal Energy Storage, which stores energy either in a form of sensible heat or as latent heat (for example, using molten salt), which enables these plants to continue to generate electricity whenever needed, day or night. Are there any benefits of Thermal Energy Storage system for CSP, and in your opinion, are there any areas for development on Thermal Energy Storage?	The researcher wants to establish whether SA can rely solely on PV dominating over CSP without the unique proper energy storage facilities provided by CSP technology.
	SECTION 3.5: Legal factors	
21	**Legal factors** are established rules, regulations, and legislation used by a government to ensure the wellbeing of a country's economy and the protection of assets and individual rights. Please indicate the importance of the following legal factors relevant to CSP technology as an RE source (please indicate with an X).	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial in the assessment of CSP's economic viability.
	SECTION 3.6: Environmental factors	
22	**Environmental factors** involve the impact of natural events on a project and a project's impact on the natural environment. Please indicate the importance of the following environmental factors relevant to	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial in the assessment of CSP's economic viability.

THEMATIC ANALYSIS OF INTERVIEW QUESTIONS **INTERVIEW QUESTIONS: PLANT MANAGERS & OPERATIONS MANAGERS**		
QUESTION		***REASON***
	CSP technology as an RE source (please indicate with an X).	
23	Considering ***operations and maintenance activities*** (especially mirror and tube cleaning), are there any ***future improvements*** that could be made to, e.g., reduce operations and maintenance costs within CSP plants?	The researcher wants to establish any risk of water shortages. All CSP plants in SA are currently based in the Northern Cape, which is the driest province in the country. The researcher also seeks insight on the existing cooling technology used and to find out whether this could be improved to use less water.
24	A **CBA** is the process of comparing projected costs and benefits associated with a project decision to determine whether it is sound to invest in that specific project. CBA considers a project's benefits and costs in monetary terms to determine the best project proposal by tallying up all costs of a project and subtracting that amount from the total projected benefits. Please indicate the importance of the following costs and benefits relevant to CSP technology as an RE source (please indicate with an X).	This question aims to get the participants to rank factors obtained from the literature review in order of importance; these factors can be crucial in the assessment of CSP's economic viability. Participants can also add relevant factors that the researcher might have missed in the literature review. This question will assist the researcher in gaining a better understanding of the main factors, as well as the less important factors, contributing to CSP's economic viability.
25	Are there any ***other important aspects/ factors*** that have not been covered during the interview that you would like to ***bring to the attention of, or discuss*** with the interviewer? If so, please list and elaborate on these aspects.	The question will assist the researcher in finding other relevant information from the participants which might have not been covered in all the questions asked to the plant managers and operations managers.

TAALPRAKTISYN | LANGUAGE PRACTITIONER

PROOF OF LANGUAGE EDITING

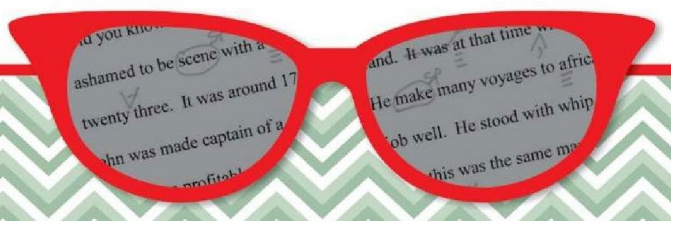
23 November 2023

I, Elmarie Viljoen-Massyn, hereby state that I have language edited the attached mini-dissertation, Evaluating the economic viability of Concentrated Solar Power systems as renewable energy source, by VB Ngomane.

Please take note that I returned the edited document with recommended changes to the client. I have not reviewed the final document with the accepted or rejected changes.

I am a language practitioner registered at the South African Translators' Institute (member number 1001757) and my highest qualification in this field is an MA Language Practice.

Sincerely,

Elmarie Viljoen-Massyn

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