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Economic impact of captive solar technology and an ideal grid penetration level

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ABSTRACT

Since the 2008 energy crisis, the national utility has been under stress to meet the country's electrical demand. Moreover, the costs of building new conventional power stations and the operation and maintenance costs of existing ones are taking a toll on the economy. The utility has hence resorted to hiking electricity tariffs. This combination of rising electricity prices and decreasing costs of photovoltaic (PV) technology have hence led a number of households to cover part of their electricity demand by self-produced captive solar PV technology. Reliable supply of energy is the backbone of a growing economy, hence the integration of captive solar PV technology, and self-generation seems to be growing on the back of an impending energy crisis. Although the integration of cleaner energy sources is good, uncontrolled or over penetration of captive solar technology could become a threat to the utility.

This exploratory research investigated the impact of solar captive technology on the economy. With an increase in the adoption of captive solar technology, the study also explores the possibility of finding an ideal penetration level, as well as the drivers that motivate the need to find this level.

The results of this study showed that there is an overall positive relationship between captive solar PV technology and economic growth. Furthermore, it was identified that finding an ideal penetration level is possible, however there are a number of constraints and variables that need to be considered when modelling the ideal penetration level. Participants mentioned a few approaches to how the ideal penetration level may be found. One approach could be to align the motivators for solar penetration, and the motivators for the need to find an ideal penetration and ensure that the one does not overly influence the other, i.e., they need to meet at a neutral point. Moreover, it can be deduced that the ideal penetration will be at a point where the economic benefits are high. Additionally, there are a number of drivers that motivate the need to find an ideal penetration level, and these were found to be similar to those that were mentioned in existing studies.

KEYWORDS: captive, solar, penetration, energy

DECLARATION

I declare that this research project is my own work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University. I further declare that I have obtained the necessary authorisation and consent to carry out this research.

Date: 18 January 2017

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Signature: ______________________________

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List of Abbreviations

CCS	Carbon Capturing and Sequestration
CO_2	Carbon Dioxide
COP	Conference of Parties
CSP	Concentrating Solar Power
DG	Distributed Generation
FID	Foreign Direct Investment
GCPV	Grid Connected Photovoltaic
GDP	Gross Domestic Product
GHG	Green House Gas
GW	Giga-watt
IPP	Independent Power Producer
kW	Kilo-watt
LCOE	Levelised cost of Electricity
MW	Mega-watt
PV	Photovoltaic
REIPPP	Renewable Energy Independent Power Producer Programme
RES	Renewable Energy Source
RTP	Real Time Pricing
TCE	Transaction Cost Economics
TOU	Time of Use
UNFCCC	United Nations Framework Convention on Climate Change
US$	United States Dollar

Chapter 1: Introduction to the Research Problem

1.1 Background and Description of the Research Problem

January 2008 marked the beginning of South Africa's energy crisis, when the national supplier of electricity, came under pressure to meet the country's electricity needs. Inadequate investment in infrastructure has led to power shortages and calls for new capacity since that time. The cost of new investments, combined with traditionally low electricity prices, caused an underfunding of the utility, which resulted in a sharp rise of electricity rates over the last eight years (Mayr, Schmid, Trollip, Zeyringer, & Schmidt, 2015).

According to Inglesi (2010), there is an ongoing relationship between electricity consumption, price, and economic growth. Photovoltaic (PV) solar energy is becoming more accessible as a result of lower technology costs, so "a surge in rooftop solar systems is driving heated debate about the future shape of the electric power sector, especially the status of electric utilities" (Graffy & Kihm, 2014, p.2). Graffy & Kihm (2014) and Menegaki (2014) have argued that integrating solar into the grid will have a positive influence on the economy and the environment as a result of a decrease in carbon emissions. Additionally, the introduction of solar PV technology is said to have a positive impact on an economy in terms of job creation (Loomis, Jo, & Aldeman, 2015).

The combination of rising electricity costs and decreasing photovoltaic (PV) technology costs leads high income households to cover part of their electricity demand by self-produced (captive) PV (solar) electricity. The majority of higher-income residents are expected to invest in PV power production by the year 2020, and use home battery systems by the year 2028 (Mayr, Schmid, Trollip, Zeyringer, & Schmidt, 2015).

However, a study by Tobar, Massague, Bellmunt & Penalba (2015) stated that there are concerns associated with increasing renewable energy penetration into the grid. The development of solar power plants connected to the medium and high voltage grid is a concern, because it could result in current utilities and distribution networks becoming obsolete. In support of this, Graffy & Kihm (2014) went on to say that the amount of power that is sold by the utilities could decrease with increasing solar power penetration. This prompts the question of whether the utility would be able to sustain itself with increasing solar PV competition.

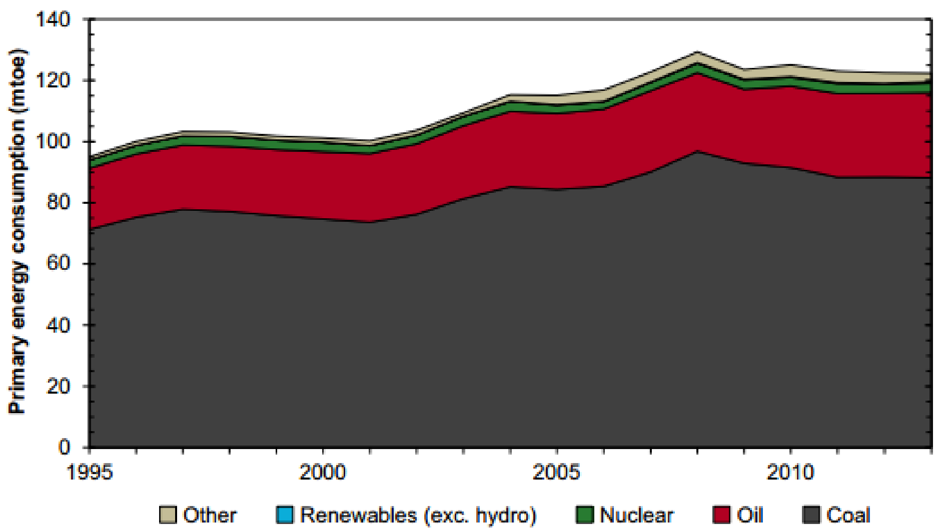
On the other hand, energy consumption causing carbon dioxide (CO_2) emissions has a negative impact on the economic growth of a country (Saidi & Hammami, 2014). Saidi and Hammami (2014) stated that for every 1% increase in pollutant emissions, there is a decrease in economic growth by 0.04%.

Traditional utilities and conventional methods of power production have a negative impact on the economy as a result of carbon emissions and unsustainability. Solar PV penetration is a cleaner and more sustainable method of electricity generation, however too much penetration of solar may lead to the 'death' of traditional utilities, which will in turn have a negative impact on the economy. There is thus a need to understand the extent to which solar penetration onto the grid affects the economy, and determine whether it is possible to find an ideal mix of solar and grid electricity.

This forms the groundwork to develop similar relationships (emissions on economic growth) that will help the South African government meet the commitment made at the 2009 Conference of Parties (COP17) summit, which was approved and gazetted in October 2011. Supporting this, Menegaki (2014) emphasised that inefficient use of energy would lead to further global warming, which in turn adversely affects Gross Domestic Product (GDP).

As shown in Figure 1, most of South Africa's electricity is provided by coal fired generation.

Figure 1: Energy consumption in South Africa



Source: Pollet, Staffell, & Adamson (2015)

Although the amount of renewables contributing to the generation of electricity is currently small, the Renewable Energy Independent Power Producer Programme (REIPPP) forecasts that in 20 years, almost 42% of the country's electricity will be produced from renewable energy sources, because the South African government has recognised that energy is an "important catalyst for economic growth and increased social equality with a focus in investing in energy infrastructure" (Pollet, Staffell, & Adamson, 2015, p.16688).

This predicted growth in electricity production using renewable energy sources, such as captive solar PV technology, could have various impacts on the traditional utility, independent solar installers, and the economy of the country as a whole. Identifying an ideal level of penetration of technologies such as captive solar PV technology, as well as its drivers, could prove beneficial for the utility in terms of planning its business model in order to cater for this projected growth and possible incorporation of renewables onto their system. The study will also prove useful for solar installers and may even assist in the development of policies and structures to allow traditional utilities and renewables to co-exist in harmony.

1.2 Research Aim

Electricity is central to social, economic, security, and environmental necessities (Graffy & Kihm , 2014). Employment impacts since the introduction of solar PV vary from 1,223 to 6,010 job years (Loomis, Jo, & Aldeman, 2015). In the current context of high unemployment rates, the implementation of solar technology will increase employment opportunities through the various phases of implementation, such as production, feasibility studies, and architectural design.

However, there is a counter-argument that as more solar power is utilised, less power will be required from existing utilities due to a point of so-called "grid parity", wherein the cost of generating power from captive solar PV decreases to the level of being competitive with conventional power generation (Blumsack, 2015). This may result in a loss of revenue to the government-owned utility, which demotivates the utility from promoting solar power penetration.

The researcher has selected this topic to better understand the perceptions of utility and solar power producers on the economic impact of captive solar PV penetration onto the grid, in reference to its effects on GDP, job creation, foreign direct investment (FDI), as well as environmental impacts such as meeting carbon emission targets. The study also investigates if it is possible to determine an ideal level of solar onto the grid, and if so, what the drivers are that allow this ideal penetration level to be identified. Therefore, the focus of this research is to uncover the economic impact of the penetration of captive solar penetration onto the grid, to discover whether it is possible to find an ideal level of penetration onto the grid that is beneficial for both the utility and customers. Furthermore, this study aims to determine if the role players understand the concept of an ideal penetration level; and if their understanding is similar, which would allow for the development of a policy framework that encourages and promotes PV adoption

1.3 Research Motivation

Andersen & Dalgaard (2013), in their study on the effects of power outages on economic growth in Africa, concluded that a substantial growth drag is accompanied by weaker power infrastructure in Sub-Saharan Africa, and the current impact of rolling blackouts is felt predominantly by businesses. These blackouts also affect the quality, safety and security of all individuals. Due to the shortage of electricity, the growth forecasts for South Africa were reduced by 0.3% in 2015 and 0.5% in 2016 (Reporter, 2009).

Renewable energy, such as solar, is thought of positively as it is a cleaner, more sustainable form of energy. Even though it is a potential pathway for business opportunities and growth, this industry is growing at a rate that is exceeding the capacity of the electrical utilities to adapt to, from both a technological and financial point of view (Graffy & Kihm , 2014). Graffy & Kihm (2014) also explored the impact of rooftop solar systems on electrical utilities, stating that “characterization of renewable energy innovations, such as rooftop solar, is a “mortal threat” or “radical threat” to utilities” (p.6). There is disruptive competition between solar PV and the electrical utility, hence an adequate mix needs to be found that will be beneficial to both.

Although studies have found that a socio-economic impact is caused by the implementation of hybrid (solar-grid) systems (Azimoh, Klintenberg, Wallin, Karlsson, & Mbohwa, 2015), the authors do not provide any information on how the ideal mix (ideal penetration) can be identified. This has prompted this researcher to investigate whether it is possible to identify an ideal penetration of solar power onto conventional power systems (grid) that will be beneficial to both the utility and consumers.

This study addresses both theoretical and business needs. From a theoretical perspective, few studies have been conducted on identifying the ideal penetration level of solar onto a grid that may prove beneficial to a utility and consumers. From an economic perspective, penetration of solar onto the grid can have advantages, such as supplying power back to the grid when excess electricity is produced, i.e. when generated power is greater than the local load demand (Obi & Bass, 2016). This may enable consumers to save more money as a result of better efficiency rates, net metering, and lower equipment and installation costs (Singh, et al., 2016).

This drives the need to determine what the economic impacts of integrating solar onto the grid are, and to understand what drivers influence the identification of the ideal penetration level.

1.4 Research Management Implications

This research has implications for the utility and the industry. The research will provide information regarding the economic impact of the integration of solar onto the grid, and it will provide the consumer with insight into the amount of savings that they could obtain by implementing captive solar technology. In addition, the study will help the industry understand how to reliably integrate solar power into system operations, and how this integration will actively improve the quality of the electric grid and the overall cost of electricity. If the research is proven beneficial, energy management systems and policies may have to change to accommodate solar integration onto the grid.

1.5 Research Questions

The research aims to answer the following research questions

- **RQ1:** What are the perceptions of the utility, solar power producers and installers with regards to the economic impact of captive solar technology?
- **RQ2:** Is it possible to find an ideal penetration level beneficial to both utility and customer?
- **RQ3:** What drivers influence the need to find an ideal penetration level?

1.6 Research Structure

The remainder of this document is organised as follows: Chapter 2 presents a review of the relevant literature, exploring the relationship between energy consumption and solar PV penetration, its influence on the economy, and how it affects utilities. The chapter introduces the concept of grid parity and explains how PV penetration onto the grid may affect the operation of utilities, and tentatively builds an argument using relevant research questions that are summarised in chapter 3. Chapter 4 details and describes the proposed research methodology, taking into consideration methodology choice, population, sample method and size, unit of analysis, data gathering process and finally the limitations of the study, while chapter 5 presents the research findings that emerge from the study. Chapter 6 details the findings by presenting an in-depth discussion of the results. Finally, chapter 7 draws attention to the main conclusions of the study, the contributions these findings will make to literature, and their implications for business management. The chapter also looks at the limitations of this study, and provides recommendations for future research.

Chapter 2: Literature Review

2.1 Introduction

Inefficient use of energy leads to global warming and climate change, and also negatively affects the growth of a country's GDP (Menegaki, 2014). Previously conventional fossil fuel plants were sufficient to meet electricity demands, however as a result of climate change implications and environmental concerns, this method of electricity generation is being questioned (Obi & Bass, 2016) and countries across the world have begun to incorporate renewable energy sources onto the grid (Loomis, Jo, & Aldeman, 2016). Now, with more innovation within the PV market and lowering costs of the technology, a surge in captive solar technology (rooftop PV) is expected. PV technologies are considered to be of high potential because the sun provides "10 000 times the planets energy demand" daily (Hurtado Munoz, Huijben, Verhees, & Verbong, 2014, p.179). However, uncontrolled penetration of solar onto the grid or "surges in rooftop solar installations could lead to disruptive competition for electrical utilities" (Graffy & Kihm, 2014, p.1), resulting in the "death" of traditional utilities.

The scope of this literature review covers the relevant literature regarding solar PV penetration. The study includes discussions on: (1) the different types of power supply networks; (2) drivers affecting economic growth such as job creation and carbon emissions, and their impact on the economy, environment and society; (3) the concept of grid parity; and (4) the need to identify a penetration level (an ideal mix of solar and conventional grid power as part of the power supply network).

Additionally, this study looks at three frameworks that will be used as a basis to analyse and discuss the results of the study. It also explores existing papers that have studied the potential impact (both economic and environmental) of the seamless integration of solar onto the grid, and finally, concludes with an explanation on why there is a need to identify an ideal level of solar penetration onto the grid.

2.2 Types of Power Supply Networks

The "primary focus within the electricity industry is on what value a particular technology brings to a power system (Bazilian, et al., 2013). This usually depends on the nature of demand, the network, and the mix of existing power generation methods and their operating rules" (p.70). The level of penetration of captive solar PV onto the grid could be related to the type of power supply network configuration an area or country has in place. Three network configurations may be used to supply power to consumers. The following subsections define and discuss the three main types of network systems that may be used and/or are being used to generate power to meet electricity demands.

2.2.1 Full-grid

"Electric utilities connected by regional, centralised transmission systems emerged in the early 1900s as a governance innovation that could best meet the public policy goal of providing low cost, reliable power to communities nationwide" (Graffy & Kihm, 2014, p.14). An electrical grid or full-grid is an interconnected network for delivering electricity from suppliers to consumers through transmission and distribution lines.

According to studies, such as the one conducted by Graffy & Kihm (2014), such monopolies enjoy periods of low risk during times of stability, but face high risk with the emergence of disruptive technology. However, since the onset of the electricity crisis in 2008, South Africa's only electrical utility, has been under pressure to meet the country's electricity demands. The cost of building new conventional power stations and the operation and maintenance costs of the existing ones are increasing, placing a strain on the economy (Kumar, Sharma, & Tewari, 2014). This suggests that a possible integration or penetration of other forms of power generation onto the grid could be beneficial in situations such as the energy crisis in South Africa.

2.2.2 Grid-tied

Grid-tied or on-grid networks refer to solar powered systems that are connected to the utility power grid (Singh, et al., 2016). These systems operate in parallel with the electric utility grid. Grid-tied systems require no storage systems because they use solar during the day to generate power, and rely on electric grid power at night (Obi & Bass, 2016). According to Bazilian et al. (2013), such PV systems have now been in use as grid-tied systems for over 20 years.

Grid-tied or grid connected photovoltaic (GCPV) networks can be found in different scales, i.e. small scale, medium scale and utility scale. Medium scale configurations range from 10 kW to 1 MW. Smaller plants under the category of medium scale networks can produce up to 100 kW of power, and are connected to the secondary line (120/240V), while larger plants have the same connection as utility scale GCPV systems. Finally, small scale networks with capacities up to 10 kW are usually installed at the residences of customers, who normally own the PV system (Mirhassani, Ong Chyuan, Chong, & Leong, 2015).

According to Obi & Bass (2016) and (Singh, et al., 2016), on-grid systems are advantageous since they are able to supply power back to the grid when excess electricity is produced, i.e. when the power that is generated by the PV system is greater than the local load demand. This enables consumers to save money as a result of better efficiency rates, net metering, and lower equipment and installation costs. Grid-tied systems also offset greenhouse gas emissions by displacing the needed load by the connected local load by providing additional “clean” electricity to the grid (Obi & Bass, 2016).

In South Africa reverse feeding is not allowed, as the national utility and the South African municipalities are concerned that reverse feeding may compromise the safety of maintenance staff when the grid has been switched off on purpose (Fritz, 2013). Electricity cannot be sold to the national grid, but there are many customers who are connecting grid-tied systems to the national grid illegally.

However, with electricity tariffs increasing, it makes sense for policies to be streamlined and reverse feedback to be promoted, as more and more people are moving into roof-top solar power. Finding an ideal penetration level will ensure that the utility does not have to worry about over feeding into the grid, and at the same time the customers will not have to pay exorbitant amounts for power due to the electric utility failing to meet demand.

2.2.3 Off-grid

Off-grid systems are power supply networks that are completely isolated from the electrical utility, and are an alternative to a grid-tied system (Singh, et al., 2016). Such systems comprise of a solar panel which is used to convert sunlight into useful electrical energy, a battery to store energy during low or zero solar resource availability, a charge controller that regulates the charging and discharging of the battery, and some load (Chowdhury & Mourshed, 2016).

According to Rose, Stoner & Perez-Arriaga (2016), the advantages of going completely off the grid include that:

- solar PV installations have short construction times, enabling smaller scale investments to be made continuously, thereby providing a hedge for system planners against load growth uncertainty and helping to lower investment risk;
- PV plants can be built close to load centres, which will eliminate the need for costly investments in transmission infrastructure associated with distant mine-head or coastal fossil fuelled plants; and
- PV would also tend to displace more expensive diesel generation and reduce total production costs.

Unfortunately, off-grid systems are more expensive to implement than grid-tied systems, as they require a means of energy storage. A study by Obi & Bass (2016) which compared the cost of a 7 kW off-grid system and 5.5 kW grid-tied system that were implemented to meet a demand of 5 kWh found that the initial cost of implementation of the off–grid system was US$ 23,601, while that of a grid-tied system amounted to US$ 13,253. When looking at the estimated cost of generation, the off-grid system amounted to US$ 0.13/kWh, while the grid tied-system amounted to US$ 0.08/kWh. Further, the maximum PV power generated for the off-grid system was 6.61 kW for an installed capacity of 7 kW, and the maximum PV generation for the grid-tied system was 5.13 kW for an installed capacity of 5 kW.

The study found that it is 1.8 times more expensive to implement an off-grid system to supply the same amount of energy as a grid-tied system. Additionally, off-grid systems require battery storage and a backup generator to ensure that there is access to electricity at all times. Unfortunately, battery banks are complicated, expensive, decrease overall system efficiency, and typically need to be replaced after 10 years (Singh, et al., 2016). This continuous replacement of the batteries over time implies that there will be constant capital investment in order to maintain such a system. For this reason, it is more feasible to have a grid-tied network rather than a system that is fully off the grid, at least until batteries become more efficient and have longer life cycles. This suggests that the seamless integration of captive solar PV technology and the move onto fully off-grid systems are merely limited by the price and efficiency of technologies that are coming down and constantly being improved upon.

2.3 Solar Energy

Conventional power plants or traditional utilities suffer from fuel scarcity, unavailability of sites, and other environmental concerns. Alternative technologies, especially solar PV technologies, are being used to overcome these problems, however. The sun is the only source of energy for earth, and every living organism, from plants to animals, thrive on this source. The sun produces 885 million TWh of solar energy, which adds up to over 6,200 times the energy demand for the entire population of the world (Bijarniya & Barendar, 2016). The mere fact that the sun's energy can cover over 6,000 times the world's energy demand means that with cost effective technology, electricity can be generated and sold at very cheap rates to the consumer. Furthermore, solar energy, if harnessed properly and efficiently, will do away with carbon emitting forms of power generation, reducing carbon taxes and other carbon emissions related penalties.

Solar power can either be in the form of concentrating solar power or captive solar power. The differences, advantages and disadvantages of the two types are discussed in the sub-sections that follow.

2.3.1 Utility-scale solar PV

Concentrating solar power (CSP) is a large-scale commercial way to generate electricity using solar energy. These technologies make use of concentrated solar radiation from the sun as a high temperature energy source to produce electrical power (Purohit, Purohit, & Shekar, 2013). CSP technologies are usually used by independent power producers (IPPs), which are private entities that use their own facilities to generate electrical power for sale to utilities and end users to generate electricity using solar energy on a large scale.

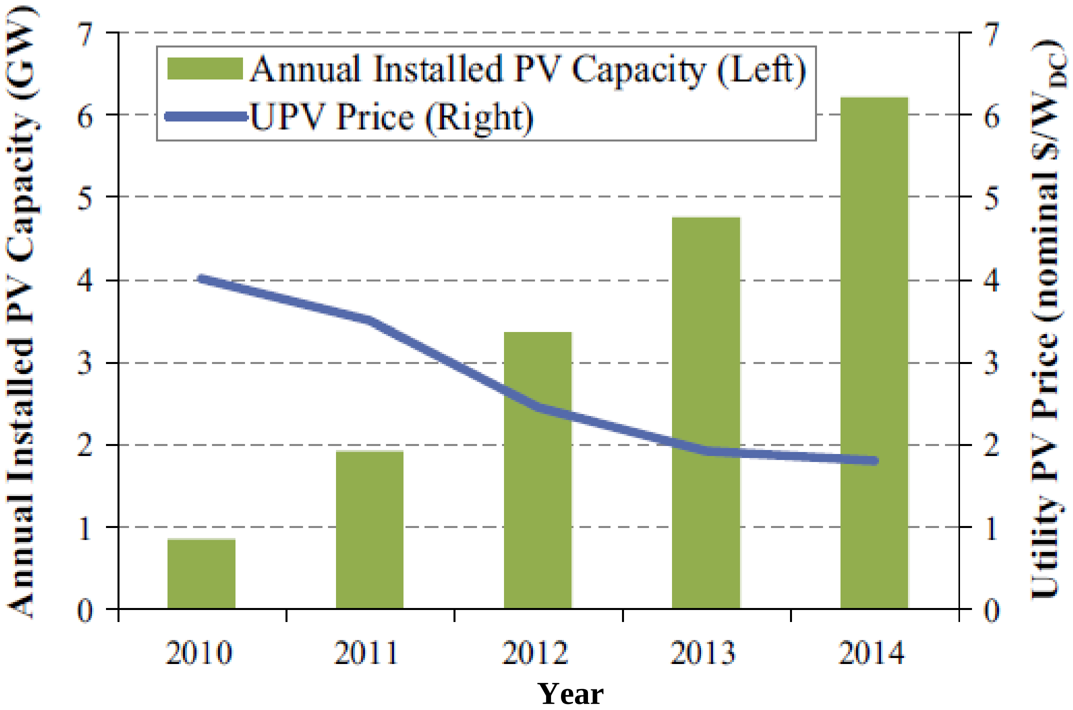
Unfortunately, CSP technologies are not as flexible as solar PV (roof-top, building integrated) as they require an area that has high levels of solar radiation. These technologies can only be implemented in areas where the threat of rehabilitation and resettlement issues are minimal. Furthermore, the generation of power through CSPs require a substantial amount of water for cooling compared to captive solar PV technologies (Purohit, Purohit, & Shekar, 2013). Moreover, the fact that CSPs require hectares of land for the installation of solar collectors limits the technology to large scale energy producers, such as IPPs. Thus, the requirements associated with CSPs could potentially limit the level of penetration of solar PV onto the grid. On the other hand, if the utility finds such production feasible, they themselves could allow for more solar to penetrate the grid.

2.3.2 Rooftop solar PV

The main attraction of solar PV systems are that they produce electric power without harming the environment (Singh G. , 2013)The main components of rooftop solar PV system are modules, inverters, support structures, and battery back-ups in some cases (Sooriyaarachchi, Tsai, Khatib, & Farid, 2015). These systems generate electric power, and can either be connected to the network (grid-connected) or not (off-grid) (Noberto, Gonzalez-Brambila, & Matsumoto, 2016).

There has been remarkable growth in residential PV systems around the world, as a result of the decrease in solar PV technology costs. Installed prices declined more than 50% between 2010 and 2014, and installations in 2014 reached a massive 2.2 GW (Cole, Haley, Sigrin, & Margolis, 2016).
Figure 2 illustrates the increase in solar PV installations with the decrease in price of the technology.

Figure 2: Annual installed rooftop PV capacity and utility PV (IPP) price



Source: Cole, Haley, Sigrin & Margolis (2016)

These falling prices, together with subsidies and other incentives offered by central and state authorities, are motivating the adoption of several smart grid pilots, consequently promoting the growth in rooftop solar (Kappagantu, Danel, & Venkatesh, 2015). As per Figure 2, as the installed PV capacity increases, the price of the power produced per watt by this technology decreases. This can be related to the theory of demand and supply (Parkin, 2014), i.e. as demand for PV increases, supply costs (utility PV price) decrease. The expansion of renewable technologies such as captive solar PV is considered positive and a potential pathway for business opportunities and economic growth (Graffy & Kihm , 2014). This was further reiterated by (Azimoh, Klintenberg, Wallin, Karlsson, & Mbohwa, 2015), who stated that "there is a close link between energy access and economic development" (p.268).

Although both IPP and rooftop PV rely on the sun as their primary source of energy, there are a number of differences between the two technologies, as per Table 1.

Table 1: Differences between utility-scale solar (CSP) and rooftop PV

Utility PV (IPP)	Rooftop PV
One-axis tracking	Rooftop is fixed tilt
Optimally situated	Available roof space
Transmission and distribution required	Built next to load centre

Source: (Kappagantu, Danel, & Venkatesh, 2015)

The sheer size of IPP plants (CSP), poses a threat to the utility. However, as seen in studies by Graffy & Kihm (2014) and Azimoh, Klintenberg, Wallin, Karlsson & Mbohwa (2015), the decreasing prices of solar technology could also see an increased penetration of rooftop PV onto the grid as well. Furthermore, as captive solar PV is more easily accessible to anyone who can afford it, this could also potentially manifest as a reason for more penetration of solar onto the grid.

2.4 Economic Impact

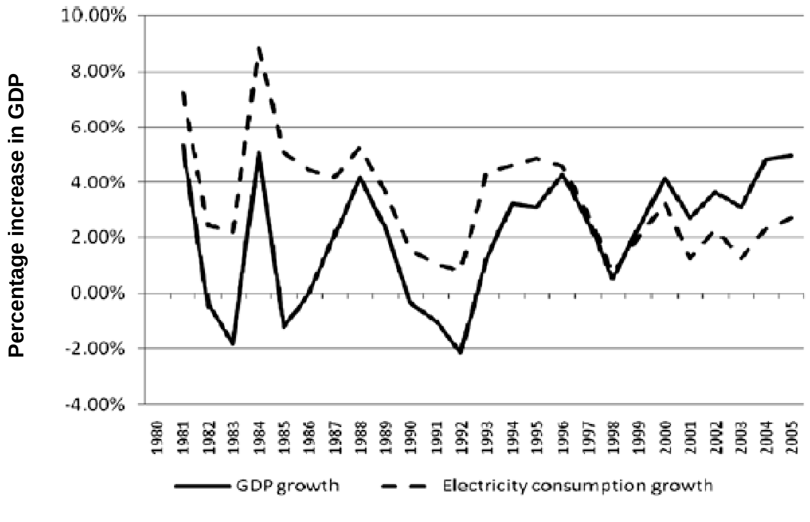
Improved energy efficiency can reduce total energy consumption and emissions of greenhouse gases (GHGs) such as CO_2 while ensuring economic growth (Dai, Xie, Xie, & Liu, 2016). Furthermore, the South African government has recognised that energy is an "important catalyst for economic growth" (Pollet, Staffell, & Adamson, 2015, p.16688). The subsections that follow look at the impact of the relationship between energy consumption and carbon emissions on economic growth, as well as the potential for job creation as a result of increasing solar energy technology and its effects on the GDP.

2.4.1 Relationship between energy consumption and economic growth

A study by Caraiani, Lungu & Dascalu (2015) showed that there is a bi-directional causality relationship between energy consumption and economic growth, i.e. economic growth, FDI, and population growth have a positive impact on electricity consumption, but at the same time, electricity consumption has a positive impact on economic growth, energy consumption and FDI. FDI is a important source of capital that is increasingly contributing to export activities, trasferring technologies and the creation of job opportunities in developing countries (Tang & Tan, 2014). Furthermore, electricity consumption and economic growth have a positive relationship with CO_2 emissions, and the long run coefficient of CO_2 emissions to economic growth can be up to 0.40. This means that a 1% increase in real GDP per capita causes a 0.40% increase in CO_2 emissions (Salahuddin, Gow, & Ozturk, 2015).

Figure 3 illustrates the relationship between economic growth and electricity consumption growth.

Figure 3: Economic growth and electricity consumption growth in South Africa



Source: Inglesi (2010)

The economic value of adding solar PV is based on changes to the total annual production costs, including operating and annual fixed costs. The annual savings from added solar PV in each scenario is the difference in the total system production cost with respect to the base case with no PV in each tested year (Rose, Stoner, & Perez-Arriaga, 2016). Since positive energy consumption relates to a positive GDP, if the costs of PV technology can be mitigated, it could possibly become a better, cheaper, cleaner and more reliable way to produce energy on a large scale, thereby improving GDP.

2.4.2 Job creation and savings

There are different units of measurement to identify job creation potential, such as jobs/MW, man-years/MW, job-year/MW, jobs/year/$ Million, and person-years/$ Million, of which jobs/MW and person-year/MW are the most common (Sooriyaarachchi, Tsai, Khatib, & Farid, 2015). A study by Loomis, Jo & Aldeman (2016) mentioned that a project underway in Colorado, USA, aimed at installing 2,750 MW of roof-top solar PV from the remainder of 2013 through to the end of the year 2030, would result in almost 32,500 job years, US$ 1.9 billion in employee earnings, and over US$ 3.85 billion in total output. Job opportunities created in the PV value chain include direct ones such as the manufacturing of PV modules, inverters, racking equipment, and on roof or on ground installers, while indirect jobs include raw material suppliers (glass, steel bars etc.), electricity production equipment, electrical devices and public officers for administration and taxation. Additionally, the installation of PV systems can create jobs, for example the installation of rooftop PV systems would create work for roofers, sheet-metal workers and electricians (Sooriyaarachchi, Tsai, Khatib, & Farid, 2015).

As seen in a study by Darghouth, Barbose & Wiser (2014), in addition to creating jobs, solar penetration is beneficial to consumers as it decreases their electricity bills. Furthermore “with high solar penetration, the value of bill savings from net-metered PV may be greater under flat rates than under time-varying rates” (Darghouth, Barbose, & Wiser, 2014, p.298). In electricity systems with peak loads in winter months during evening hours, for example, “it can be anticipated that time of use (TOU) and real time pricing (RTP) rates would lead to a decline in the value of bill savings relative to the flat rate even in low solar penetration scenarios” (Darghouth, Barbose, & Wiser, 2014, p. 298).

Additionally, Loomis, Jo & Aldeman (2016) mentioned that solar PV deployment in Colorado has created jobs that have earned employees over US$ 534.1 million and produced a total economic output of US$ 1.42 billion. Similarly, the study found that there will be 179,600 to 222,000 jobs created by 2020 in Turkey, while in Morocco, the economic impact on GDP is said to increase by 1.21% to 1.99% by the year 2040, with an employment effect of 269,252 to 499,000 job years (Loomis, Jo, & Aldeman, 2016). Therefore, captive solar technology clearly has an economic impact in terms of job creation and savings.

2.4.3 Carbon emissions

Energy generation contributes to more than 60% of GHG emissions (Schinko & Komendantova, 2016). Increasing the use of fossil fuels to meet the growing worldwide electricity demand, especially in developing countries, not only counteracts the need to prevent climate change globally, but also has negative environmental effects locally (Hossain Mondal & Islam, 2012). This implies that the major driver for the increase in solar PV technology is the ecological limit of the planet. GHG emissions have been identified as a major threat “for the collapse of globalised human civilization in this century” (p. 610), which has steadily increased over the past decade (Breyer, Koskinen, & Blechinger, 2015).

Carbon Capturing and Sequestration (CCS) technologies, which are used to try to mitigate the amount of carbon released into the atmosphere, have not proven economically viable so far in reducing or eliminating CO_2 emissions from fossil-fired electricity generation. CCS costs are not only high, but there is also a penalty in energy production of 25–40% when a CCS is installed on coal plants. Moreover, carbon storage on vast scales carry environmental risks (Sener & Fthenakis, 2014).

According to Saidi & Hammami (2014), energy consumption, and consequently CO_2 emissions, have a negative impact on the economic growth of a country. Their study stated that for a 1% increase in pollutant emissions, economic growth decreases by 0.04%. This implies that integrating solar onto the grid will have a positive influence on the economy and the environment as a result of a decrease in carbon emissions. To illustrate this impact, Table 2 shows the potential of solar PV in terms of costs per ton of GHGs avoided.

Table 2: Solar PV CO2 eq. substitute prices

Country	Tp [€/kWh]	ACO_2 [kg CO_{2eq}/kWh]	$AACO_2$ [kg CO_{2eq}/kWh]	SPAC [€/tCO_{2eq}]
South Africa	0.350	0.949	0.917	283
Thailand	0.217	0.544	0.512	314
Argentina	0.110	0.277	0.245	333
Vermont (US)	0.300	0.630	0.598	372
Peninsular Malaysia	0.370	0.593	0.561	489
Germany	0.388	0.553	0.521	552
Greece	0.64	0.749	0.717	661
Japan	0.520	0.505	0.473	814
Victoria (Australia)	0.800	0.752	0.720	823
Ecuador	0.400	0.217	0.185	1602
Ontario (Canada)	0.780	0.220	0.188	3073
France	0.626	0.120	0.088	5269

Source: Breyer, Koskinen & Blechinger (2015)

In this table, the solar PV life-cycle emissions are assumed at level of 32g CO_2 /kWh, where Tp is tariff price, ACO_2 is the average CO_2 equivalent emission for 1 kWh of generated electricity, $AACO_2$ is the average CO_2 emission avoidance, and SPAC is the substitute price of avoiding CO_2 emission. As per Table 2, it is evident that South Africa produces the highest amount of CO_2 per kWh of energy generated, and is paid the lowest for avoiding carbon emissions. From a South African context, this is an indication that the development of solar PV and generation of electricity using “cleaner” methods will have a positive impact on the economy.

2.5 Frameworks

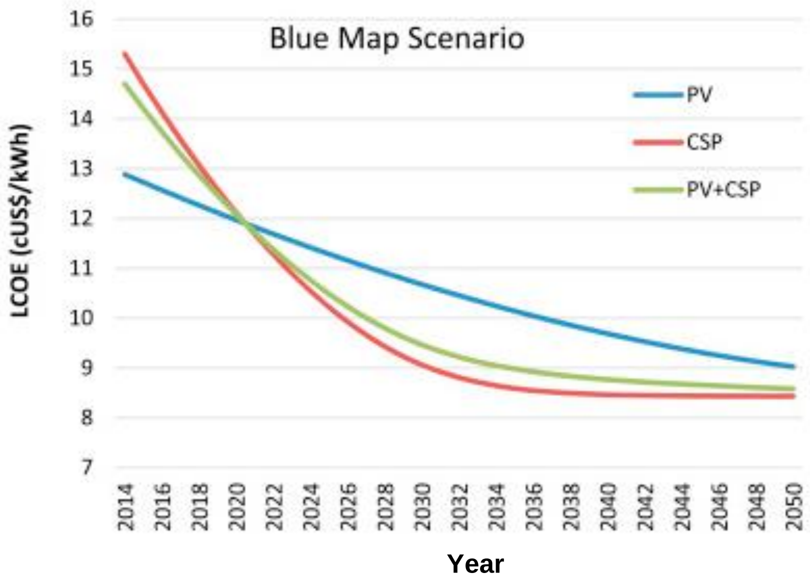
The frameworks that will be discussed in the subsections that follow include the Levelized Cost of Electricity (LCOE), the United Nations Framework on Climate Change in relation to the Kyoto Protocol, and finally, demand and supply. These are tools that can be used to analyse the results gathered with respect to the economic impacts of captive solar PV technology.

2.5.1 Levelized Cost of Electricity

The LCOE is a framework that is used to determine the economic viability of the solar PV systems. From an economic point of view, the smallest LCOE is desired, because a low LCOE means that electricity is being produced at a low cost, likely with higher returns (Mirhassani, Ong Chyuan, Chong, & Leong, 2015). The LCOE is equal to the sum of all the costs incurred during the lifetime of the project divided by the units of energy produced during its lifetime (Parrado, Girard, Simon, & Fuentealba, 2016).

Figure 4 predicts the cost of producing electricity for PV, CSP, and a combination of PV-CSP technologies until 2050.

Figure 4: LCOE projection between 2014 and 2050 for PV, CSP and PV-CSP



Source: Parrado, Girard, Simon & Fuentealba (2016)

The blue map scenario refers to a model whereby PV and CSP systems would provide 6% of the world's annual electricity production by 2050 (Parrado, Girard, Simon, & Fuentealba, 2016). In terms of penetration level, this could imply that more integration from PV could bring down the price of electricity to a point where it is competitive with traditional utility prices. This LCOE framework could potentially help utilities identify what exactly the economic impact of the solar PV integration onto the grid will be.

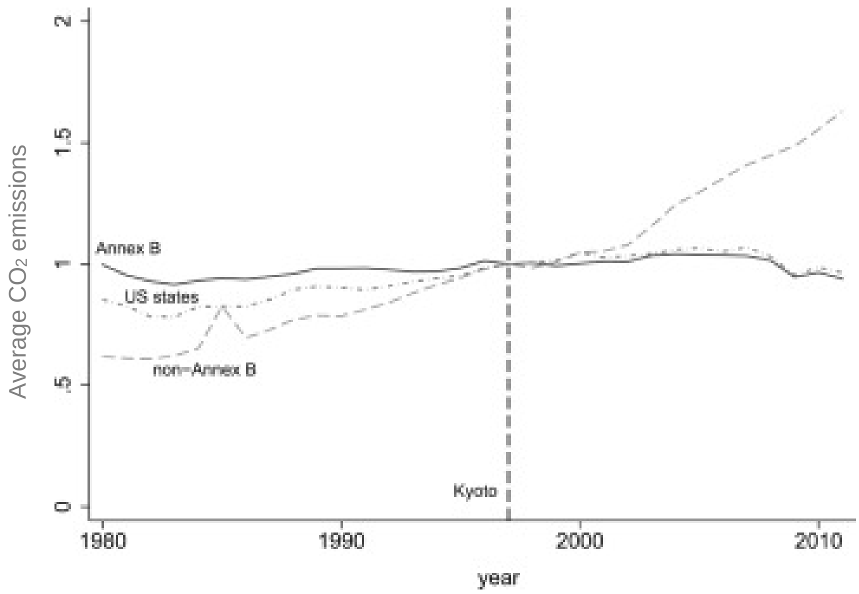
2.5.2 United Nations Framework on Climate Change and Kyoto Protocol

According to Zakkour, Scowcroft & Heidug (2014), the United Nations Framework Convention on Climate Change (UNFCCC) provides an "important source of financing and technological learning to support uptake of CO_2 capture" (p.6945). This Framework is an international agreement aimed at preventing pollutant interference in the atmosphere (Zakkour et al., 2014). Fossil fuel consumption and greenhouse gas emissions are direct indicators of climate change (Chen, Cheng, Song, & Wu, 2016). There are 194 states that are part of the UNFCC, which differ in terms of their energy consumption and economic development. The objective of this Framework is for these 194 states to establish policies and measures to reduce the emission of greenhouse gases (Chen et al., 2016; Zakkour et al., 2014).

The UNFCCC is enhanced by the Kyoto Protocol, which was established in 1997 and became effective from 2005. The Kyoto Protocol applies to what are referred to as countries that were industrialised by the 1990s. Countries such as South Africa that were not industrialised by the 1990s do not have any binding GHG targets, and as a consequence may not feel the need to limit or mitigate carbon emissions (Almer & Winkler, 2017). Yet, as shown in studies such as the one by Azimoh, Klintenberg, Wallin, Karlsson & Mbohwa (2015), there is a relationship between carbon emissions and economic growth. Further supporting this, Saidi & Hammami (2014) stated that energy consumption, and consequently CO_2 emissions, have a negative impact on the economic growth of a country. More carbon emissions will affect the economy negatively, especially if there are no stricter laws and penalties imposed, such as carbon taxes.

Figure 5 shows the average carbon emissions for Annex B countries and Non-Annex B countries. Annex B countries refer to those countries that committed to the reduction of six GHGs by 5.2% between 2008 to 2012, compared to the 1990 levels. Non-Annex B countries refer to all the countries that have not committed to this regulation.

Figure 5: Average CO_2 emission for Annex B countries and non-annex B countries



Source: Almer & Winkler (2017)

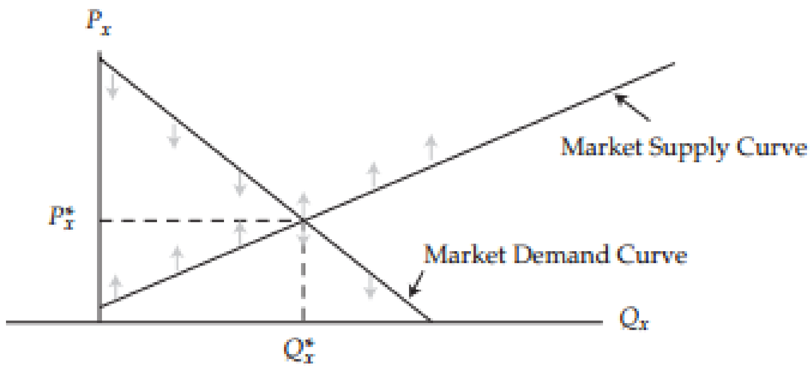
Transferring low carbon technologies to developing countries could have developmental benefits such as contributing towards economic growth and job creation. The UNFCCC approach looks at the appropriate conditions for the uptake and deployment of these technologies (Boyd, 2012). Furthermore, Zakkour et al. (2014) stated that the UNFCCC can be an important catalyst for “supporting project investments, capacity building and technology transfer” (p.6956). Adhering to the Kyoto Protocol under the UNFCCC framework can limit GHG emissions and carbon taxes, and thus be beneficial for the economy. If such frameworks and policies are to be reinforced more strictly, it may be necessary for traditional utilities to allow more penetration onto the grid.

2.5.3 Demand and supply

The analysis of demand and supply indicates how buyers and sellers interact to determine transaction prices and quantities. Demand in economics is the willingness and ability of consumers to purchase a given amount of goods and services for a given price, and supply is defined as the willingness of sellers to offer a good or service for a given price (Outcomes, 2011).

According to the law of demand, as the price of a good rises, buyers will buy less of it, but if the price decreases, buyers will buy more. However, at the same time, the law of supply says that the willingness to supply depends on the price at which goods can be sold, as well as the costs for production of an additional unit (Outcomes, 2011). This implies that the willingness to supply is dependent on both the price of the producer's output as well as the inputs to produce it.

Figure 6: Demand and supply curve



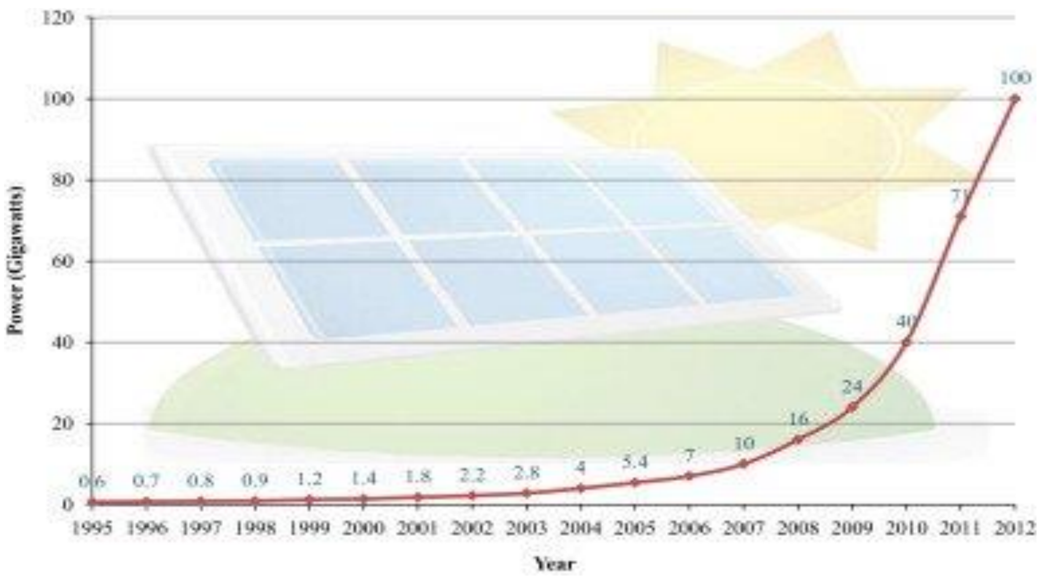
Source: Outcomes (2011)

From the above, it can be seen that buyers will buy at any price below the demand curve, and suppliers are willing to accept any price above the supply curve; people will not buy goods or services if prices asked by the suppliers go above point Q^*_x.

2.6 The Need for an Ideal Penetration Level

Solar penetration refers to the increase in power generated by solar energy connected/integrated onto the grid (Lin, Hseih, Chen, Hsu, & Ku, 2012). The rapid development of solar PV technology over the past few years has made this viable, even for small scale power generation in the distribution system, thus solar PV penetration levels increased from 10 GW in 2007 to 40 GW in 2010 (Karimi, Mokhlis, Naidu, Uddin, & Bakar, 2016). Figure 7 is an illustration of the growth curve of the solar PV market around the world from 1995 to 2012.

Figure 7: Generation power of PV market around the world



Source: Karimi, Mokhlis, Naidu, Uddin & Bakar (2016)

Primary energy sources including oil, coal and gas are anticipated to be depleted in the next 40–50 years, while conventional electric power systems, being dependent on large base-load power plants, have limited ability to sweep output power level (Zafar, Zafar, Zafar, & Gibson Andrew, 2016). Furthermore, Hurtado Munoz, Huijben, Verhees & Verbong (2014) stated that at the current growth rate of energy consumption and technology innovation, the world's capacity for meeting the energy needs of the future is insufficient. The cost of renewable energy has also dramatically declined over the years, thus making them competitive compared to non-renewable energy sources such as fossil fuel generated power (Karimi, Mokhlis, Naidu, Uddin, & Bakar, 2016).

The deployment of GCPV may bring many benefits to the grid, such as alleviation of peak load periods, voltage support, frequency support, fault ride through, and even the postponement of investments for grid expansion (Manito, Pinto, & Zilles, 2016). In addition, the prices of fossil fuel, CO_2 emissions, global warming and energy sources depletion are further reason for a transition to a more sustainable energy source (Hurtado Munoz, Huijben, Verhees, & Verbong, 2014).
Moreover, as stated by Strydom (2015), "energy security is a major contributing factor to achieving economic growth and stability" (p.8). According to Creti & Fabra (Strydom, 2015), security of supply means the readiness of existing capacity to meet the actual

load. Jamasb & Pollitt (as cited in Strydom, 2015) added that supply security is often discussed in terms of the availability of energy sources and their commodity price risks. Strydom (2015) continued that systems with lower risks of system interruptions are more secure. This implies that finding an ideal level of penetration will ensure that there is a constant and uninterrupted supply of electricity to the consumer.

Furthermore, there is positive relationship between energy use and CO_2 production; that is, more energy is used as a GDP grows, or, as a GDP grows, more energy is consumed. CO_2 emissions are also directly linked to the growth of the economy, as mentioned in a study by (Salahuddin, Gow, & Ozturk, 2015). This is enough motivation to increase solar PV penetration, because cleaner fuel can boost the growth of the economy, while cutting out carbon emissions and consequently carbon tax.

Unfortunately, too much solar penetration could also have negative impact. In fact, a study by Costello & Hemphill (2014) stated that the entry of new Distributed Generation (DG), like rooftop solar PV systems, will increasingly erode a traditional utility's retail sales over time. The paper went on to say that "once losing sales to DG, utilities will try to recover lost revenues by increasing their rates to a fewer number of customers. This attempt to regain lost profits will aggravate the problem of yet more customers leaving the utility system for DG" (Costello & Hemphill, 2014, p.8). This means that over penetration, or uncontrolled penetration of solar PV, will affect those who cannot afford to move off the conventional grid system, as they will be beset with heavier tariffs.

Another aspect to investigate is the impact of the "death of utilities" (Graffy & Kihm, 2014, p.2) on the economy. As explained above, too much penetration of solar PV may cause utilities to become obsolete as a result of competition. In addition, too much penetration could also cause harm to the utilities' equipment as a result of too much feed-in onto the grid. Since utilities are a major contributor to a country's GDP, especially a country like South Africa where there is only one major electricity supplier (Minnaar, 2016), the economy can be impacted negatively if this occurs.

This implies that there is a need, from an economic point of view, to ensure that the penetration of solar PV is such that the economy is not harmed in any way. This could be done by ensuring that the drivers promoting the need for solar PV penetration are identified and worked on such that it is beneficial to both the traditional utility and the consumer.

2.7 Drivers for an Ideal Penetration Level

According to Karimi, Mokhlis, Naidu, Uddin & Bakar (2016), the penetration of solar PV impacts utilities, so there is a need to address its seamless penetration onto the grid. The following subsections discuss the possible drivers that motivate a need to find an ideal penetration level of solar onto the grid, such as the possible impacts of solar PV penetration on the utility; the finances involved with the integration of captive solar PV onto the grid, the influences on current business models; and the effects of net metering and feed-in tariffs.

2.7.1 Impact on a utility

The integration of Renewable Energy Sources (RESs) in power system networks will cause some problems. For instance, some types of RESs such as solar PV can cause an oscillation in the power system's voltage and frequency, and an increasing penetration of solar PV at the distribution level applies more stress on utility voltage regulation devices, even causing them to malfunction. The major impacts of solar PV integration include voltage variations and unbalance, current and voltage harmonics, grid islanding protection, and other power quality issues such as flickering and stress on distribution transformers (Karimi, Mokhlis, Naidu, Uddin, & Bakar, 2016).

On the other hand, Manito, Pinto & Zilles (2016) showed that penetration of solar onto grid avoids excessive aging of the distribution transformer in situations of overload, which may even result in long term savings and improvements in power supply, due to reduced wear and number of failures. However, their paper also mentioned that "in some situations, the wide penetration of the PV generation could present a problem to the distribution system's assets" (p.700). Further studies, such as the one by Graffy & Kihm (2014) which explored the impact of rooftop solar systems on electrical utilities, stated that *"characterisation of renewable energy innovations, such as rooftop solar, is a 'mortal threat' or 'radical threat' to utilities"* (p.6). As mentioned in the research problem, as more solar power is utilised, less power will be required from existing utilities due to a point of so-called "grid parity (Blumsack, 2015).
Impact or damage to utility components results in a loss of revenue to a government-owned utility, which demotivates the utility from promoting solar power. Additionally, utilities are aware that the amount of power that they can sell will decrease with

increasing solar power penetration, thus they will not be able to sustain themselves (Graffy & Kihm , 2014).

2.7.2 Financial impact

“Regulators and policy makers are increasingly concerned about the negative financial impacts of customer-sited solar PV on utilities and rate payers as PV deployments rapidly accelerate” (Satchwell, Andrew, & Barbose, 2015, p.115). According to Satchwell et al., utility sales are closely tied to volume of sales and capital investments. Now, however, advancements in technology and public policies which drive the growth of alternative sources are reducing sales and opportunities for capital investments.

An increase in electricity generation by private individuals decreases the demand for electricity from utilities, and consequently leads to an erosion in their revenues. However, according to interviews conducted with German utility managers, it has been found that they do not see PV distribution as a threat to the utilities. This contradicts recent studies such as those by Graffy & Kihm (2014) and Blumsack (2015), and raises the question of whether researchers are overestimating the importance of solar PV, or whether utilities are underestimating the threat to their business models. Instead of treating solar PV penetration as a threat, utilities could benefit greatly if they see solar PV as a strategic gateway into the emerging DG and service market (Richter, 2013).

Janko, Arnold & Johnson (2016) studied the effect of different penetration levels on the net system load. The simulation results of the test showed PV penetration levels differ by location and season. The study also showed that an increase in solar PV penetration increases the utility ramp rate requirements. This is as seen in Table 3.

Table 3: Loss in utility revenue versus increasing solar PV penetration levels

Location	On-peak price ($/kW h)	Utility revenue [$ 000,000/yr] (change relative to reference case of 0% solar [%])					
		0%	20%	40%	60%	80%	100%
Chicago	0.16	13.4 (−)	11.9 (−12%)	10.3 (−23%)	8.8 (−35%)	7.3 (−46%)	5.9 (−56%)
	0.24	14.1 (−)	12.4 (−12%)	10.7 (−24%)	9.0 (−37%)	7.3 (−48%)	5.9 (−58%)
	0.32	14.8 (−)	12.9 (−13%)	11.0 (−26%)	9.2 (−38%)	7.4 (−50%)	5.9 (−60%)
Phoenix	0.16	21.2 (−)	17.5 (−17%)	13.8 (−35%)	10.1 (−52%)	7.1 (−66%)	4.9 (−77%)
	0.24	23.1 (−)	19.0 (−18%)	14.9 (−36%)	10.9 (−53%)	7.4 (−68%)	5.0 (−78%)
	0.32	25.1 (−)	20.6 (−18%)	16.1 (−36%)	11.6 (−54%)	7.7 (−69%)	5.0 (−80%)
Seattle	0.16	12.2 (−)	11.4 (−6%)	10.6 (−13%)	9.8 (−19%)	9.1 (−25%)	8.3 (−32%)
	0.24	12.6 (−)	11.7 (−7%)	10.9 (−14%)	10.0 (−20%)	9.2 (−27%)	8.3 (−34%)
	0.32	13.1 (−)	12.1 (−7%)	11.2 (−15%)	10.2 (−22%)	9.3 (−29%)	8.3 (−36%)

Source: Janko, Arnold & Johnson (2016)

The figures provided in Table 3 show that with increasing penetration of captive solar PV, revenues lost by the utilities increase almost exponentially. In the South African context, this could affect the utility drastically, as the country has only a single electricity supplier, which is the national utility. If penetration is not controlled in South Africa it could affect the utility negatively, and may even lead to its obsoleting.

2.7.3 Business models

The business model concept is a useful way for researchers to analyse and compare companies and markets in a structured way. This tool can help managers to design, implement, operate, change, and control their business.

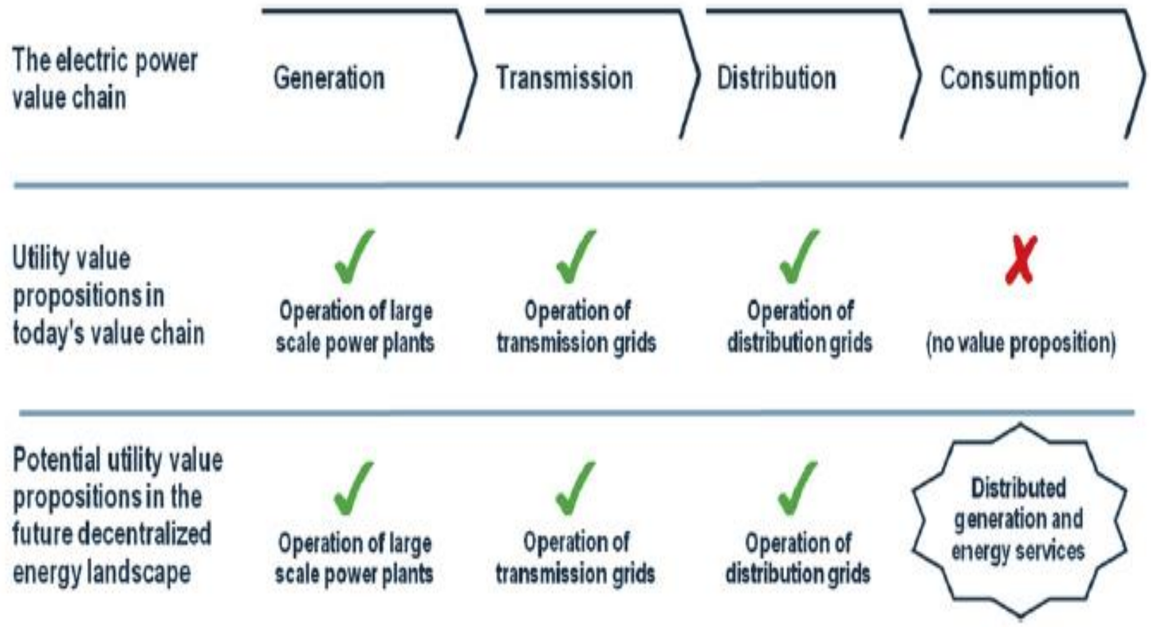
A business model is based on four elements (Richter, 2013):

- Value proposition
- Customer interface
- Infrastructure
- Revenue model

As more and more people move towards solar PV as a source of energy generation, revising businesses models could be one way for utilities to avoid becoming obsolete and adapting to the challenges posed by the energy transition. In fact, "the theory of organisational ambidexterity claims that organisations are successful in the long term if they are able both to exploit their existing capabilities and develop new competencies at the same time" (Richter, 2013, p.548).

Figure 8 illustrates the business models used currently by traditional utilities. It can be seen that the current business models do not have any value propositions in place for the integration of power generation using solar PV, rooftop etc., thus they should consider placing it into the business model.

Figure 8: Utilities' value propositions in the electric power value chain



Source: Richter (2013)

Richter (2013) also identified the barriers to business model innovation in solar PV from the utility point of view. These barriers included lack of products and services; lack of customer demand; lack of competencies; and lack of profitability. Richter (2013) found that utilities struggle to offer attractive and economically sustainable products and services in the field of distributed PV generation, which could result in more and more people moving into private PV systems, decreasing utilities' profitability. "The central question for utilities is, thus, how they can develop profitable business models for this emerging segment in order to turn the threat from increasing shares of distributed PV generation into an opportunity" (Richter, 2013). This is especially a challenge when the financial viability (based on economies of scale and long-term cost recovery of investments in physical structure) makes utilities reluctant to abandon infrastructure with decades of useful life remaining (Graffy & Kihm, 2014).

2.7.4 Feed-in tariffs and net metering

Feed-in tariffs (FITs) and net metering are programmes that allow consumers to sell excess electricity that is generated by power generating households; these mechanisms vary in how they account for and price the electricity produced and consumed by households (Yamamoto, 2012). FITs provide a guaranteed premium price to the renewable energy producers (Poullikkas, 2013). Both Poullikkas (2013) and Yamamoto,(2012) stated that utilities in certain countries like Germany are obliged to purchase the excess electricity produced by household PV generators. According to Poullikkas (2013), the biggest advantage of FIT schemes is the long-term certainty of financial support, which lowers investment risks considerably.

Net metering, on the other hand, is an electricity policy which allows utility customers to offset some or all of their electricity use with "renewable energy sources for power generation" (Poullikkas, 2013, p.1). The net metering system uses a meter that can spin in both directions, i.e. the net meter spins forward when the customer is drawing power from the utility and spins backwards when the customer feeds energy back into the grid (Poullikkas, 2013). Net metering policies and FITs can be considered drivers for ideal penetration because consumers are motivated to switch to renewable sources of energy as they will get remunerated for feeding back into the grid. Although this is good, high and uncontrolled penetration onto the grid could cause disturbances in voltage and frequency that fatigue hardware and reduce equipment lifetimes. This will have an adverse effect on the utility and could result in a loss of revenues (Janko, Arnold, & Johnson, 2016).

2.7.5 Grid parity

In the debate around solar PV, the concept of 'grid parity' has emerged as the dominant benchmark for competitiveness, while some even argue that it will determine the point in time after which the PV industry will boom (Hurtado Munoz, Huijben, Verhees, & Verbong, 2014). The term can generally be defined as the moment at which the decreasing cost of electricity from a renewable energy technology due to its technological advances intersects the cost of electricity generated from conventional fuels, such as coal and natural gas. It is generally thought that, without any subsidies, a renewable energy technology will have cost-competitiveness in the market when the technology reaches the 'grid parity' point (Choi, Park, Park, & Hong, 2016).

Higher solar irradiation and technical improvements will increase the power output of the system, reducing the generation costs and thereby also bringing the grid parity point closer (Hurtado Munoz, Huijben, Verhees, & Verbong, 2014).

There are a number of conditions for reaching grid parity. A study by Fokaides & Kylili (2013) stated that manufacturing costs, the selling price of energy produced and the performance of PV systems over a range of values can be used to determine the specific conditions to reach grid parity. The paper went on to say that the main decision factor for grid parity is financial feasibility, expressed by the internal rate of return (IRR). Any project is deemed feasible from an IRR point of view if the IRR is a positive value, although this also depends on the investors' "aspirations for profit" (Fokaides & Kylili, 2013, p.226).

As solar PV manufacturing costs decrease, the point of grid parity grows closer. This implies that solar PV penetration is growing rapidly and is becoming increasingly competitive. Traditional utlites need to meet this competition head on to ensure that they do not become obsolete (Graffy & Kihm , 2014), as a result of over penetration and acceptance of captive solar PV technology.

2.7.6 Advancements in solar PV technology

The global demand for PV has increased as a result of the rapid reduction in manufacturing costs; solar PV module costs reduced by 62% between 2011 and 2013. Although batteries are not currently cost effective, there is a growing expectation that local battery storage will become so in the near future. This will motivate a high uptake of the technology, and may cause grid balancing issues (Balcombe, Dan, & Azapagic, 2015). Advancements in solar technology may therefore result in over penetration of the grid, or complete "leaving of the grid" (Khalilpour & Vassallo, 2016).

2.8 Research Gap

The research gaps within the existing literature regarding the main three themes of this study, namely economic impact, ideal penetration level, and drivers for ideal penetration, are identified and discussed in the subsections that follow.

2.8.1 Economic impact

Electricity has been the major driver for economic activity over the last century, and the solar PV industry has grown rapidly in response to "booming global demand" (Sener & Fthenakis, 2014, p.856). Further, the benefits of solar PV technology with regards to climate change cannot be denied.

Many studies back up the fact that solar PV penetration has a positive impact on the economy. These include studies by:

- Graffy & Kihm (2014), who stated that solar PV is a potential pathway for business opportunities and economic growth.
- Saidi & Hammami (2014), who stated that for a 1% increase in pollutant emissions, economic growth decreases by 0.04%.
- Loomis, Jo & Aldeman (2016), who stated that solar PV deployment in Colorado has to date created jobs that have earned employees over US$ 534.1 million and produced a total economic output of US$ 1.42 billion.

Although these studies have all suggested a positive impact on the economy as a result of the integration of solar PV technology onto the grid, there are some shortcomings. A paper by Graffy & Kihm (2014) mentioned that the excessive integration of solar power will lead to utilities becoming obsolete, adversly impacting the economy. However, the study does not state explicitly whether the positive impact on the economy outweighs the negative impact on the economy, so no conclusion can be made as to the exact impact of solar PV integration onto the grid.

In terms of CO_2 emissions, it is clear that a decrease in carbon emissions will prove beneficial for the economy, as indicated by Saidi & Hammami (2014). However, a decrease in CO_2 emissions is highly dependent on the nature of the area and the availabilty of resources to move onto cleaner energy sources such as solar PV. Most developing countries do not have the infrastructure or skills requred to set up solar PV at a fast pace, hence it is necessary to evaluate the actual impact of solar PV on carbon emissions within the South African context.

Further, a study conducted by Loomis, Jo, & Aldeman (2016) assessed the technical potential of PV integration onto the grid, as well as the number of jobs that would be created as a result of this integration. Job creation has been listed as one of the drivers for economic growth within the current study. Unfortunatlely, Loomis et al. (2016) did not investigate the potential for job creation using captive (rooftop) solar PV, but focused instead on large-scale PV integration, making it impossible to validate whether the job creation effects would be as substantial as stated in their study when implemented on a smaller scale. The framework used by the authors to study the job creation potential was the Job and Economic Developments Impace (JEDI) model. The same framework could have been used for this study if it was quantitative in nature, but it requires the outputs of one industry as the inputs into another, as well as the specific industry multipliers.

Furthermore, most of these studies were conducted in first world countries such as the USA and Germany. The studies are also primarily quantitative in nature, implying that there is room for a qualitative approach in order to determine the reasons behind how economies of developing countries like South Africa can benefit from captive solar PV integration onto the grid. This research paper will thus study and provide a more in-depth analysis of the impact of captive solar PV on the economy from a South African context.

2.8.2 Penetration level and its drivers

Numerous studies illustrate the impact of solar penetration (excessive) onto the grid. Studies by Richter (2013), Mayr, Schmid, Trollip, Zeyringer, & Schmidt (2015) and Janko, Arnold, & Johnson (2016) claimed that more solar being integrated onto a grid leads to a decreasing demand for electricity from utilies, and consequently an erosion in their revenues. In addition, grid parity has become a key indicator of competitiveness for renewable energy such as solar PV, because more penetration of solar technology could result in increasing competition to the utilities.

In the South African context, the country has a single buyer framework, i.e. a monopoly, while the power purchase programme runs independently (Minnaar, 2016).The utility's transmission planning has not been synchronised with the REIPPP programmes, and consequently "completed renewable energy projects may not be able to connect to the grid in a timely fashion" (Minnaar, 2016, p.1147). This also prompts a need to find suitable grid penetration, or the loss in revenues as a result of excessive or unseamed penetration of solar PV will lead to a utility "death spiral" (Graffy & Kihm , 2014).

The plethora of information on penetration levels provides details on both the negative and positive impacts on an economy and its utilities. These studies, however, provide little to no information on whether it is possible to find an ideal penetration level that could be beneficial to the both the existing utility and the economy, nor do they look at the possible drivers that can help identify an ideal penetration level.

2.9 Conclusion

The recent and rapid decline in solar PV prices has brought about grid parity or near grid parity for solar PV. This, together with an expectation of a similar reduction in battery prices, has prompted a new wave of social and academic discussions about the possibility of installing solar PV–battery systems and "leaving the grid" or "living off-grid" (Khalilpour & Vassallo, 2016). Renewable energy such as solar PV is deemed positive and a potential pathway for business opportunities and growth (Graffy & Kihm , 2014). Additionally, energy consumption seems to have a positive impact on economic growth, FDI and CO_2 emissions (Salahuddin, Gow, & Ozturk, 2015). This implies that energy consumption is directly linked to economic growth, however it also results in an increase in carbon emissions, thus motivating the use of cleaner energy sources such as solar technology.

When considering the effect of solar penetration levels, a study by Karimi, Mokhlis, Naidu, Uddin & Bakar (2016) suggested that an uncontrolled penetration of solar PV will have a negative impact on an utility. To further support this, a study by Tobar, Massague, Bellmunt & Penalba (2015) found that the increasing level of penetration of solar onto the grid could result in utilities and distribution networks becoming obsolete. This concern motivates the need to understand whether it is possible to find an ideal penetration level that is beneficial to both the utility and consumer, because as stated by Azimoh, Klintenberg, Wallin, Karlsson & Mbohwa (2015), with proper planning and identification of the right energy mix (ideal penetration level), the levelised cost of electicity can be reduced.

In conclusion, if an ideal penetration level cannot be identified, utilities and Independent Power Producers (IPPs) may go out of business as a result of the uncontrolled move into captive solar technology. Utilities and IPPs may therefore have to increase the levelised cost of electricity in order to sustain themselves, further driving customers to look for other alternative methods of electricity supply such as captive solar technology.

Chapter 3: Research Questions and Objectives

This section of the study outlines the research questions that have to be answered in order to better understand the impact of captive solar PV penetration on the economy, and to identify whether it is possible to find an ideal penetration level. This chapter will be divided into the following sections:

- Research objectives
- Research questions
- Research propositions

3.1 Research Objectives

RO1: To determine the perceptions surrounding the economic impact of integrating captive solar technology onto the grid.

The objectives of this research question was met based experience of the respondents who were interviewed. The respondent's insights on the industry helped better understand the impact of captive solar technology on the economy within a South African context.

RO2: To investigate the possibility of finding an ideal solar PV penetration level.

This research objective was met based on the opinion or view of the respondents which helped the researcher qualitatively determine whether or not it is possible to find an ideal penetration level.

RO3: To ascertain the drivers that motivate the need to find an ideal solar PV penetration level.

This research objective was met based on the perception of the respondents, allowing the researcher to determine whether the drivers selected in this study did actually motivate the need to find an ideal penetration level.

3.2 Research Questions

RQ1: What are the perceptions of the utility and solar power producers with regards to the economic impact of captive solar technology?

RQ2: Is it possible to find an ideal penetration level that is beneficial to both utility and customer?

RQ3: What are the drivers that influence a need to find an ideal penetration level?

Chapter 4: Research Methodology

4.1 Introduction

This chapter provides a description of the chosen methodology, population, unit of analysis, measurement instrument, data gathering process and analysis, as well as the limitations of the study. The objectives of this study were to determine the perceptions of the utility and solar power producers with regards to the economic impact of captive solar technology, and whether it is possible to identify an ideal mix, and if so, to identify what the drivers are. This research is classified as a qualitative research that is exploratory in nature.

4.2 Research Method and Rationale

According to Swanson & Holten (2005), research is an orderly investigative process with the purpose of creating new knowledge. Research methods can be qualitative, quantitative or mixed. In quantitative research, objective theories are tested by examining the relationships among variables, and the data gathered is analysed using statistical procedures. In qualitative research, data are collected by observing a participant's setting, making use of open-ended questions rather than closed-ended ones, and uses words rather than numbers. Finally, mixed methods employ both quantitative and qualitative research in equal amounts (Creswell, 2009). Saunders and Lewis (2012) stated that exploratory research is carried out by interviewing subject experts, conducting interviews and searching academic literature, and it aims to seek new insights, ask new questions and assess topics in a new light. The purpose of this study was to discover new insights, with the aim of gaining a broad understanding of the impact of PV penetration and developing new concepts around this topic. This study was exploratory and qualitative in nature because:

- these project initiatives are still young and more lessons still need to be learnt;
- key informers were surveyed to help solve problems and clarify concepts; and
- the research sought to find new insights into the concept of an ideal mix of solar and grid.

Most qualitative studies are inductive in nature as they are aimed at testing new theory from emerging data. On the other hand, deductive studies are aimed at testing existing theory. Quantitative analysis was not considered to be feasible for this study, as it predominantly focuses on the perceptions of the utility when it comes to solar PV penetration onto the grid.

4.3 Population

According to Swanson & Holten (2005), the population refers to a larger group to which the results of the research being conducted are believed to be applicable. The population that was identified as being relevant to this study can be described as all stakeholders that use electricity from an economic context or social point of view, be it from the grid, from solar PV technology, or a mix of the two. The population consisted of the state-owned utility, IPPs, and captive solar PV installers. This population was chosen as they had first-hand experience of the energy industry. Furthermore, the researcher wanted to obtain unbiased points of view, and thus considered having samples of each industry that could potentially be impacted by captive solar PV penetration.

4.3.1 Target population

A target population is the population to which the researcher would ideally like to generalise his results (Fraenkel & Wallen, 1993). The target population in this study included representatives from the state-owned utility and IPP (large-scale) and independent solar PV installers (small-scale, such as roof top solar installers).

4.3.2 Inferential population

The results of this study can be applied directly to traditional utilities and solar power producers that support these utilities. If utilities are aware that the increasing solar penetration is a threat and it is difficult to ascertain an ideal penetration level, this information can be used to change their business models to ensure that they sustain themselves.

4.3.3 Sampled population

The sampled population in this study refers to all the respondents who were defined in the target population, who could be contacted either via Skype, telephone calls or face-to-face meetings for interviews.

4.4 Sampling Method

A sample is the relevant subset of the population; the appropriateness of the sample ensures that research results are credible (Saunders & Lewis, 2012). Sampling methods include probability sampling and non-probability sampling. Saunders & Lewis commented that, depending on the possibility of obtaining a complete list of the population, two types of sampling techniques can be used - probability sampling (which can be used when a complete list of the population is available) and non-probability sampling (when it is not). As it was not possible to obtain the entire list of the population, this research implemented non-probability, purposive sampling using snowballing techniques. Purposive sampling was applied when the researcher's judgement was used to select the sample, and snowball sampling was used when subsequent participants were identified by earlier participants. Both are a type of non-probability sampling (Saunders & Lewis, 2012).

Snowball sampling was used if the purposive sampling techniques did not result in interviews as planned. The individuals in the sample met the following criteria:

- Experienced individuals in the fields of energy.
- Had had exposure to solar technology either directly or indirectly.

It was important that these conditions were met. Energy and solar power is a specific field of study, and although the layman is aware of these concepts, subject experts were interviewed in order to get meaningful insights and thoughts about the topic.

4.5 Sample Size

Saunders & Lewis (2012) stated that "the actual sample size from which you need to collect data will depend upon the nature of your population" (p.134). The sample considered was homogenous in nature, and according to Saunders & Lewis, for similar (homogenous) populations, the non-probabiliity sample size is likely to be approximately

10. In this paper, the method of sampling considered was non-probability sampling, and since the sample was homogenous in nature, an initial sample size of 10 paticipants were selected for the research. However, the researcher interviewed eight more participants in order to provide a better representation and accuracy of the results.

As the study was qualitative in nature, the sample was small in size, consisting of 18 individuals who were experts in their fields. Participants included subject matter experts from the state-utility, which is responsible for 95% of the electricity produced in South Africa; subject matter experts from the IPP office currently involved in the generation of electricity using solar to support the utility; and captive solar technology PV installers. The sample was taken from across three different sectors within the energy industry, namely state-owned utility/national electricity producers, IPPs, and captive solar technology. This will be detailed further in chapter 5.

4.6 Unit of Analysis and Sampling Unit

This study involved understanding the economic impact of the penetration of captive solar PV onto the grid, and determining whether it is possible to find an ideal penetration level. The unit of analysis for this study was the participants in the interviews who provided information from a utility perspective, an independent solar power producer perspective, and an economic perspective. The questions required answers regarding the economic impact of captive solar PV penetration onto the grid, in reference to its effects on GDP, job creation, FDI, as well as environmental impacts. Further questions were asked to garner the participants' opinions on whether it is possible to find an ideal level of solar penetration onto the grid, and if so, what the drivers that influence this level of solar penetration are.

The sampling unit refers to the individual items in a sample. This could be a single observation unit or a set of observation units (Zikmund, Babin, Carr, & Griffin, 2009). In this study, the sampling unit was made up of the following three groups:

- Group A: Energy experts and professionals who were proficient in solar technology. This group was characterised by their real-world experience on the subject matter, such as officials from the utility.
- Group B: These were respondents who had worked with solar IPP projects on a large scale, i.e. power plants that assist the traditional utility.

- Group C: This group of people were independent solar PV installers, who had first-hand knowledge on solar PV modules, installation costs and production costs.

4.7 Measurement Instrument

A semi-structured interview guide comprised of themes and questions was used as the research instrument in this study. This helped the researcher arrive at conclusions on the three research questions. The interview questions were set with guideline information from Saunders & Lewis (2012). Semi-structured interviews, which are a method of data collection that allows the interviewer to ask predetermined questions in no particular order (Saunders & Lewis, 2012), were used in this study.

The interviewees were invited to participitate in the interview via e-mail, wherein the purpose of the interviews was explained. The email invite also included the consent form, so that the participants were able to review it. Each participant was asked to complete the form to ensure that the data gathered were used in an ethical way. The consent form used is shown in Appendix B. The interview questions were not sent to the participants prior to the interviews in order to ensure that any potential bias was avoided, however questions on background information, such as name, qualitification, position and years of experience, were sent to the participants before the face-to-face interviews.

4.8 Data Collection and Analysis

The following techniques were used to gather data in this research:

- Identification of the key stakeholders to be interviewed within the various sectors.
- Development of questions for interviews with key personalities.
- Development of a timeline and schedule to gather data.

Qualitative data are data in the form of words, and are derived from interviews, observations or documents (Swanson & Holten, 2005). This was further reiterated by Yin (2005), who stated that sources of data collection include documentation, archival records, interviews, direct observation, participant observation, and physical artefacts. Data sources for this study included documents, academic literature and semi-structured interviews. Academic literature was used to support the evidence within the various sub-units. The interviews, which incorporated a list of predefined questions, were recorded and transcribed. The data collected were then analysed using descriptive and thematic content analysis.

Saunders & Lewis (2012) stated that descriptive analysis is a method of analysis that compares variables numerically, describes how frequently data are distributed across the categories, and explains how the responses fit into the categories. The second form of analysis, thematic content analysis (Crowe, Inder, & Porter, 2015), consisted of the following steps:

- Becoming familiar with the data.
- Initial generation of codes.
- Searching for themes.
- Defining and naming of the themes.
- Illustrating the themes with examples.
- Synthesizing the themes in relation with each other.

Each participant was emailed a consent form prior to the interview, which gave them time to review the document before the interview began. To ensure that confidentiality of the participants was maintained, no information regarding the age, race or gender of the respondents was recorded as these were not a requirement for the study. Furthermore, all transcripts have been anonymised to ensure the interviewees' confidentiality remains intact.

Two pre-interviews were conducted prior to the actual collection of data in order to test the interview guidelines and the technique of interviewing that would be used by the interviewer. The researcher used the findings from these pre-interviews to review any challenges, and made adjustments where needed. After concluding the initial formalities, which included a brief explanation of the research context, the researcher began the task of interviewing the participants.

Data were gathered through semi-structured, open-ended, face-to-face interviews of 18 subject matter experts and decision makers within the field of energy, both conventional and renewable. According to Saunders & Lewis (2012), it is important for questions to be centred around a set of predetermined themes, so the researcher aligned the interview questions to the research questions set out in chapter 3. This is presented in Table 4.

The questions asked were developed by the reseracher. Questions on the current energy situation (as shown in Appendix A) were asked in an attempt to limit any pre-determined bias regarding the study. Furthermore these questions ensured that the participants were all on common ground prior to answering the research questions.

The researcher used sub-questions to build up to the main reaserarh questions. In research question 1, it was evidenced from the literature review that factors such as energy consumption, carbon emissions and FDI influence the economy. Thus, the researcher aligned sub-questions to these factors in an attmept to understand the influence of captive solar technology on such factors, and consequently the economy. Since it was noticed that research question 2 could quite simply be answered by a ‘yes’ or ‘no’, the sub-questions helped to prompt the participants to elaborate on the factors that could either help or prevent finding an ideal penetration level. Once again, the reseracher linked these sub-questions to the findings in literature. Research question 3 was developed by the reseracher in an attempt to understand the need for finding an ideal penetration level. Research question 3 was leveraged on the back of research questions 1 and 2. The sub-questions aimed to identify and prompt the participatns to think about the main drivers that infuence the need to find an ideal penetration level. This was also then linked back to finding in existent studies.

Table 4 represents the alignment of the sub-questions to the main reserarch questions.

Table 4: Alignment of interview questions to research questions

Research Questions	Interview Questions
RQ1: What are the perceptions of the utility and solar power producers with regards to the economic impact of captive solar technology?	1. In your experience, what is the relationship (both positive and negative) between electricity consumption in South Africa and its growth in terms of Gross Domestic Product (GDP)? 2. Do you think that there is a link between carbon emissions and economic growth? 3. What are the consequences of Foreign Direct Investment (FDI) into a country that has more renewable energy such as solar incorporated into their energy sector than those that do not? 4. Which grid type, in your opinion (full-grid, off grid, and mix of solar and grid), is most conducive for economic growth? Why is this the case? 5. From an economic point of view, what drivers could motivate or demotivate the increase in captive solar PV penetration onto the grid? 6. If the people who can afford solar energy decide to use this technology instead of electricity provided by the utility, what impact would that have on those who cannot afford to move onto solar, i.e. those people still dependent on the utility for power supply?

Research Questions	Interview Questions
RQ2: Is it possible to find an ideal penetration level beneficial to both utility and customer?	7. In your view, should businesses and the public invest into solar technology or continue using electricity supplied by traditional utilities? 8. How do you see the growth of the Solar PV industry in South Africa, and what are the potential threats of this growth, if any, that this technology poses to the utility? 9. In your opinion, is it possible to find an ideal level of solar penetration onto the grid? 10. What are the constraints of finding an ideal solar penetration level onto the grid for South Africa? 11. If these constraints are bridged, what steps should be taken to achieve an ideal level of solar penetration onto the grid?
RQ3: What drivers influence the need to find an ideal penetration level?	12. In your opinion, what factors do you think highly influence the penetration level of solar onto the grid? 13. How will identifying an ideal penetration level be an advantage or disadvantage to South Africa, the utility, and solar installers? 14. From a financial point of view, how will the utility and supporting solar power producers (IPPs) be affected in South Africa with increasing captive solar penetration onto the grid? 15. What do you think is the most profitable way in which solar power can be incorporated into the utility's business model? 16. What are the technical risks in South Africa with implementing net metering and feed-in tariffs? 17. How should the utility tackle grid parity (the decreasing cost of electricity produced through Solar PV)?

The researcher sought to identify any common themes and insights from the data that were gathered through the interviews during the data analysis process. Most of the data analysis took place post the interview process. This was done by means of thematic analysis on a question by question basis as suggested by (Saunders & Lewis, 2012), using Atlas.ti, a computer-aided qualitative data analysis software. A count was allocated when a theme was discussed or mentioned by a participant in some cases themes were not fully discussed or mentioned or sometimes a participant mentioned more than one sub-theme. Thematic analysis is a method that is used to analyse and identify patterns or themes in a qualitative study (Braun & Clarke, 2006). A total of 18 interviews were transcribed using a transcription service. The researcher validated the transcriptions received against the audio recordings to ensure accuracy of the content.

4.9 Limitations

The key limitations of the study are listed below:

- As mentioned in Saunders & Lewis (2012), "An exploratory study may well provide tentative answers to these initial questions, which need to be followed up with more detailed research to provide more dependable answers" (p.110). Future quantitative analysis will need to be undertaken to provide more dependable results, to ensure that research bias overlooked.
- As the population was chosen by non-probability sampling, it was not an accurate statistical representation of the population (Saunders & Lewis, 2012).
- Snowball sampling used in this research identified similar respondents, resulting in a homogenous sample and creating a bias towards participants with similar ideologies and minimum variation in possible data collected (Saunders & Lewis, 2012).
- Due to the researcher's travel limitations, the participants interviewed were mainly located in the region of Gauteng, hence the experiences of the participants were biased to a geographic location.
- Interviewer bias was a limitation as the researcher previously worked in the solar industry, hence comments or the tone of the interviewer created bias in the interviewees' responses.

Chapter 5: Presentation of Results

5.1 Introduction

This chapter presents the main findings of the research questions and research objectives provided in chapter 3. The interviews performed as part of this research have given insight into how the penetration of captive solar technology onto the grid impacts the economy, as well as whether it is possible to find an ideal penetration level and what the possible drivers influencing this need are. This chapter provides a summary of the interviews that were conducted, with the details of the participants, as well as a discussion of the processes that the researcher followed to ensure the credibility and accuracy of the data that was collected and transcribed. The results presented within this chapter are further discussed and analysed in chapter 6.

5.2 Description of the Interviewees and the Interviews Conducted

The researcher conducted a total of 18 interviews with subject matter experts and decision recommenders within the energy sector. Seven of the 18 participants interviewed worked for the national utility, five worked as solar installers and the remaining six worked for IPPs. The interviews were conducted over a period of four weeks. Most of the interviews were conducted in person, at locations that were convenient to the interviewees. The researcher tried utmost to conduct the interviews in quiet areas to ensure the quality of the audio recordings. Only one of the interviews was conducted electronically, over the video chat/ call platform, Skype. Almost 20 hours of audio recordings were taken. The interviews were conducted until a point of saturation was reached (Saunders & Lewis, 2012), to ensure that there were no more new contributions to the study. The longest interview took one hour and 42 minutes, while the shortest interview was conducted in 43 minutes. On average, most interviews lasted one hour and five minutes. In addition to the audio recordings, the researcher took down hand-written notes of the key points and recurring concepts that were highlighted in the interviews.

Table 5 provides the details of the interviewees, sorted according to the energy sector they were involved in.

Table 5: Details of Interviewees

Participant	Description	Highest qualification	Background	Role in the industry	Years of experience
1	Utility	National Diploma Engineering	Engineering	Decision Maker	20 years
2	IPP consultant	M.Eng and Engineering Management	Engineering	Decision Recommender	7 years
3	Solar Installer	MBA	Commerce	Decision Maker	1 year
4	IPP consultant	CA(SA), B. Com, BACC, MTP	Commerce	Decision Recommender and Subject matter expert	20 years
5	Solar Installer	MSc. Pr. Engineering	Engineering	Subject matter expert	22 years
6	IPP consultant	B.Eng., MBA	Engineering	Manager	14 years
7	IPP consultant	Post Graduate	Engineering and Commerce	Decision Recommender and Subject matter expert	10 years
8	Utility	Technologist, Energy Manager, M&V Professional	Engineering	Decision Maker, Decision Recommender	22 years
9	Utility	MSc. Engineering	Engineering	Subject matter expert	20 years
10	Utility	MSc. Mechanical Engineering	Engineering	Subject matter expert	3 years
11	Solar Installer	Msc. Electrical Engineering; MBA	Engineering	Subject matter expert	27 years
12	Solar Installer	BSc.(Hons) Chemistry	Commerce and Investment banking	Subject matter expert	5 years

Participant	Description	Highest qualification	Background	Role in the industry	Years of experience
13	Utility	M. Engineering	Engineering	Decision Recommender	15 years
14	Solar Installer	MBL	Engineering	Subject matter expert	6 years
15	IPP Consultant	PhD Chemical Engineering	Engineering	Subject matter expert	15 years
16	Utility	National Diploma Engineering	Engineering	Subject matter expert in energy storage	39 years
17	Utility	Graduate Diploma in Engineering, BSc Engineering and Pr. Engineering	Engineering	Decision Maker, Decision Recommender, Subject matter expert	41 years
18	IPP Consultant	Post graduate	Economist	Decision Recommender	5 years
		Post Graduate	Commerce	Decision Maker	10 years
		Honours Degree Economics	Development Economics advisory and strategy	Programme development and implementation	5 years

Before the formal interviews, three interviews were conducted as test/pilot interviews, in an attempt to understand how best to approach the questions and conduct the interviews. The test interviews provided the researcher with a good opportunity to understand the flow of the questions during the interview, allowing the researcher to be more prepared and comfortable with the rest of the interviews. Once the researcher identified the best way to deliver the questions to the interviewees, certain questions were amended. The researcher also realised that probing was needed, especially for Research Question 2, to prompt the interviewees for more information on the topic. The researcher realised that the addition of a preamble provided a good way to start the interviews and create a rapport with the participants (Meyers, 2013). The formal interviews were conducted and recorded, after which the audios were transcribed by the researcher. The researcher then verified the accuracy of the transcriptions by re-listening to the audio recordings. (Refer to Table 5 in section 4.8 or Appendix A for the interview guide that was used in this study.)

5.3 Transcriptions and Coding

All 18 interviews were transcribed by the researcher himself. The researcher verified the accuracy of the transcriptions by re-listening to the audio recordings. Spelling mistakes, and incorrect terms that were picked up in the transcriptions were corrected during this process. Any inaudible areas in the scripts were corrected by recollecting the interview discussion and using the hand-written notes taken during the interview. The researcher used bold font for the interviewer and normal font for the interviewee when transcribing the interviews. The transcriptions were then analysed and coded using the computer aided programme Atlas.ti.

According to Friese (2014), codes should not be lumped under one code name; rather, they should be developed in layers so that it is easier to identify similar themes and content. The researcher assigned one main number to each of the research questions and then added another number per group sampled. The researcher coded in this manner to ensure that themes were picked up according to both the research questions and the sample group the participants were from. The questions pertaining to the current electricity situation were assigned the code number ‘0’. Research question 1 was assigned the number ‘1’; research question 2, was assigned the number ‘2’, and research question 3, the number ‘3’. The researcher then assigned a code to the three different sample groups, i.e. utility, IPP and solar installers. This was done in order to identify specific themes that emerged from these groups more easily. The researcher assigned code number '1' to the utility, code number '2' to the IPP and code number '3' to solar installers. Finally, the main sub-themes that were identified were assigned a third code number. For instance, if a code was assigned as 1 1 3, this implied that a theme was identified in research question 1, by a member of the utility, in relation to the sub-theme assigned as '3'. The full list of code descriptions is shown in Appendix C.

5.4 Presentation of Results

The results are presented as per the research questions set out in chapter 3. It is important to note that the data was analysed separately based on the key themes found in each research question. Frequency counts (across interviews) of the occurrences were used to determine what role the data played, i.e. whether it was an indication of a positive or more negative role, or even if there was any influence at all.

The questions presented to the interviewees are as shown in Appendix A. For ease of presentation and to ensure that each question was dissected and analysed thoroughly, the researcher has subdivided the following sections according to each of the sub-questions that were asked within each of the research questions. The results are presented in detail, however the discussions in chapter 6 will only use the findings that the researcher feels are most relevant for answering the three main research questions.

Table 6 provides a summary of the main sub-themes that were identified per research question from the data gathered per sample group. The data are further explained and concluded in the rest of chapter 5. The data was analysed by means of frequency counts. However, some of the counts do not necessarily add up to 18 (the number of participants) because some participants may not have commented on a particular sub-theme, or answered all the questions. The data is further explained and concluded in the rest of chapter 5.

Table 6: Summary of the main sub-themes identifed

Research Question	Utility	IPP	Solar Installer
Current Electricity Situation			
5.5.1 Affordability of Electricity in South Africa	Cheap, Expensive, and Competitive		
5.5.2 Meeting Demand	Infrastructure, Capacity, and Renewable sources		
5.5.3 Infrastructure	Outdated, Generation and Upgrade		
Research Question 1			
5.6.1 Relationship between electricity consumption and GDP	5.6.1.1 Positive relationship	5.6.1.2 Positive Relationship	5.6.1.3 Positive Relationship
5.6.2 Impact of Carbon Emissions on the Economy	5.6.2.1 Positive Impact	5.6.2.2 Positive Impact	5.6.2.3 Positive Impact
5.6.3 Attraction of renewable energy on FDI	5.6.3.1 Renewable Sources	5.6.3.2 Return on Investment	5.6.3.3 Renewable Sources
5.6.4 Grid Type	5.6.4.1 Mixed Grid	5.6.4.2 Mixed Grid	5.6.4.3 Mixed grid
5.6.5 Drivers for solar penetration	5.6.5.1 Cost	5.6.5.2 Cost	5.6.5.3 Cost
5.6.6 Impact of Solar penetration	5.6.6.1 Increased Prices	5.6.6.2 Increased Prices	5.6.6.3 No change in Prices
Research Question 2			
5.7.1 Reasons for investing into solar	5.7.1.1 Cost and Economics	5.7.1.2 Cost and Economics	5.7.1.3 Cost and Economics

5.7.2 Constraints for Ideal penetration	5.7.2.1 Technical and environmental	5.7.2.2 Technical and environmental	5.7.2.3 Technical and environmental Lack of data
Research Question 3			
5.8.1 Drivers	5.8.1.1 Environment / Technical/ Financial	5.8.1.2 Feed-in Tariffs and Net Metering	5.8.1.3 Feed-in Tariffs and Net Metering
5.8.2 Threat to Utility	5.8.2.1 No Threat	5.8.2.2 Revenue Loss and Death Spiral	5.8.2.3 Revenue Loss and Death Spiral
5.8.3 Advantages and disadvantages of finding an ideal penetration level	5.8.3.1 Advantage	5.8.3.2 Advantage	5.8.3.3 Advantage
5.8.4 Grid Parity	5.8.4.1 Yet to be achieved	5.8.4.2 Yet to be achieved	5.8.4.3 Yet to be achieved

5.5 Current Electricity Situation

The main aim of determining the current electricity situation was to provide clarity and context for the three main research questions. The researcher felt that a discussion about the current electricity situation would allow each member within the sample group, irrespective of their source of employment, to reach a common starting point in order to answer the three main research questions. This was also done in order to avoid any pre-determined biases.

5.5.1 Affordability of electricity in South Africa

The main aim of this question was to prompt the participants to think about the actual cost of electricity in South Africa. This question was raised in order to give context to Research Question 1, which looks at the perspectives of the utility, IPP and solar installers on the economic impact of captive solar technology. Most of the participants agreed that the electricity price offered by the traditional utility currently is affordable, for various reasons.

Table 7: Sub-themes for the affordability of electricity in South Africa

Rank	Sub-Theme	Participant Code	Frequency
1	Cheap	P1, P5, P7, P11, P15, P14	6
2	Expensive	P2, P12, P8, P18	4
3	Competitive	P3, P9	2

A number of participants commented that affordability depends on the perspective one looks at it from, i.e. *"depending on the bracket they fall in…it's not very affordable" (P5, 2:2),* and *"when you ask a customer if the price is affordable their response mostly will be "no it's not it could always be cheaper, but if you're looking from a power producer perspective, we believe that it is affordable…" (P1, 4:4).*

Other participants were of the opinion that electricity prices in South Africa are indeed affordable, remarking that it is relatively cheap compared to the rest of the world, however the problem lies with the fact that electricity is being used inefficiently. According to participant 15, the electricity price is "*affordable. I know in other countries, like other European countries like Germany, the electricity is quite expensive. But I think the main issue in South Africa is that we are not efficient" (P15, 3:3).* This sentiment was shared by participants 11 and 14, who further highlighted that the electricity price in South Africa compared to the rest of the world is "*still relatively cheap…" (P11, 2:11),* and is "*much cheaper compared to international standards" (P14, 3:3).* Participant 7 also agreed that the electricity price is affordable, however mentioned that the main problem is the inefficient use of electricity, i.e. "*not too expensive; we just don't use electricity efficiently" (P7, 3:3).*

However, a few participants disputed that the electricity price is affordable. Participant 2, an IPP consultant, suggested that the electricity price is "*fast becoming unaffordable and we are in line for a number of years of additional increments not for the reasons that some people might typically think…the biggest things that will push the prices even more is going to be the overruns of Medupi and Kusile and if a potential nuclear plant comes in" (P2, 3:3)*. Participant 12 also agreed with this notion, but reasoned that the unaffordability is not because of the price of electricity, but rather the fact that people are not able to afford it based on their economic condition; *"…so the issue isn't that our* *electricity prices are too expensive, it's actually the economic condition of the bulk of our people is so bad that they can't afford the product" (P12, 4:4).* At the same time, two participants from the group felt that the prices are competitive in comparison to international prices.

5.5.2 Meeting demand

This question highlights the core of the thesis, because understanding how the demand is met, and whether or not it is met, links to the need to find an ideal penetration level. This question tried to create awareness in the interviewees' minds that solar could be a potential resource that could be tapped to meet demand. This question links to both research questions 2 and 3, in that it prompts participants to think of the need for solar, and then whether or not an ideal penetration level can be found.

The main sub-theme that emerged was that of 'capacity', which ranked the highest with a frequency count of 7 as shown in Table 8.

Table 8: Sub-themes for meeting demand

Rank	Sub-Theme	Participant Code	Frequency
1	Capacity	P1, P3, P5, P6, P7, P13, P17	7
2	Infrastructure	P1, P8, P13, P14, P17, P18	6
3	Renewable Sources	P2, P4, P5, P6	4

The data showed that improved workmanship, maintenance and increased generation capacity are all factors contributing to the fact that the traditional utility is currently able to meet the electricity demands. Although the overall consensus was that the demand is being met, the participants strongly suggested that the current demand is being met mainly thanks to the utility's increased capacity.

Participant 1 expressed that the way work is being done in the utility has improved in terms of "*workmanship"* and as a result of increasing capacity, i.e. "*the availability when the unit comes back to expand so that it's a lot more available".* This means that the utility is "*quite comfortable to meet the demand…" (P1, 16:16).* This was supported by participant 13, who highlighted that there were "problems *in the past, like in 2007, 8 and 9 that time. But I think currently there's a lot of load that is being reduced and especially* *the mines are reduced. We have actually excess now" (P13, 7:7).* Participant 1 further elaborated on this by saying there has been "*new capacity put onto the system, which is Medupi unit 6, and we've had 4 Ingula units that have come online" (P1, 16:16).*

However, another theme that emerged was that the electricity demand is being met, not due to better infrastructure or additional capacity, but merely because many heavy users of electricity, such as mines, are offline, and the increasing price of electricity over the last few years have reduced. Participant 17, a subject matter expert from the utility commented that "*these plants are not maintained to the best".* The participant added "*there is a risk, that the plant will not be available to supply everything. Especially, if all the economy came back. Remember that utility has asked plants to shut down, like Alu-saf. They have stopped smelters, and mines… if they all came back, there will be a shortage of electricity" (P17, 8:8).* This was further re-iterated by participant 4, who mentioned that the demand is lower *"mainly because of the lower economic growth and some renewable coming on grid" (P4, 5:5).* One participant felt that adding renewables or self-generation was another reason as to why the electricity demand was being met currently; *"…some businesses are beginning to generate their own electricity, so it's a combination" (P15, 5:5).* Furthermore, participant 18 remarked that the electricity demand is not being met because there is not "*efficient enough sources of energy at the moment" (P18, 13:13).* This statement was supported by participant 14, who elaborated that "*there is a reason we are here, I think around 2007 and 2008, when we had a lot of the initial load-shedding because there was not enough energy available. So, there is a reason we are here" (P14, 7:7).*

Overall, the majority of participants believe that there are increased capacity new units coming online. However, this does not confirm that the electricity demand is being met, because from the results it is evident that certain energy intensive sectors, such as mines are still offline, and there is additional capacity coming from renewable sources.

5.5.3 Infrastructure

This question was asked in relation to Research Question 3. By asking the participants about the electricity infrastructure, the interviewees were prompted to look at infrastructure as a potential reason or driver motivating the need to find an ideal penetration level. When asked about the current condition of the electricity infrastructure in South Africa, the highest ranked theme that emerged with a total frequency count of 9, was that the infrastructure is 'outdated'.

Table 9: Sub-themes for infrastructure

Rank	Sub-Theme	Participant Code	Frequency
1	Outdated	P1, P3 P4, P6, P7, P11, P12, P13, P15	9
2	Generation vs Distribution	P1, P4, P12, P13, P15	5
3	Upgrade/Refurbish	P1, P7, P10, P18	4

An interesting, and probably obvious, sub-theme that emerged in the overall theme of electricity infrastructure, was that the current infrastructure is old and outdated, but sufficient to generate the capacity required. Most of these comments were provided by non-utility participants, i.e. IPPs and solar installers.

Participants 4, 12 and 18 were of the opinion that the infrastructure is *"aged" (P4, 7:7), "outdated" (P12, 8:8),* and *"old" (P18, 19:19).* According to participant 10, *"there are some constrained areas which need to be upgraded but obviously, the utility would see and priorities, what to upgrade and then you plan for upgrading before the expansion starts" (P10, 12:12).*

Another common sub-theme that emerged from majority of the participants was regarding the difference between generation infrastructure and distribution infrastructure, and the importance of refurbishment on the existing structures. Participant 3 highlighted the fact that *"we've got the generation side of things which is the power stations, then we got our distribution side; the distribution side of things, well whilst we have problems in both, generation at the moment probably sufficient for where we are as an economy, when that grows generation's going to be a problem but, we got Medupi, Kusile and potential nuclear and as well as a mix coming in it, so the generation whilst we be undersized" (P3, 11:11).* This statement was supported by participant 7, who remarked that the *"South African economy needs infrastructure because a lot of their focus is on generation, our transmission and distribution and infrastructure is suffering and is falling into a state of disrepair" (P7, 9:9).* To add to this, participant 12 commented that the *"generation plant is old, pretty much old if I look at the fired coal power plant for example its operating above their permitted emissions limits, they are all probably in the last phase of their operating cycle, I would say they have been badly maintained" (P12, 8:8).*

Overall, the majority of the participants remarked that the current electricity infrastructure is outdated and old. Another key point that was raised is that there is generation and distribution infrastructure, so since the utility is concerned with generation, then there should be sufficient maintenance "*in terms of sustaining our assets" (P1, 16:16).*

5.5.4 Conclusion

From the frequency counts gathered, it can be seen that most participants think that the electricity price is relatively cheap in South Africa, i.e. it is affordable. Furthermore, most participants were of the opinion that the utility was able to meet demand as a result of new capacity coming on board. An interesting factor that was picked up was that the infrastructure is quite old and outdated, and there were remarks from the participants that the utility should focus on distribution rather than generation. This could be due to the fact that the transmission and distribution network is quite good in the country. Also, this implies that generation could possibly be taken over by other renewables such as solar.

5.6 Data Analysis for Research Question 1

Research Question 1: What are the perceptions of the utility, solar power producers and installers with regards to the economic impact of captive solar technology?

The aim of Research Question 1 was to identify the perceptions of the utility, solar power producers and installers about the economic impact of captive solar technology. Research Question 1 was set up to understand the relationship between energy consumption and economic growth from a South African context; to identify whether there is an impact of carbon emissions on the economy; and to find out whether more renewables attract more FDI. Additionally, the question sought to identify the type of network configuration (grid-type) that could prove to be the most beneficial for the economy. For the sake of clarity, when presenting the results, the researcher has sub-sectioned the main themes identified in the first research question as follows:

5.6.1 Relationship between electricity consumption and GDP

One of the key questions that the researcher sought to investigate was what the perceptions of the utility, IPP and solar installers were when asked whether there is a relationship between electricity consumption and growth in terms of GDP. Many studies have shown the link between energy consumption and growth in the economy (Graffy &

Kihm, 2014; Loomis, Jo, & Aldeman, 2016 and Saidi & Hammami, 2014). The researcher also attempted to establish if the perceptions of the respondents from the three different sample groups were similar.

5.6.1.1 Utility

The highest ranked sub-theme identified from the utility was that there is a 'positive relationship' between energy consumption and economic growth, as seen in Table 10. In analysing the three main sub-themes, it was seen that the majority of the participants from the utility agreed that there is a positive relationship between energy consumption and economic growth.

Table 10: Utility's perception on the relationship between electricity consumption and GDP

Rank	Sub-Theme	Participant Code	Frequency
1	Positive Relationship	P1, P8, P9, P10, P13, P16, P17	7
2	Neutral	P8	1
2	Negative Relationship	P10	1

As seen from the frequency counts, the majority of participants believed that there is a positive relationship between electricity consumption and growth in GDP, with the sub-theme of positive relationship being picked up seven times.

All seven participants interviewed from the utility agreed that *"it is positive that if there is electricity, the GDP will grow. If there is no electricity, GDP will definitely be held back" (P17, 13:14).* Participant 9 and participant 16 echoed similar sentiments regarding the correlation between electricity consumption and the growth of the economy, mentioning that *"it should be a positive relationship, because usually, consumption means there is more factories, there's more manufacturing, and obviously, people are getting paid and there are more products being sold" (P9, 33:33),* and *"GDP comes down your electricity comes down as well, so I would say there is quite a strong link" (P16, 31:31).*

5.6.1.2 IPP

Again, there were more counts picked up indicating that there is a positive relationship between GDP and energy consumption, i.e. four counts as seen in Table 11.

Table 11: IPP's perceptions on the relationship between electricity consumption and GDP

Rank	Sub-Theme	Participant Code	Frequency
1	Positive Relationship	P4, P6, P7, P15	4
2	Neutral	P2	1
2	Negative Relationship	P2	1

Participant 18 commented that "the *growth of the GDP, because we are so reliant on primary and secondary industries, is intrinsically linked to sustainable and affordable supply of electricity" (P18, 34:36).* Another interesting perspective was given by participant 4, who mentioned that there is a direct correlation between energy consumption and economic growth because *"…as soon as we've seen a lower economic growth we are able to meet our electricity demand, if we had been growing at 5% we would not have been able meeting our electricity demand" (P4, 9:9).*

Participant 2 introduced the notion that although there is a relationship between electricity consumption and the growth of the economy, this does not always hold true; *"there's been a significant decoupling between electricity demand and economic growth and it's a natural occurrence in a very undeveloped economy… electricity demand growth outstrips your GDP growth" (P2, 13:13)*. However, participant 7 refuted this notion of a positive relationship between GDP and electricity consumption by stating that *"if electricity is a very low input cost, people tend to be wasteful of it" (P7, 17:17).* This implies that if electricity is more affordable its consumption will increase, however this does not necessarily mean that more people are using it productively or in any way that contributes positively to the GDP, but rather the increase is merely because people are less thoughtful about wasting it due to cheaper prices.

5.6.1.3 Solar installers

Similar results were identified for the participants from the solar installers group. The counts indicated that the participants believe that higher energy consumption is an indication of economic growth. The sub-theme 'positive relationship' was ranked the highest with a frequency count of four, as shown in Table 12.

Table 12: Solar installers' perceptions of the relationship between electricity consumption and GDP

Rank	Sub-Theme	Participant Code	Frequency
1	Positive Relationship	P3, P5, P12, P14	4
2	Negative Relationship	P3	1
	Neutral		0

Similar to the responses given by members of the utility and IPP. Participants 3 and 14 both commented that there is a positive relationship between electricity consumption and economic growth, by stating *"…the more growth, the more energies we consume because we translate it into building or expanding manufacturing facilities using them to their peak" (P14, 15:15)* and as "*GDP grows, the electricity requirements are more" (P3, 15:15).*

5.6.1.4 Conclusion

Overall, the sub-theme 'positive relationship' ranked the highest with a total frequency count of 15. From the findings, it is evident that the utility, IPP and solar installers perceive energy consumption to have a positive influence on the growth of the economy.

5.6.2 Impact of carbon emissions on the economy

Another theme that the researcher sought to investigate was the perception of the utility, IPP, and solar installers on the influence of carbon emissions on the economy. Three main sub-themes were identified from the study, namely carbon emissions have a positive relationship on energy consumption, a negative impact on energy consumption, or little to no impact on energy consumption.

5.6.2.1 Utility

In analysis, of the three main sub-themes, 'positive impact' had the highest frequency, with a count of four. The majority of participants from the utility agreed that there is a positive relationship between economic growth and energy consumption as seen in Refer to Table 13.

Table 13: Utility's perception on the impact of carbon emissions on the economy

Rank	Sub-Theme	Participant Code	Frequency
1	Positive Relationship	P8, P9, P10, P13	4
2	Little or No Impact	P8, P10	2
	Negative Relationship		0

Participants 8, 9 and 17 linked the growth of the economy to higher carbon emissions. As per Participant 8, *"…economic growth is dependent on electricity use. Electricity used in South Africa, is mostly from coal and therefore the carbon emissions will increase" (P8, 16:16)*. This was further reiterated by participant 9, who said that *"…more carbon emissions mean increase in GDP, because they are producing electricity" (P9, 45:45).* As emphasised by participant 17, *"South Africa's electricity…majority of it, 85%, is coal fired power stations. I think we are in the unfortunate position that we are reliant on coal as our source of energy and electrical energy and, I think, carbon emissions do come in…" (P17, 16:16).*

However, two of the seven participants from the utility seemed to think that carbon emissions currently have zero impact on the economy. According to participant 10, there is no link *"between carbon emissions and economic growth, unless you are obligated to it by policy" (P10, 26:26).* This was supported by participant 8, who mentioned that the main reason for this is because *"there are no carbon taxes yet" (P8, 18:18).* The researcher found this to be a valid point, as there are talks of policies and regulations for carbon emissions, however none are strictly reinforced currently.

Although not mentioned as part of the three main sub-themes, another sub-theme that emerged from the discussions was the impact of carbon emissions on the health and wellbeing of people. According to participant 13, the impact of carbon emissions has not been understood. *"You don't know how it effects health, because we don't really understand the effect…" (P13, 37:37).* The researcher found this to be an interesting, and additional factor that could possibly affect the economy, as unhealthy people implies a disruption in the labour force, which adversely impacts economic growth.

5.6.2.2 IPP

Most of the participants interviewed from the IPPs seemed to share similar sentiments, as seen in Table 14, about carbon emissions and economic growth as did the ones from the utility. The sub-theme 'positive relationship' once again ranked the highest with a frequency count of four.

Table 14: IPPs' perceptions on the impact of carbon emissions on the economy

Rank	Sub-Theme	Participant Code	Frequency
1	Positive Relationship	P4. P6, P15, P18	4
2	Little or No Relationship	P7, P15	2
3	Negative Relationship	P2	1

Once again, the views that were expressed by a number of participants centred on the subjects of coal generation. Participant 4 shared the view that *"in a South African context, 80 or 90 percent of…generation capacity comes from coal which is obviously carbon emitter" (P4, 11:11).* One participant looked at the history of energy and noted that historically, all technologies that have been used to grow the economy are *"carbon intensive" (P6, 69:69).* These sentiments were shared by participant 18, who stated that *"if you are coal-based, then if you want to grow, then you need more power, you need more coal, you will have more emissions" (P18: 38:38).*

Participants 4, 6 and 18 all focused on the fact that South Africa's energy is produced through coal, thus greater consumption of energy results in more carbon emissions. Participant 18, however, also viewed this question from another aspect, by stating that *"…first world countries that are growing, but mainly don't emit as much, because they have got green energy; so, they'll be growing, but maybe their growth curve is going down in terms of CO_2 emissions" (P18, 40:40).* There is an underlying implication here that an improved integration of cleaner energy sources, such as captive solar technology, will be beneficial for the economy, especially if there are stricter carbon penalties and taxes in place.

Participant 15 did not fully agree with the concept that carbon emissions are an indication of energy consumption. The IPP consultant mentioned that carbon emissions are dependent on the way you generate power and the ease of measurement, by stating that *"at a much smaller scale there may not be a direct correlation because if you look at poor countries, and I mean poor countries where not everyone is connected to the grid. You will find that as those countries develop more and more people start to move into urban areas and they want to be connected to the grid. And so, you might find that now the emissions they create from using bio-mass are being avoided but the question is: who is* *there to measure? We are able to measure emissions from a coal power plant is easy but you can't measure the emissions that have been avoided by people coming to the urban areas and getting connected to the grid" (P15, 19:19).* This suggests that there might be a bias in the actual CO_2 emission measurements. People seem only to be focused on measuring CO_2 that has been emitted from coal fired power stations, however fail to look at the emissions given off by generating electricity through other means, such as biogas.

Participant 7, on the other hand, was of the opinion that carbon emissions have an impact on the growth of the economy, and expressed the view that *"if you have a high emission factor but your selling your product or service at the right price, I still think economic drives more than carbon emissions" (P7, 19:19).* This implies that "affordability" is the actual key driver of the economy; the more people are able to buy, the better the growth of the economy.

5.6.2.3 Solar installers

Interestingly, there was an almost 50/50 split on this question, however the highest ranked sub-theme was that there is a 'positive relationship' between energy consumption and carbon emissions.

Table 15: Solar installers' perceptions of the impact of carbon emissions on the economy

Rank	Sub-Theme	Participant Code	Frequency
1	Positive Relationship	P5, P11, P14	3
2	Little or No Relationship	P3, P12	2
	Negative Relationship		0

Like the majority of the participants, participants 5 and 11 agreed that there is a link between carbon emissions and economic growth, however participant 14 offered a different view, saying that the link could either be positive or negative, depending on the industry you are looking at *"…there is a link, but that depends on the nature of the energy that's being used. If you are using more coal-based energy for the growth of the GDP, then there will be a negative impact on the greenhouse emissions. But if you are using more of the green energy, then the relationship will be the opposite" (P14, 17:17).*

On the other hand, participant 12 argued that unemployment contributes significantly more to a decline in an economy than carbon emissions, by saying that the level of unemployment should be more cause for worry than the "*industrial policy, the economic policy and then whether carbonization policy has an influence" (P12, 20:20).* Sharing this sentiment, participant 3 said that "*carbon emissions and economic growth are not the two strongest levers to put together" (P3, 25:25).*

5.6.2.4 Conclusion

The sub-theme that was picked up the most was that there is a positive relationship between carbon emissions and energy consumption, and consequently economic growth. However, this should not be interpreted as carbon emissions are positive for the economy, but rather the results indicate that with increasing energy consumption, there is an increase in carbon emissions as well. Furthermore, as picked up from the results, South Africa pre-dominantly depends on coal-based generation, thus higher carbon emissions indirectly show that there is higher energy consumption, and this is indicative of a growing economy. Thus, it can be concluded that carbon emissions increase with increasing energy consumption, especially in coal-based countries, however ultimately carbon emissions have a negative impact on the economy. Also, it was noticed that there does not appear to be any difference between the three sample groups in their responses.

5.6.3 Attraction of renewable energy on FDI

It has already been established that FDI is an important driver for economic growth (Tang & Tan, 2014). Thus, the researcher wanted to establish whether the incorporation of renewables onto the grid influenced the attraction of FDI into a country in some way, subsequently enabling economic growth.

5.6.3.1 Utility

The main sub-theme that emerged from the findings was 'renewable sources', which ranked the highest with a total frequency count of five.

Table 16: Utility's perception on the attraction of renewable energy on FDI

Rank	Sub-Theme	Participant Code	Frequency
1	Renewable Sources	P1, P9, P10, P13, P16	5
2	Energy Security	P10, P13, P16	3
3	Return on Investment	P8, P17	2

From the data, the researcher noted that participants attributed the attraction of foreign direct investment into a country to more than just renewables. The sub-theme 'renewable sources' was ranked as highest mentioned because many people compared it to other factors that attract FDI. The data indicated that 'renewable sources' are important, but not as important as factors such as 'energy security' and 'return on investment'. These two sub-themes received the second and third highest counts.

According to participant 9, *"…it is a reliable source of energy….so, whether the power source is renewable or from fossils stations, it is irrelevant as long as it is stable. So, going back to South Africa, more than 95% are fossils fuel based whereas Germany more than 30% are renewable energy…" (P9, 65:65).* These sentiments were also expressed by participants 10, 13 and 16. They were also of the opinion that reliability of supply (energy security) was the main factor that would motivate any kind of investment. Participant 10 mentioned that renewables would have been *"a high concern back on the load-shedding days" (P10, 36:36),* while participants 13 and 16 once again reiterated that there needs to be "*security of supply",* especially if it is a highly energy intensive system like a "*smelter or things like that" (P13, 49:49),* or *"you would have to look at the reliability of the supplying…you going to have to look at the electricity industry especially if your business is electricity intensive" (P16, 41:41).*

'Energy security' and reliability of supply were the main drivers that four out of seven members of the utility mentioned as being the key driver for investment into a country. This could possibly be due to the fact that South Africa had experienced an energy crisis a few years earlier, which drove many investors to leave the country. Participant 10 shared the view that having renewables in the system has not become such a strong driving factor as yet, because "*incentives by green credits and taxes but that hasn't hit this country as yet".* Furthermore, participant 10 said that "*all policy things that haven't been looked within this country and firmly put down" (P10, 38:38).*

The sub-theme ‘return on investment’, which ranked third among the sub-themes that emerged, was also seen as a factor that more strongly influences the attraction of FDI than renewables *“we are not very reliable on renewable energy at the moment and the amount of money that is available for investment in South Africa... Africa as an investment focus, but the focus is to get clean energy because that’s where the New World can take off and assist all countries, not only South Africa. Once the renewables are there, they will still invest but they will now start to invest in other things. And some have already started to diverse their investment portfolios to cover all these” (P8, 24:24).*

5.6.3.2 IPP

As seen from Table 17, the sub-theme ‘return on investment’ ranked the highest with a frequency count of four. The sub-theme ‘renewable sources’ attained the second highest frequency counts.

Table 17: IPPs’ perceptions on the attraction of renewable energy on FDI

Rank	Sub-Theme	Participant Code	Frequency
1	Return on Investment	P6, P7, P15, P18	4
2	Renewable Sources	P2, P7, P18	3
3	Energy Security	P6	1

Similar to the data gathered from the interviews with the participants of the utility, the majority of the IPP participants felt that factors such as ‘return on investment’ were more of an attraction for FDI than ‘renewable sources’ were. In participant 15’s view, “*any foreign direct investor in the energy sector would look at the return of the investment” (P15, 27:27).* These sentiments were shared by participant 8, who elaborated that one would only invest into a more renewables rich country if one were “*certain that I will get my returns… So, if it is cheaper here than in Thailand, they will do it here” (P6, 81:81 and 85:85).* Participant 7 expressed the view that if “*the product or service that I’m offering is highly; electricity has a higher input cost, then I’d look for the country that can provide me with the cheapest electricity and the longest-term projections…” (P7 29:29).* Thus, it was evidenced from these responses that price was the main factor that influenced investment.

However, some participants did draw attention to the possible advantages of investing into a country that has more renewables. Participant 7 noted that *“…because your* *renewable energy pricing is primarily linked to the capital cost of the plant going in as opposed to the operational costs. You've got a much better long term projection of what that pricing is going to be" (P7, 29:29).* This implies that investment into a country where there are more renewables incorporated could be beneficial, as there is more accuracy in the projection of the investment, as the investee does not have to worry about the possible implications of future taxes that will be coming in compared to a highly fossil fuels dependent country.

Overall, all the participants from the IPP were strongly motivated that the main factor influencing investment is the return on investments expected - more strongly than the fact that there are renewables. Renewables, however, will always be an advantage, and is not taken to be a factor that will hinder investment.

5.6.3.3 Solar installers

Similar to the data gathered from the utility, 'renewable sources' ranked the highest with a frequency count of 5 (see Table 18). The sub-theme 'return on investment' ranked second.

Table 18: Solar installers' perceptions of the attraction of renewable energy on FDI

Rank	Sub-Theme	Participant Code	Frequency
1	Renewable Sources	P3, P5, P12, P14, P18	5
2	Return on Investment	P3, P11, P12	3
3	Energy Security	P11	1

The responses from the solar installers did not give one consistent re-emerging theme. All the participants from this sample group had different views on how the incorporation of renewables has an effect on investment. Participants either considered 'energy security' or 'return on investment' as the main factors for FDI.

Participant 3 remarked that the choice for investment "*depends on the type of industry" (P3, 35:35),* which was supported by participant 11 who mentioned that it is not so much how the energy is generated but rather its availability that matters, i.e. *"If they are a very intensive energy business, so for instance there an aluminium smelter, then perhaps the energy is particularly important but how that energy is manufactured I don't think features in investment criteria for investors" (P11, 27:27).* Participant 5 shared an entirely new perspective by mentioning that one needs to look at sustainability and whether it is working "*in their current best practices globally or is it not" (P5, 18:18).*

One factor that kept re-occurring was the concept of return on investment. Similar to what participants in the previous two groups (utility and IPP) mentioned, return on investment seems to be a major influencer on FDI. In participant 11's view, *"investors take lots of factors into consideration but the key thing is can they get a return on their investments" (P11, 25:25).* As was also seen from the interviews with the other two groups, energy security was believed to be a primary motivator for FDI, i.e. *"energy is particularly important… and there the primary thing is going to be the security of it" (P11, 27:27).*

According to participants 12 and 14, 'renewable sources' do indeed play a vital role in bringing in FDI, especially into developing countries. These two participants brought up the REIPP programme, which has "*brought in R 200 billion worth of private sector FDI into the country" (P12, 24:24).* Furthermore, participant 14 shared the view that "*today our foreign direct investment is based on the use of renewables. Our economy is at zero growth because we have something; otherwise it would have been negative" (P14, 19:19).*

From a South African context, it seems that renewables have a lot of potential, especially due to the influence of government projects such as the REIPPP.

5.6.3.4 Conclusion

From the results, it is evident that the major factors influencing FDI are return on investment and the energy security offered by the country, especially for investments into energy intensive businesses. It was also seen that renewables will always prove to be an advantage, even though it will not be the primary motivation for investment. So, in terms of FDI, it can be concluded that having renewables is an advantage, however this is not as strong a driving factor as the main sub-themes that emerged from the study, such as 'return on investment' and 'energy security'.

5.6.4 Grid type

In an attempt to understand what the perceptions of the participants from the utility, IPPs and solar installers were regarding whether there is a need to integrate solar onto the grid, the researcher asked the participants which grid type would be the most ideal to supply power. This question was asked as a build up to Research Questions 2 and 3. The answers to this provide clarity on why there needs to be integration of solar onto the grid.

5.6.4.1 Utility

As seen from Table 19, the sub-theme 'mixed grid' ranked the highest with a frequency count of 7.

Table 19: Utility's perceptions on grid type

Rank	Sub-Theme	Participant Code	Frequency
1	Mixed Grid	P1, P8, P9, P10, P13, P16, P17	7
2	Full Grid	P10, P16	2

Although a number of reasons were mentioned as to why the mixed grid is the most ideal, the factor that emerged most was reliability of supply. Seemingly, the perception that the grid is unreliable is one of the main reasons the participants said they prefer a mix of grid and solar to provide energy.

All seven participants from the utility were in agreement that a mixed grid is the ideal configuration, and the one they would most like to have in place. This was a key revelation, as the researcher now had an indication that the penetration of renewables like captive solar technology was something that was being considered, especially from a reliability point of view. This was evident in the responses. Participant 13 remarked that a mixed grid has two advantages, firstly, "*you can ask for the grid connection completely for a security of supply",* and secondly, "*you can reduce your operating expenditure by using solar" (P13, 53:53).* Participant 9 shared the view that the integration of solar captive technology onto the grid can be advantageous because "*you have a thousand houses, generating power more than they can use, then they push on to the grid and help the rest of the country, everyone else" (P9,77:77).*

Not everyone was convinced that mixed grid was most ideal. Participant 8 went on to explain why a fully off-grid system would not work; *"…one of the main disadvantages that people bring to the fore when they discuss the renewables issue…it's not flexible, it's only available during the day for sun or during the night for heat (P8, 28:28).* This is another reason as to why the ideal grid configuration would be a mixed grid system. Participant 16 shared the view that reliability is the main concern, and if "*the grid becomes unreliable, well then, I'd prefer a mix" (P16, 47:47).*

5.6.4.2 IPP

Similar responses emerged from the IPP participants. As seen in Table 20, 'mixed grid' had the highest ranking with a frequency count of six.

Table 20: IPPs' perceptions on grid type

Rank	Sub-Theme	Participant Code	Frequency
1	Mixed Grid	P2, P4, P6, P7, P15, P18	6
2	Full Grid	P4, P6	2

The views of the interviewees from the IPP were in line with those of the participants from the utility. Although the reasons for the selection varied, all six participants from the IPP conceded that the best type of network configuration was the mixed grid. In an attempt to understand the main themes that emerged from the study, the answers were dissected further.

Going fully off grid was ruled out by participants 4 and 6, who suggested that some industries are energy intensive thus need reliable supply of energy, so *"it depends on the industry you are in" (P4, 17:17)*. These sorts of industries would need to get their base load from traditional utilities because *"they are really energy intensive projects. They would probably want a technology which gives you a very strong base load. That is where things like wind and solar struggle" (P4, 17:17).* This implies that a mixed grid would allow energy security because the base load can be supplied from the utility and the rest can be supplemented using solar. Furthermore, participant 6 added that it is actually beneficial to have a mixed grid, especially in rural areas that are far from the grid; "*an off-grid solution which is a mix might be the best option, because it's going to be too costly for a utility to bring the grid there, so that could be the best solution for that specific area" (P6, 93:93).*

However participant 15 related the choice of grid type to economic growth. In their view, "*…whether it's mixed technology or not necessarily going to improve your economic condition. But maybe because you might have more reliable energy supply you might see investors coming through which is good" (P15, 33:33*). Participant 18 also focussed on the cost implications of the grid configuration by saying that *"the mix is great because utilities are an amazing source of revenue for a government" (P18, 61:61).*

From the IPP perspective, the theme that appeared the most in relation to the choice of grid configuration, specifically mixed grid, was the theme of reliability of electricity supply. Other factors to be considered include the effect of the grid configuration on economic growth.

5.6.4.3 Solar installers

The sub-theme 'mixed grid' also ranked the highest with a frequency count of four. The counts are as seen in Table 21.

Table 21: Solar installers' perceptions on grid type

Rank	Sub-Theme	Participant Code	Frequency
1	Mixed Grid	P3, P5, P11, P14	4
2	Full Grid	P12	1

Like the IPP and utility, 80% of solar installers agreed that the mixed grid configuration is the most conducive for economic growth. Participant 5 commented that a mixed grid is the most viable option because "*to be completely off the grid, it's not very easy, it's possible but not very easy, and very few people can manage it… (P5, 20:20).* At the same time, "*to be on full time grid is so very expensive for the populations in Africa here. So, the third one, the hybrid one should be the one conducive." (P5, 20:20).*

Participant 14 suggested that the utility is "*suffering a lot when it comes to peak energy production. Take solar in particular; with solar the yields are higher during the peak which means effectively they actually lessen the strain on the utility. So, that is very good. But then, what it means, because the yields are high, it means that the companies that are producing that energy and they can then feed it back. They will have a portion for their own consumption, but the surplus they will feed it back into the grid making it available to everybody else who needs it, thereby lessening the load on the utility" (P14, 25:25).*

Thus, it can be concluded that a mixed grid would prove to be most beneficial to the utility, as it will decrease the load and also provide an opportunity for excess energy to be sold back onto the grid.

However, there was one participant who disagreed with this notion. Participant 11 insisted that full-grid is the best, and was convinced that cost-wise, "*grid is the best, it is below to its cost option…whereas alternative off grid it's always going to be higher in terms of the energy cost across it" (P11, 33:33).* The researcher considered this to be an interesting point of view, as economic growth can be accelerated if there is a reliable and cheap supply of electricity, and if the electricity from the grid can provide this then there could be no need to consider otherwise.

5.6.4.4 Conclusion

Only one out of the 18 participants interviewed chose a grid configuration besides the mixed grid. A variety of reasons were mentioned as to why a mixed grid would be an ideal configuration, chief of which were energy security and reliability of supply. Furthermore, from a cost perspective, captive solar PV technology may still be quite expensive, especially to those more disadvantaged, hence a mix would allow savings on cost. Overall, the results indicate that there is indeed an opportunity and need for captive solar PV penetration, as the mixed grid is the ideal network configuration.

5.6.5 Drivers for solar penetration

Since there was unanimous consensus among the participants that a mixed grid is the preferred configuration choice, the researcher sought to investigate which factors drive or demotivate solar penetration from an economic standpoint.

5.6.5.1 Utility

The three main sub-themes that emerged from the findings were 'cost', 'energy security' and 'regulations'. The driver 'cost' received the highest frequency counts and was ranked as the main sub-theme. This was followed by energy security, which ranked second, and regulations, which ranked third. This is as shown in Table 22.

Table 22: Utility's perception on the drivers for solar penetration

Rank	Sub-Theme	Participant Code	Frequency
1	Cost	P1, P8, P9, P10, P13, P16, P17	7
2	Energy Security	P8, P13	2
3	Regulation	P10	1

Participant 9 commented that the current costs of electricity or *"exorbitant tariffs" (P9, 81:81)* are motivating people to move onto captive solar technology. This was also supported by Participant 17, who mentioned that *"the time of use tariff comes in to push people to try and cut the peak loads which is the grid's problem and try and shift that into some alternative" (P17, 17:17).*

At the same time, participant 16 remarked that the price of solar coming down is another reason that more people are moving onto solar, i.e. *"if these things are locally available, obviously, the costs are going to come down and they talking in terms to be able to purchase and manufacture, backup and all those kinds of things" (P16, 53:53).* However, at the same time, the participant mentioned that *"the cost of the systems and the batteries... need to be improved…" (P17, 28:28).*

The researcher found participant 10's view on the subject quite enlightening. According to them, *"the main thing is the driver behind it would be people who want power…" (P10, 16:16).* Although this was not the most common theme that emerged, the researcher found that this is something that is subsequent to issues such as reliability of supply and cost. If people find it more secure energy-wise to move onto solar, then they will do so.

Overall, from the utility's perspective, the costs of electricity prices and the need for energy security or reliability of supply are the main drivers motivating the move onto solar energy.

5.6.5.2 IPP

As with the participants from the utility, the sub-theme 'cost' was seen to be the main theme, with the highest frequency count. However, the sub-theme 'regulation' ranked second, and 'energy security' third, when compared to the data gathered from the utility.

Table 23: IPPs' perceptions on the drivers for solar penetration

Rank	Sub-Theme	Participant Code	Frequency
1	Cost	P2, P4, P6, P7, P15, P18	6
2	Regulation	P2, P6, P18	3
3	Energy Security	P4	1

All six participants agreed that cost is huge motivator pushing solar penetration. Once again, cost of electricity and a decrease in solar prices were identified as a reason to move onto solar. Participant 7 spoke of the levelised cost of electricity and said that *"if you look at the levelised cost energy from an embedded solar generation system relative to what you are paying in municipalities or your utility provider, you can generate electricity cheaper" (P7, 39:39).* Another cost factor that could potentially be seen as a driver for ideal penetration is feeding back onto the grid. Participants 2 and 18 were of the opinion that if people were allowed to sell back into the grid, that would motivate more of them to move onto solar. However, many participants also mentioned that the actual cost of implementing the technology is a factor that is hindering its absorption among people. As participant 4 remarked, *"price becomes more of an issue" (P4, 27:27).*

The sub-theme 'regulations' was mentioned by three of the six interviewees from the IPP. According to them *"regulation and policy influences it" (P18, 78:78),* i.e. movement onto the grid. Furthermore, participant 15 expressed the view that "*policies that are going to encourage people to sell renewables, especially during the day. You are at work, you are producing so if you can produce and produce and sell it to the grid and when you come back home you can take that back and you are going to get credited, or whatever it is, that's much better than not having any income. Because what you are doing is creating a business for yourself, you are a power producer and you get paid for what you are producing when you are not consuming that much" (P15, 35:35).* This implies that if net metering and feeding-in are allowed, more customers will be motivated to move to solar.

5.6.5.3 Solar installers

The sub-theme 'cost' was also seen to be the main theme among this group of participants as well. However, energy security was not brought up by any of the participants in this group.

Table 24: Solar installers' perceptions on the drivers for solar penetration

Rank	Sub-Theme	Participant Code	Frequency
1	Cost	P3, P5, P11, P12, P14	5
2	Regulation	P12	1
	Energy Security		0

Although the central theme was around price, the participants brought up interesting concepts in relation to pricing and cost. For example, participant 14 thought that price is the limiting factor for the layman, however it may not necessarily be an issue for big companies. *"The drivers…let me just say at the moment, who can afford the solar panels? You'll find it's bigger companies that have a lot of money because if you look at the paybacks for those kind of system, because of the initial hike that is required for the equipment, it will take 7, 8, 9, 10 years' payback" (P14, 35:35).* Two of the participants looked at the cost in relation to the utility. Participant 5 mentioned that *"in the current economics time, it's not very possible, they will do it but at very small percentage they cannot manage 6%, solar is to very expensive, solar panels, the wiring, the installation" (P5, 24:24).*

Only one count was brought up in terms of regulations. Overall, all the participants from this group agreed that the increasing cost of electricity is the primary motivator for a move onto solar.

5.6.5.4 Conclusion

As seen from Table 22, Table 23, and Table 24, 'cost' emerged as the primary driver for solar penetration with a total frequency count of 18. Other drivers that were mentioned as drivers for captive solar technology were the influence of regulations and policies and energy security.

5.6.6 Impact of solar penetration

This section was aligned to the thoughts and answers set out in section 5.6.5. Since cost was brought up as the central theme in the previous section, the researcher asked the participants what would happen to those customers who remain on the utility if more people move onto solar. The main sub-themes that were picked up from this section were 'increased prices', 'no changes in prices' and 'lower prices'.

5.6.6.1 Utility

As seen in Table 25, the sub-theme 'increased prices' ranked the highest with a frequency count of three.

Table 25: Utility's perception on the impact of solar penetration

Rank	Sub-Theme	Participant Code	Frequency
1	Increased Prices	P8, P9, P16	3
2	No change in Prices	P17	1
	Lower Prices		0

The researcher expected most of the answers to be centred around an increase in the price of electricity sold by the utility, which was indeed the case for three out of seven participants. Participant 9 remarked that *"it will have an impact, because now the network operators will increase the charges to be connected and will charge you a higher revenue, because the maintenance cost of the network will always be there" (P9, 89:89).* Furthermore, participant 8 expressed that *"if the utility cannot get other ways and means to keep their income at levels where they had it before, they will have to do something… the price of electricity will not go down; probably, it will increase" (P8, 34:34).* Participant 16 echoed similar sentiments and mentioned that *"if it happens country wide large then the cost of electricity is going to increase, so you now going to pay more cause the same infrastructure needs to be there" (P16, 63:63).*

However, at the same time, these same participants mentioned that solar penetration will not increase to such a level where the people who are still on the utility will not be able to buy the power, because "*it doesn't help, in general, to sell something that no one can buy" (P8,36:36).* This implies that there might be an increase in price, however it would not be so drastic that the customers still on the utility would not be able to afford it any longer.

On the other hand, participant 17 shared the view that there will really be no impact on the price. According to this participant, *"even if you go onto a mixed grid, you are going to pay for the service and availability, so they need to look at that" (P17, 40:40).* Participant 17 raised a valid point in that the utility will still be able to charge for the service fee, because it is not possible to go completely off-grid unless there are storage measures in place, and these are currently too expensive to purchase. This means that more people moving onto solar will not really have a drastic impact on the utility, and consequently there will be no impact on those customers depending on the utility for their power supply.

An additional construct that emerged was that of 'business models'. Participant 16 suggested that utilities may have to revise their business models to ensure that such events do not cause drastic alterations to their current operations, and commented that *"the utility will have to look carefully at its business and they will have to get in involved in the particular market as well and not just be purely generation in terms of coal, nuclear etc.…so their business model will have to be examined (P16, 61:61).* This suggests that the utility should consider incorporating renewables such as solar onto their system so they do not have to battle the competition and increase their prices in the case that more people move onto solar.

5.6.6.2 IPP

Similar sub-themes were picked up from the IPP participants, and, like the utility, the sub-theme 'increased prices' ranked the highest with a frequency count of two. See Table 26.

Table 26: IPPs' perceptions on the impact of solar penetration

Rank	Sub-Theme	Participant Code	Frequency
1	Increased Prices	P2, P18	2
2	No change in Prices	P15	1
	Lower Prices		0

Two out of the six participants highlighted that theoretically the price should be driven up, which would affect the lower end customers; *"it drives the price up for everybody… It becomes a massive issue because it's going to hit the bigger users, because it's the people that can afford that go off, and then your lower end and your subsidised customers then becomes a massive problem"* (P2, 25:25). These increasing prices, according to participant 18, might cause more people to switch to solar, thus *"it might force the utility to also go renewable and decrease its own cost, and maybe it will have a positive impact and force them to streamline, make them become more efficient, more cost effective, and then it will have a positive impact" (P18, 85:85).*

On the other hand, participant 15 commented that there will be no impact if more people move onto solar, because *"it does not necessarily mean that the utility will charge these people a lot of money because they are only a few… the prices only go up when there is high demand, not when there is low demand – that's bad economics" (P15, 37:37).*

The construct of 'business models' was once again highlighted. According to participant 7, *"the large consumers of that electricity are the higher income portion of the population" (P7, 41:41),* hence it was suggested that the method of electricity distribution should change.

Overall, the majority of IPP participants foresee an increase in price for those that remain on the utility. This is the same as the findings from the utility itself.

5.6.6.3 Solar installers

Similar responses were given by the solar installers; no new themes emerged from the interviews with these participants. However, the highest ranked sub-theme, with a frequency count of three, was 'no changes in prices'. Unlike the participants of the utility and IPP, solar installers were more adamant that there will be no changes in the prices of electricity even if more people move onto solar. This is as shown in Table 27.

Table 27: Solar installers' perceptions on the impact of solar penetration

Rank	Sub-Theme	Participant Code	Frequency
1	No change in Prices	P3, P5, P12	3
2	Increased Prices	P14	1
	Lower Prices		0

Three out of the five solar installers emphasised that the electricity prices cannot change. According to participant 5, "*people that literally can't afford, they are most in the rural areas" (P5, 30:30).* This implies that even if the grid decides to increase prices the most disadvantaged people will have no way of paying the tariffs, thus there is no point in hiking them. In relation to this, another perspective was that there will be no changes in electricity price because "*infrastructure would take more and more of a knock, so impact there would simply mean the quality of power" (P3, 64:64).* This implies that if the prices remain the same, the quality of power will decrease. Participant 14, on the other hand, commented that the prices will increase because the utility will have to support the same infrastructure to generate less power, i.e. *"…they will end up paying more because the costs to utility to generate are the same" (P14, 41:41).*

The majority of the participants from this group were of the opinion that there will be no price hike, however there will be a decrease in the quality of the power that is provided due to the knock on the utility's revenues.

5.6.6.4 Conclusion

Overall, the sub-theme 'cost' ranked the highest with a total frequency count of six. It was evidenced from the results that those that remain on the utility will have to pay higher tariffs as a result of more people moving onto solar. This, according to some participants, is an indication that the utility needs to revise its business model in order to incorporate renewables, so that in the event that more solar pentation occurs, the utility will not suffer losses in revenue.

5.7 Data Analysis for Research Question 2

<u>Research Question 2: Is it possible to find an ideal penetration level that is beneficial to both the utility and customer?</u>

Research Question 2 was aimed at identifying whether it is possible to find a level of captive solar PV penetration that will prove beneficial to both the customer and the utility. From the themes that emerged from research question 1, it became evident that finding an ideal penetration level is important, as it could impact the customers that remain on the utility, as well as the utility itself. However, the researcher wanted to find out whether it was actually possible to do so.

Once again, this section will break down the common themes that have emerged through discussions with the participants. The sections will be sub-divided into the data gathered from the three stakeholders, similar to what was done in section 5.6. In an attempt to understand the viewpoint of the participants in terms of whether or not an ideal penetration level can be found, the researcher broke down the question and studied it from different angles. Sub themes that the researcher looked for included reasons that favour investing in solar; reasons that favour investing onto the grid; and possible constraints for finding the ideal penetration level. The results obtained are presented below.

5.7.1 Reasons for investing in solar

This question was similar to the question that the researcher asked in section 5.6.5. The researcher wanted to understand the reasons for investing into solar in an attempt to understand and reinforce the need to find an ideal penetration level. The main sub-themes that emerged from the study are shown in Table 28, Table 29, and Table 30.

5.7.1.1 Utility

When asked whether businesses and the public should invest in solar technology or electricity supplied by traditional utilities, the responses emanated around the economics and costs involved in such a decision, as well as whether the decision was being made from an industrial perspective or a residential one.

From Table 28 it is evident that the main sub-theme influencing more investment into solar is ‘cost and economics’, with a frequency count of seven.

Table 28: The utility’s reasons for investing in solar

Rank	Sub-Theme	Participant Code	Frequency
1	Cost and Economics	P1, P8, P9, P10, P13, P16, P17	7
2	Environment and Energy Security	P8, P9, P13, P16	4
3	Type of Industry	P1, P8, P10	3

The majority of the participants emphasised that cost and the economics involved are the major factors influencing investment into solar technology. This ties up with the findings in section 5.6.5, where cost was the found to be the main driver for solar penetration.

Four out of the seven participants commented that investment eventually comes down to *“the economies of either staying with the one or going to the other” (P8, 38:38).* This was echoed by participant 10, who mentioned that if you can *“afford to independently supply yourself without knowing anything about it and then still focus on your core* *business and increase your business and your company" (P10, 61:61),* then you should invest into solar. Moreover, if investment into solar comes with a benefit, then one would invest into solar because "*if there is no benefit to me I am not interested as a business" (P17, 44:44).*

'Environment and energy security' was ranked second, with a frequency count of four. Participant 9 looked at the environmental concerns. *"Number one, we are going to save the environment, secondly, it is cheapest form of generation… most utilities around the world are going into renewables to save themselves, because the costs are lower" (P9, 105:105).* This was also supported by participant 16, who commented that one would invest into solar if *"you want to give an image of being environmentally friendly" (P16, 79:79)*. In addition to this, participant 4 brought up the issue of reliability of supply as a strong reinforcement as to why one would invest into solar; *"where there are energy security issues even households will look to it" (P8, 42:42).*

Another driver for investment is the sector one belongs to, i.e. whether one is making the decision from an industrial point of view or from a residential point of view. Participant 1 suggested that *"from an industry perspective if I was a business man that's what I'd look at, so I was a business man owning a shop, and I need my lights on and I need my cash register to be working properly I'd put a generator because I'm still having channel. If I'm like smelter, I'll be comfortable. If I'm a very high use of electricity like Sasol, I'll build my own infrastructure, depending on their technology" (P1, 82:82).* This implies that investment into solar is driven by the type of energy one needs to perform core functions. If solar is able to meet these functions, then that is reason for investment. Further, participant 8 highlighted that *"if you look at industries, it's a different story. In many instances, they could easily adopt that because they can get the tax benefit for the taxing incentives and they can, because its expense, cover some of it through taxes. But for the normal 'man on the street' they need to pay for it, get it installed and they don't know the technology very well and it is not cheap, not at this stage" (P8, 38:38).* Once again, the implication is that the reasons for investment into solar will vary according to the industry or sector that one is in.

5.7.1.2 IPP

Like the responses obtained from the participants from the utility, the interviewees from the IPP brought up similar topics and factors during the discussions. Once again 'cost and economics' emerged as the main sub-theme with a frequency count of six. Following this the sub-themes of 'environment' and 'energy security' emerged, and finally 'type of industry'.

Table 29: IPPs' reasons for investing in solar

Rank	Sub-Theme	Participant Code	Frequency
1	Cost and Economics	P2, P4, P6, P7, P15, P18	6
2	Environment and Energy Security	P4, P6, P18	3
3	Type of Industry	P4, P18	2

Participants 2 and 4 from the IPP commented that a major influencer of the choice of whether to invest into solar is cost and economics; *"So, it's all about the forecasting…understanding what your current cost would be and generally if those costs are going to be accelerating more than your other cost base they'll effectively become a bigger proportion of your costs" (P4, 35:35).* Participant 2 brought up costs in terms of solar technology, and responded that the actual expense depends on the user profile; *"…without sufficient battery backup, it'll be very difficult for them to go completely on to solar just because they're not going to do all their energy set requirements during daylight especially in winter. So, when you say going 100% onto solar it's not just panel and inverter its, panel, inverter and battery. Then cost then goes up exponentially…" (P2, 53:53).*

This implies that a user's profile influences the move onto solar. People from the higher income classes are more prone to moving onto solar than those from the middle and lower income classes because they are able to afford the technology. Furthermore, participant 15 mentioned that people should invest into solar as the current utility's infrastructure is old, consequently *"the cost of electricity going up because of the operating costs"* (P15, 47:47). This notion was supported by Participant 18, who mentioned that *"we should always be investing in these new technologies, and as much as possible encouraging the utility to make that switch" (P18, 95:96).* The underlying motivator for investment thus boils down to cost.

In terms of the 'environment' and 'energy security', participant 7 mentioned that the issue is about energy efficiency rather than a cleaner energy source. *"So, quite simply, businesses and households should invest in embedded generation technology because it makes economic sense. But before investing in embedded generation technology, they* *should be looking at energy efficiency first. So, it's about measuring and then optimising your utilisation of energy and then looking at the embedded generation" (P7, 45:45).*

Furthermore, participant 6 emphasised that *"…businesses should continue investing into solar, from an energy security point of view" (P6, 141:141).* Once again, the issue of energy security or reliability of supply came up as another reason to invest into solar technology. However, this was only mentioned by one of the participants from the entire IPP group.

Overall, the themes that appeared from the discussions in this group were similar to those mentioned by the participants from the utility. Once again, cost was ranked as the number one theme. The IPP participants also mentioned energy security as a reason for people to invest into solar. Additional concepts that appeared were the need to invest into solar because of the utility's aging structure, and energy efficiency.

5.7.1.3 Solar installers

Similar to the results observed with the utility and IPPs, 'cost and economics' once again was ranked the highest, with a total frequency count of five.

Table 30: Solar installers' reasons for investing in solar

Rank	Sub-Theme	Participant Code	Frequency
1	Cost and Economics	P3, P5, P11, P12, P14	5
2	Environment and Energy Security	P3, P5, P11	3
3	Type of Industry	P5	1

Participants introduced factors such as the payback period, the possibility of feeding back into the grid and net metering as prompters to move into solar. Some participants also mentioned savings if investment is made wisely. Participant 3 mentioned that *"if you invest smartly in technology you are going to save money, you're going to save money against what you're currently paying on today's rate, on old coal powered plants, the R1.67 versus the R1.05" (P3, 75:75).* Furthermore, *"…solar is a substitute for grid, so if it costs less, people will consider" (P11, 93:93).*

Participant 5 remarked that one needs to consider the environmental aspects of investing into solar, i.e. *"there will always be environmental aspect on the side of solar energy* *whether it's public service or private sector" (P5, 34:34).* This implies that there is a positive outcome, because cleaner methods of energy production are better for the environment. Participant 14 considered the health effects of electricity generation using coal fired stations, and remarked that one should invest in solar to improve the health and wellbeing of the people of the country. According to participant 14, *"a lot of people are suffering from a lot of illness caused by pollution that's made by…I mean there's grain and there's sulphur in the air and so people suffer from lung diseases people suffer from sinuses, and so forth, and irritations. And these are the costs that are borne by the society. The producer is not actually paying for these costs…" (P14, 51:51).* This implies that more serious issues such as the effect on health and the environment are often overlooked merely because of the costs involved in implementing cleaner forms of energy generation. The comment participant 14 brought up alerted the researcher to this.

Overall, the main factors driving investment into solar from the perspectives of the solar installers are cost and the impact that coal-based generation has on the environment and the health of the people.

5.7.1.4 Conclusion

From the results, it was evident that the major decision driver for investment into solar is the bottom line or cost of investment. Depending on the category or sector and the costs involved, and if investing into solar is not detrimental in any way to the core business and manages to make the business more profitable, then it provides sufficient reason for investment into solar. In addition, the effect that solar has on the environment is another reason for investing into solar. The need for energy security was also an aspect that was brought up by a number of participants. Additional factors that were mentioned were the influence of the utility's aging infrastructure and the health effects of coal based generation.

5.7.2 Constraints to ideal penetration

In an attempt to find out whether or not it is possible to identify an ideal penetration level, the researcher prompted the participants to remark on the possible constraints or variables that could influence finding this level.

5.7.2.1 Utility

From the findings, the main sub-themes that appeared were 'storage', 'technical or environmental' factors, and 'lack of data or awareness'. The sub-theme 'technical or environmental' factors ranked the highest with a frequency count of four, as seen in Table 31.

Table 31: Utility's constraints for ideal penetration

Rank	Sub-Theme	Participant Code	Frequency
1	Technical/Environment	P1, P10, P13, P17	4
2	Storage	P13, P16	2
2	Lack of Data/Awareness	P1, P17	2

Participant 17 commented that different weather patterns over different areas make it challenging to identify just one ideal penetration level that will work over the entire country. *"So, in the Cape area, the cost of sunshine is limited, but in Highveld regions, in Limpopo there is an economy to hit there as they have moderate climate" (P 17, 52:52).* This implies that different areas will most likely have different ideal levels of penetration, depending on the weather patterns and the other constraints mentioned above.

Furthermore, the transportation of power from the major load centres was mentioned as an issue by participants 10 and 13. Participant 10 was of the opinion that *"as you see one sector increase in penetration level, now how does that affect the other level because on our map your larger load centres are here in Johannesburg, Durban and Cape Town but your higher potential for solar is the Northern Cape so to take that from there to there is the same problem a coal station taking the power from there to there, the losses are still there so you've got to see the benefit of penetration" (P10, 79:79).*

This was further supported by participant 13, who mentioned that *"you need that establishment. So, that is actually, our problem. Unless we have a storage system… we need the peak times, and maybe you don't have enough money to go and have a big battery bank and things like that, unless something else comes. So, the complete business would change, and we all want to generate power to closer to the load" (P13, 105:105).* This was further re-emphasised by participant 10, who said *"we need the peak times, and maybe you don't have enough money to go and have a big battery bank and things like that, unless something else comes. So, the complete business would change,* *and we all want to generate power to closer to the load" (P10, 81:81).* This implies that unless there are measures for energy storage in place, it is difficult to identify a penetration level that will be suitable for every area. Also, depending on the area, the level of penetration could differ.

Additionally, it seems that a major constraint for finding the ideal penetration level is the fact that there is insufficient data about the weather profiles and the subject as a whole. Participant 17 commented on this issue, raising some valid points about the lack of data needed to make such deductions. According to participant 17, *"there are a lot of studies overseas trying to take that watts per square meter into light per square meter availability. It's a matter of getting a good educated system there"* and getting *"the technical advice out" (P17, 58:58).*

5.7.2.2 IPP

Similar to the findings from the IPP, 'technical or environmental' factors ranked the highest with a frequency count of four.

Table 32: IPPs' constraints for ideal penetration

Rank	Sub-Theme	Participant Code	Frequency
1	Technical/Environment	P2, P4, P7, P18	4
2	Storage	P4, P7, P15	3
2	Lack of Data/Awareness	P18	3

"It's a dynamic system. So, we could have a theoretical ideal level, but it's going to change… the level of economic growth; it's not in your control, and it will vary so over a period of time that penetration level, it will probably increase, so you can't say that this is an ideal level and peg it there" (P6, 165:165). This could be attributed to variables such as weather patterns, location and the availability of technology. This was supported by participant 15, who said that "*the models vocating for renewable energies are going to increase. In the renewable energy mix do these models and they can estimate, they can give you... but obviously, they have to rely on weather patterns over the period and take the technology into consideration" (P15, 73:73).*

Like the participants from the utility, the issue of storage was a hotly discussed topic. It seems that a constraint to find an ideal penetration level is the actual storage of the energy generated by solar. Participant 4 shared the view that "…*panels are the one issue and storage is the other one. You have to get them both right so the panels can be as cheap as possible but if you can't store it you haven't solved the problem" (P4, 39:39).* This was backed up by participants 7 and 15, who remarked that *"energy storage can be that balancing" (P7, 63:63),* because *"this excess has to be stored somewhere so that at a time when you don't have that excess, if it's overcast for example and you don't get three megawatts, you can put it back" (P15, 73:73).*

Participant 18 commented that *"data is always a constraint, because if it is something that has never been done before, you need to deduce what is your baseline, and that is a massive one" (P18, 119:119).* It seems that a lack of data is a common concern among most participants. The actual lack of data makes it difficult for anyone to identify the ideal level of penetration.

An additional theme that emerged included the need for *"planning around our generation and transmission infrastructure" (P7, 65:65),* as well as the need for regulations surrounding solar penetration.

Overall, the main constraints identified from members of the IPP included concerns over storage and lack of data. Additional factors that were brought up included the fact that the system is dynamic, thus there will never be just 'one' ideal penetration level.

5.7.2.3 Solar installers

The sub-themes 'technical or environmental' factors and 'lack of data or awareness' both had the same frequency counts, hence they were ranked the highest.

Table 33: Solar installers' constraints for ideal penetration

Rank	Sub-Theme	Participant Code	Frequency
1	Technical/Environment	P5, P11, P14	3
1	Lack of Data/Awareness	P3, P5, P14	3
2	Storage	P14	1

An issue that was brought up by two participants was that there seems to be a lack of awareness or interest in the subject, which is limiting the search to find the ideal penetration level. *"So, the ability to gain data is not, not a problem…it's just …because* *they not interested, because they don't want to…" (P3, 96:96).* Participant 5 echoed the sentiment by saying, *"I would think the knowledge base is still not well communicated, I think there are people that are not knowledgeable in the providers, electricity [providers that generates electricity at the national level" (P5, 48:48).* It seems that more than a lack of data, it is a lack of interest and awareness of the subject that makes it "impossible" to find an ideal penetration level. Participant 14 argued that currently *"calculations are not based on a household level" (P14, 61:61),* adding that it will be impossible to pinpoint one exact target because *"you are chasing a moving target here because it is not static" (P14, 67:67).* This implies that more information is needed on the variables that are associated with an ideal penetration level.

The issue of storage only came up in conversation with one member of this group. According to participant 14, "*you can have as much solar as you want but it will never replace the current stations because of fluctuations of the sun and you don't have it at night. The only time it will be visible or you could have 100% penetration is if you had storage and then you can supply the base loads" (P14, 75:75).*

Overall, a lack of data or awareness was the main sub-theme that emerged from the discussions with the solar installers.

5.7.2.4 Conclusion

The key finding is that an ideal penetration level cannot be pinpointed as it is a dynamic system. The main constraints that were identified were inadequate storage, lack of data, and environmental factors such as weather patterns. Additional themes that were briefly mentioned included the need for planning and management, and the influence of policies and regulations on the ideal penetration level.

5.8 Data Analysis for Research Question 3

<u>Research Question 3: If an ideal penetration level can be found, what drivers influence it?</u>

The aim of Research Question 3 was to find the drivers that influence the need for an ideal penetration level, and to see whether they link up with those from the literature (Karimi, Mokhlis, Naidu, Uddin, & Bakar, 2016; Blumsack, 2015 and Manito, Pinto, &

Zilles, 2016) The researcher also considered the advantages and disadvantages associated with finding an ideal penetration level, and whether grid parity has been reached from a South African context.

5.8.1 Need for ideal penetration

The researcher sought to understand which drivers influence the need to find an ideal penetration level. The main sub-themes that appeared, as seen in Table 34, were 'costs', 'environmental or technical' drivers and 'feed-in tariffs and net metering'.

5.8.1.1 Utility

The sub-theme 'environmental or technical' ranked the highest, with a frequency count of six.

Table 34: Utility's need for ideal penetration

Rank	Sub-Theme	Participant Code	Frequency
1	Environment/Technical	P1, P8, P16, P17, P13, P10	6
2	Feed-in Tariffs and Net Metering	P6, P8, P9, P13, P16	5
3	Costs	P9, P8, P16, P17	4

In answering the question about which drivers prompt the need to find an ideal penetration level, a number of environmental and technical drivers were mentioned. *"A lot of people want to be environmentally friendly, that's another driver" (P16, 125:125).* At the same time, Participant 10 mentioned that, *"…you actually need to understand this from a deeper perspective, rather than this is green and is saving the planet. That increase in awareness and education is also required" (P10, 98:98).* Thus, the implication is that other than environmental friendliness, people need to be aware of the actual benefits of using this technology.

Furthermore, the choice of location is a clear driver of how much penetration of solar one can have onto the grid. *"…the amount of solar you can get in the country" (P16, 125:125)* is clearly influenced by the location, and this is also another big driver that determines the amount of penetration that is possible. Also, certain areas have different issues with supply of energy. Naturally areas that have less energy security will be more enticed to encourage more penetration of solar, i.e. "*…certain areas, like the area in Alberton that* *has been out for days because of major cable farts" (P17, 64:64).* Technical factors mentioned included looking at whether you have *"enough resources, infrastructure and if you're putting it on the roof can your roof even handle it?" (P10, 98:98).*

Another major driver that was identified was that of feed-in tariffs and net metering; currently there are no regulations in place for net metering and feed-in tariffs. Participant 16 remarked that selling onto the grid could be more of an incentive to increase penetration of solar onto the grid from the customer's perspective; *"…if I had generation capacity of my home and could sell it into the grid, why wouldn't I want net metering? I would certainly would want to sell it back into the grid" (P16, 143:143).* However, there were also a number of remarks on the issue of technical risks and fraudulent behaviour associated with feed-in tariffs and net metering, consequently management is the main concern with these systems. Participant 13 remarked that the "*government is cautious about this thing. You know like here we have people from this and that. People below the border line, they will do anything… the difference between the rich and the poor is very high here. So, management of that will be very difficult now" (P13, 277:277).*

A further concern that was raised is the management of a feed-in tariff and net metering. According to participant 10, this is a "*technical challenge…" (P10, 116:116).* This point was also echoed by participant 8 who said that "*the knowledge and skill is probably the biggest issue at this stage, not all municipalities or even the utility knows how to manage these things – it's a new field" (P8, 97:97).*

This implies that if there are proper management systems in place to monitor and control feed-in and net metering, then there is more incentive for the utility to incorporate more penetration of solar onto the grid. This is thus a driver for finding an ideal penetration level.

Cost also emerged as a driver to find an ideal penetration level. In participant 9's opinion, the "*utility should know how much it costs it to operate the grid and they should get revenue to keep the grid functional" (P9, 166:166).* Participant 9 brought up an interesting point *"that value of penetration, if you had to put it to a Rand amount, there should be sufficient revenue for the utility to maintain the grid" (P9, 166:166*). This implies that if the utility can generate more revenue from the incorporation of solar PV technology, then there will be a drive to increase the level of penetration.

In addition to the three main sub-themes, two additional drivers that emerged from the findings were location and business model. According to participant 17, you are more likely to find a penetration level depending on where you are located*, i.e. "location, the area where you are, can you use it… if you are in rural area, where the network is unreliable you are more likely to do it than when you are in an urban area where there is reliability" (P17, 64:64).*

It appears that the business model that the utility adopts will influence the level of solar penetration that is allowed onto the grid. This means that there will be a certain level at which the level of penetration is capped. Participant 8 highlighted that utilities will manage and look at renewables in order to decide if "*it's actually of value" (P8, 83:83).* This also means correct integration onto the business model, because *"if you incorporate it into somewhere you are not going to go wrong on that level and if you don't… there's a possibility of that spiralling out and I've seen utility death spiral in the US" (P10, 114:114).*

Furthermore, participant 16 brought up a point that renewables will not be able to supply the whole of South Africa, so it will be an advantage for the utility to "*grow in the PV and wind as well, so they also get to have a renewable side to their business" (P16, 139:139).* This implies that the integration of solar onto the grid could actually be enhanced by utility business models adopting green technology, rather than seeing it as a way for the utility to cap the level of penetration.

5.8.1.2 IPP

In the case of the IPPs, the sub-theme 'feed-in tariffs and net metering' was ranked the highest with a frequency count of four. The other two sub-themes ranked second. This is as seen in Table 35.

Table 35: IPPs' need for ideal penetration

Rank	Sub-Theme	Participant Code	Frequency
1	Feed-in Tariffs and Net Metering	P4, P6, P15, P18	4
2	Costs	P4, P6, P15	3
2	Environment/Technical	P7, P15, P18	3

Feed-in tariffs could motivate more people to move onto solar, however they may also compromise the stability of the grid. Participants 4, 6 and 7 all agreed that the utility's aging infrastructure is a challenge when it comes to feed-in tariffs and net metering. Participant 4 was of the opinion that there is a *"technical challenge with that, and it's also linked to the aging of the infrastructure" (P4, 89:89).* These sentiments were elaborated on by participant 6, who said that infrastructure *"needs to be replaced in order to accommodate feed-in tariffs and net metering, so programs to install smart meters and things" (P6, 265:269).*

Participant 15, however, said that it is rather about *"the stability of the grid and there are technologies that are being developed to balance this" (P15, 101:101).* This implies that the level of penetration of solar will be mitigated by the utility in order to ensure that the stability of the grid is maintained and no technical issues arise. This brings about *"opportunities to redesign and reengineer our grids so that they become smart grids" (P15, 103:103).*

Participant 18 looked at feed-in tariffs and net metering from a management point of view. This was similar to participant 13's remark, i.e. there should be systems in place to ensure that people do not misuse the rebates and connect illegally; *"prevent a black market of solar roof tiles, especially if it is not a regulated thing…" (P18, 196:196).*

Once again, cost was listed as a driver for the need to find an ideal penetration level. Participant 4 highlighted that if you know the price and you have "*security of supply - being able to supply yourself so it doesn't matter what happens to everybody else" (P4, 67:67).* This was further reiterated by participant 2, who mentioned that the cost of solar was a motivator to find an ideal penetration level, because the lower the cost, the lower the payback period, motivating more people to use solar. *"The main thing is price" (P6, 205:205).*

The researcher ranked the concept of affordability under cost, because affordability ultimately links to demand. Participants 7 and 18 conceded that affordability was the primary driver.

Two additional drivers that were mentioned with regard to ideal penetration were 'regulations' and 'energy security'. The role of regulations and policies was mentioned by a couple of participants. *"There have to be certain guarantees; there have to be certain* *agreements. There have to be policies that drive that" (P15, 83:83).* This was reiterated by participant 18, who mentioned that *"it does limit the potential of being completely shut out because of regulation and the threat that they pose" (P18, 153:153).* This suggests that if utilities view increasing solar penetration as a threat, then the policies and regulations that are in place can actually drive the penetration of solar up to a certain level. This is thus taken to be a driver emphasising the need for ideal penetration. An additional driver that was mentioned was energy security. Participant 4 noted that energy security is another reason to find the ideal penetration level. *"So, if you could take the price out of it then it will effectively come down to security of supply…" (P4, 67:67).*

Other drivers that emerged included the need to go green, i.e. environmental sustainability, as well as ease of maintenance. These did not come up in discussion too often, however, so they were ranked as the least important by the researcher.

5.8.1.3 Solar installers

Drivers mentioned by this group were in line with what was discussed and brought up with the other two groups. The main sub-theme that emerged as shown in Table 36 was 'feed-in tariffs and net metering'.

Table 36: Solar installers' need for ideal penetration

Rank	Sub-Theme	Participant Code	Frequency
1	Feed-in Tariffs and Net Metering	P3, P5, P11, P14	4
2	Costs	P3, P11, P14	3
3	Environment/Technical	P3, P14	2

Feed-in tariffs and net metering arose as a definite driver for ideal penetration level. The technical risks involved in implementing such a system could motivate the utility to prevent more penetration of solar onto the grid, however bringing in structures such as rebates could increase the amount of people that move onto solar. According to participant 5, *"risk can only probably be the costs involved because you have to employ, taking co-expertise, the skilled people, skilled personnel on the installation of types of those pieces of equipment… so that would be part of the risk, to say there is money involved at an initial cost but there is more benefits than the risks because we've got the ability in terms of the metering a getting the exact consumption that someone is accurately consuming over, or an entity is consuming" (P5, 86:86).* This means that although there are risks involved the benefits outweigh the negatives, which could prove to be beneficial to the utility. If the utility finds this useful, then they may promote more integration of solar onto the grid and the penetration level could increase. On the other hand, participant 14 suggested that such systems pose no risks at all, mentioning that "*overseas they have it; it's even an old system now, it's strident as that. It's new to us, but its tried and trusted" (P14, 117:117).*

Costs was ranked as the second sub-theme. Three out of the five participants interviewed mentioned cost to be a driver for ideal penetration. According to Participant 3, *"the relative price of what we sitting with historically in generation capacity and assets… has to be used" (P3, 104:104).* This suggests that if the price of solar seems more feasible than what the consumer is currently paying for electricity, this will drive many people to move to solar, thereby increasing the ideal penetration level. Moreover, Participant 11 mentioned that *"solar is a substitute for grid, so if it costs less, people will consider" (P11, 93:93).*

Under the sub-theme of environmental drivers, solar levels were brought up as a possible driver for ideal penetration. The amount of solar level is dependent on the location and weather patterns. Similar concepts were brought up by participants from both the utility and IPPs. Participant 14 introduced an interesting insight by suggesting that the actual driver is how much energy is required by the utility. *"…driver for the penetration level will be the amount of help that the utility needs during their peak period" (P14, 77:77).* Determining the amount of solar generated during the peak periods, when the utility needs to supply the most power, will indeed influence how much solar penetration is needed. The one fault, however, is that the peak periods usually occur during times when solar energy is at its weakest.

Another driver for ideal penetration that was brought up by two of the participants were 'market forces'. According to participant 7, open markets allow for competition, which is beneficial to the consumer as it reduces electricity prices, i.e. "*there is competition on the open market so you are no longer monopolising it… so you have to be competitive in your pricing" (P5, 76:76).* Participant 12 looked at market forces from a different perspective, suggesting that unlike coal, solar is still quite expensive, so people become somewhat reluctant to move into it. Once again, this seems to relate more to the costs of implementing solar.

5.8.1.4 Conclusion

Overall, the three main themes that emerged in relation to the need to find an ideal penetration level are 'feed-in tariffs and net metering', 'costs' and 'environmental and technical' drivers. Additional drivers that were briefly mentioned included 'business model', 'energy security' and 'regulations'.

5.8.2 Threat to the utility

In an attempt to further understand the need for an ideal penetration level, the researcher focussed on whether more investment into solar poses a threat to the utility in any way.

5.8.2.1 Utility

The themes that emerged included a loss in revenue, a utility death spiral, and the instability of the grid. The sub-theme 'no threat' ranked the highest with a frequency count of three. This is as shown in Table 37.

Table 37: Drivers that are a threat to the utility according to the utility

Rank	Sub-Theme	Participant Code	Frequency
1	No Threat	P1, P10, P13	3
2	Revenue Loss and Death Spiral	P9, P8	2
2	Grid Instability/Regulation	P16, P10	2

"The utilities are going to see a loss in revenue, but it will take some time. By the time most people put solar in, the utility is going to see a drastic decline" (P9, 113:113). This suggests that more and more solar penetration could see a loss in revenue for the utility, which once again relates to the comments that were gathered for Research Question 1 about the impact of increased solar penetration on the people that remain on the utility. On the other hand, participant 8 was of the opinion that more price increases could see more people try to move into some other form of generation such as solar, which inevitably may lead to the obsoleting of the utility as a whole *or "utility death spiral" (P8, 44:44).*

More than revenue loss, participants seemed to be concerned about the effect that increasing solar penetration could have on the grid network itself. *"The threat… would* *be the constant fluctuation and research is being done into the forecasting modelling and understanding… what do I have to do with my existing fleet to either ramp up or ramp down because these are not quick responses; relatively quick but are not designed for that, they are designed for constant power generation so I would see that as the major challenge with the fluctuations and how will the network handle the fluctuation" (P10, 73:73).*

Furthermore, according to participant 16, the penetration of too many renewables resulted in grid instability. "…*in Hawaii, they lost their grid because they got so much renewables at their grid and when it was unstable they lost their grid… From our side, we believe we going to need a quite lot of storage out there just to make our grid stable for the fluctuations in renewable supply on the grid?" (P16, 87:87).*

Interestingly, almost 50% of the participants from the utility did not see solar as a threat to the traditional utility. Participant 10 shared the opinion that *"the only point any utility would find this disruptive is if you have off grid supply. If a whole suburb goes of grid, completely independent then yes but when you start connecting back to the grid then you might be consuming less and you credited at a certain rate but then you still have potential customers and it's not that you want to lose the customer but, you have to understand what I said before, is your core business managing a grid of power transmission not many people so you would rather have it that because the infrastructure is good. So, I don't see any threats in that scenario" (P10, 73:73).*

Similar sentiments were shared by participant 13, who said that *"even if another technology comes, we are only distribution and generation. There won't be any transmission, because there is a lot of losses there and so many other things there…operating expenditures and things like that. So, I don't think we are in in competition" (P13, 83:83*). Participant 1 agreed, saying that *"in the medium to short term, it's not an issue until we probably get the next predicted growth, right. So, it would not affect me. If it did grow it'll still not affect me because I'll export, I'll actually be making more money, so it's a positive. So, either way I don't think solar is having a major impact on the way we do business. However, IPPs have an impact on the way I operate because now we're in the same niche, we both supply. But the residential, no" (P1, 88:88).*

The main reason that participants do not see solar as a threat is due to the fact that utilities have the infrastructure in place that is needed for transmission and distribution.

From the responses, it seems clear that until these systems are in place, solar does not really pose much of a threat to the utility.

5.8.2.2 IPP

The sub-theme 'revenue loss and death spiral' ranked the highest with a frequency count of four, as seen in Table 38.

Table 38: Drivers that are a threat to the utility according to IPP

Rank	Sub-Theme	Participant Code	Frequency
1	Revenue Loss and Death Spiral	P2, P4, P6, P18	4
2	Grid Instability/Regulation	P7, P15	2
2	No Threat	P4, P15	2

Participants 2, 4, 6 and 18 mentioned that the biggest threat that the utility faces with more people moving onto solar is the loss in revenue that the utility will face. This was the most mentioned theme within the discussions. Inevitably a loss in revenue could cause its "death", hence the researcher grouped a loss in revenue and death spiral under one category.

Participant 4 mentioned that if more people move onto solar, the utility will have to sell their power elsewhere to ensure that there is no loss in revenue. *"We have to sell our power to someone else, or we potentially have to drop price, or we have to attract more investment to get more people to buy our power" (P4, 43:43).* Since municipalities sell electricity as well, participant 2 remarked that more investment into solar will jeopardise their revenue, by highlighting that first solar will *"kill your income generation potential via municipalities. So, before it impacts the utility it's going to cut your municipal revenue" (P2, 35:35).* Participants 4 and 18 were also convinced that the major threat to the utility is loss in revenue. They reiterated this point by saying that there is a "*possible loss of revenue to the utility, due to higher uptake of solar, or own generation" (P6, 153:153).* This statement was supported by participant 18, who mentioned that *"the only threat is that they are going to lose the low income or middle income or even the high-income consumers" (P18, 104:104).*

Furthermore, participant 7 discussed the 'graveyard spiral', commenting that if the utility *"pushes up the cost of excess to the grid and they say 'okay we'll look, we are not getting* *much on the sale of kW-hours, so what we'll do is we will push up the cost your static charge to be connected to the grid'. What behaviour is that going to drive? Well then suddenly it starts to make more sense to generate excess energy storage and then you going to get through defection. And the graveyard spiral that you mentioned earlier becomes a reality" (P7, 63:63).*

Another possible threat that the utility faces is underutilised assets. Participant 15 remarked that "*we are going to be sitting with assets that are underutilised, then yes there is a threat to that" (P15, 53:53).* The researcher found this to be a reasonable argument; it makes sense that if more people move onto solar then the generation capacity of the utility will need to decrease, which could result in equipment and systems sitting idle. This will eventually lead to a loss in revenue and possible obsoleting of the utility.

Two of the participants believed that no threat will be posed to the utility by more investment into solar. Participant 15 mentioned that there will be policies in place to ensure that the integration of solar does not become such that it poses a threat to the utility; *"the solar PV industry is mostly driven by government policies and power producer problems" (P15, 51:51).* On the other hand, Participant 4 argued that the solar industry is still too small to pose a threat to the utility.

5.8.2.3 Solar installers

As seen in Table 39, 'revenue loss and death spiral' was ranked as the number one sub-theme with a total frequency count of three, which was similar to the IPPs.

Table 39: Drivers that are a threat to the utility according to the solar installers

Rank	Sub-Theme	Participant Code	Frequency
1	Revenue Loss and Death Spiral	P11, P12, P14	3
2	Grid Instability/Regulation	P11, P14	2
2	No Threat	P5, P11	2

A number of the participants remarked that solar does pose a serious threat to the utility. In fact, some went to the extent of saying that *"its days are seriously numbered" (P11, 85:85).* On the other hand, some participants remarked that there are regulations in place to ensure that such “threats” are mitigated. The responses received from the solar installers are detailed below.

Participant 12 mentioned that the actual threat of solar is to the utility’s business model; *“… ultimately solar PV and wind and small of distributive generation feeding into that mind-set, that goes directly against the whole business model of a big utility so you have to kind of question what should the utility model be going forward, that may be a different question, yes it threatens, it threatens the status-quo of the utility as a vertically integrated monopoly, the question then is, what should the utility become to fulfil I guess the national mandate?” (P12, 54:54).* The implication is that if utilities fail to adopt a new business model which accounts for cleaner technologies, they will definitely face becoming obsolete.

On the other hand, a few participants were of the opinion that solar does not pose a threat to the utility. According to participant 11, the growth of the solar industry, i.e. investment into the industry, is actually controlled and may even be limited by the policies that the government has in place. Participant 11 remarked that, *“the growth of solar industry in South Africa is very high rated growth and it is driven mainly by the government policy and utility scale investment” (P11, 53:53).* This was supported by Participant 14, who said that *“there are those quotas that have been set” (P14, 53:53).* This implies that the utility does not need to see solar as a threat, because the levels will be regulated by the government. Since the utility is a parastatal entity, government will pose regulations which will be in favour of the utility. However, participant 14 highlighted the negative aspects of such regulations on the country as a whole; *“if you have renewables alongside… then you will end up into an over-supply of electricity and then the over-supply would also kill the renewable energies because the incentives will be pulled out because you cannot continue incentivising what you do not need it any more. But then that has a big impact on South Africa whereby it won’t be able to fill its international mandates regarding reduction of renewable power sources. They have targets that they have to get to” (P14, 55:55).* This implies that if regulations are not carefully thought out, they could have an adverse impact in terms of the country not meeting international regulations.

Like the other two groups, a few participants in this group also mentioned that more investment into solar currently poses no threat at all to the utility, especially in the South African context, because it is still relatively costly for lower and middle income households. As mentioned by participant 5, "…*any threat it's minimal… it's very dependent on the per capita income; the bracket of the income of normal South Africans in communities is not that high, unless the solar panels and solar technology and solar thermal technology is very cheap… but it's still very expensive and it would need a little bit of injection from governmental organisation or government or the utility providers themselves" (P5, 36:36).* Furthermore, Participant 11 believed that *"the big threat is essentially utility scale renewables, when the utility scales fail" (P11, 59:59),* and not so much the rooftop solar. This can once again be attributed to the fact that solar technology is still relatively expensive for the layman.

5.8.2.4 Conclusion

An additional theme that emerged from the discussions with the IPP members was underutilised assets, which was not mentioned by any of the participants from the utility. Similar observations were made about the interviewees who mentioned that the utility currently faces no threat. These members were adamant that the policies and regulations that are in place will help mitigate any threat. Additionally, they do not view the growth of the solar industry as being big enough to pose a threat.

5.8.3 Advantages and disadvantages of finding an ideal penetration level

The participants mentioned the advantages of finding an ideal level of solar penetration, but not many disadvantages were discussed. The advantages ranged from job creation to economic growth, more potential for investments, and lower electricity prices. The disadvantages considered were loss in revenue and technical risks.

5.8.3.1 Utility

The sub-theme that emerged most from the results was 'advantage'; the majority of participants believed that finding an ideal penetration level provides more of an advantage than a disadvantage as seen in Table 40.

Table 40: Utility's perceptions on the advantages and disadvantages of finding an ideal penetration level

Rank	Sub-Theme	Participant Code	Frequency
1	Advantages	P1, P9, P13, P10	4
2	Disadvantage	P1, P9	2

Participants 1 and 9 mentioned that identifying an ideal penetration level will encourage competition between solar and the utility, thereby prompting the utility to decrease the price of electricity. According to participant 1, *"there's this perception of the cost of electricity, so having competition will or can eliminate that perception as well" (P1, 144:144).* These sentiments were echoed by participant 9, who mentioned that *"it will be an advantage to the customers, since they will be paying less for electricity" (P9, 174:174).* Other advantages that were discussed included the creation of jobs and employment opportunities. Participant 1 highlighted that finding an ideal penetration will contribute to *"employment, growth, investment, capital investment in the country" (P1, 144:144).* Furthermore, this, according to participant 9, will create work for *"the maintenance and operation of the solar facilities on people's roofs" (P9, 174:174).*

Other themes that emerged included that of cleaner energy (and therefore less carbon taxes), better health, and a healthier environment. According to participant 13, *"benefits include your carbon tax, your health and things like that because you are reducing the consumption… they can burn less coal" (P13, 247:247).* Furthermore, according to participant 10, *"the ideal penetration for a country will obviously get some benefits, I would assume based on the COPs. That's from a country perspective, as well as you are showing now that you're saving the environment" (P10, 100:100).*

However, participant 10 also mentioned that finding an ideal penetration level can pose challenges if it is looked at from a utility perspective, because *"there's still challenges like how do you handle that ideal penetration because you'll see its highly dense in the Northern Cape and then you've got to see of you have enough infrastructure there" (P10, 100:100).* Furthermore, participant 9 expressed the view that *"as more renewable energy sources come onto the grid, it makes sense, for a giant like the utility, to start closing down certain power stations. There will be excess" (P9, 174:174).* This means that there will be a loss in revenue for the utilities as they will have to shut down some of their units. This was further re-iterated by participant 1, who said *"…if we do not export, then definitely there will be a financial implication on us because we are not generating as much revenue as we predicted to be…" (P1, 154:154).*

Overall, the disadvantages stated were few compared to the numerous advantages of finding an ideal penetration level. However, the main disadvantage mentioned, which is that solar could affect the revenues of the utility, is a threat to the utility, and could be seen as more of a cause to find an ideal penetration level.

5.8.3.2 IPP

The participants from the IPP failed to identify any disadvantages associated with finding an ideal penetration level, as shown in Table 41.

Table 41: IPPs' perception on the advantages and disadvantages of finding an ideal penetration level

Rank	Sub-Theme	Participant Code	Frequency
1	Advantage	P2, P4, P6, P7, P15, P18	6
	Disadvantage		0

A strong advantage that was brought up by the majority of the IPPs was that finding an ideal penetration level could help the business plan and the utility, and businesses in general to make better investment choices. According to participant 4, finding an ideal penetration level would help *"drive the business case" (P4, 69:69)* and *"create a potential manufacturing base" (P4, 73:73).* This implies that if an ideal penetration level was to be found, there would be more incentive to establish a manufacturing base in the country. This will improve employment opportunities for solar installers and others with similar skills. The theory that finding the ideal level will help support the business case was also mentioned by participant 6, who said that *"this ideal penetration level will give them an indication of how much solar they can accept before becoming a loss-making business" (P6, 213:213).* Participant 7 looked at it as an advantage for the utility, as well as a way for them to *"do their capital expenditure planning in a much more structured and value adding way" (P7, 73:73).*

Participants 15 and 18 also agreed, adding that this is *"what we need so everyone can plan properly" (P15, 86:86),* and *"you can forecast accurately and not spend in any one direction and then have to back track and fix the problem because you didn't plan properly" (P18, 155:157).*

According to the participants from the IPP, identifying the ideal penetration level could give the utility an understanding of whether or not their current business model is going to work. For example, this could incentivise the utility to bring in *"some sort of access charges and other penalties, to ensure that there is a revenue stream even though people aren't using power from the utility" (P6, 225:225). "…they would have to charge you. So, for using the infrastructure that they have placed in terms of the grid if you connect to it" (P18, 176:176).* Furthermore, according to participant 2, *"outside of them (the utility) investing directly, and it's about changing the structure of the industry, changing the tariff structures, so that whoever owns the current assets of the utility whether its generation or transmission or distribution get paid for the actual value, which is power when you need it" (P2, 75:75).*

The utility can now identify methods by which they can improve their method of electricity generation and sales, such that they are not under threat of becoming obsolete.

5.8.3.3 Solar installers

Like the participants from the IPP, the participants in this group only had positive remarks to say about finding an ideal penetration level. The main theme that emerged was centred around the planning and management of the electricity generating resources. Other advantages mentioned included the provision of cheaper electricity, the creation of jobs and energy security.

Table 42: Solar installer's perceptions on the advantages and disadvantages of finding an ideal penetration level

Rank	Sub-Theme	Participant Code	Frequency
1	Advantage	P3, P5, P11, P12, P14	5
	Disadvantage		0

Participant 14 expressed the view that finding an ideal penetration level provides solar installers, and all others who are willing to invest, with an idea of the profitability of such a decision. It could also possibly add to the planning of infrastructure and the addition of power, so that there are no power outages in future, i.e. *"the suppliers of these and the installers they have a clear focus of what is required of them if they need to increase their capacity, if they need to set up new plants, they know how long it takes to ramp up to whatever percentage of installation. So, it gives them a very clear plan so the advantage is that the investment can be done with confidence" (P14, 85:85).*

The participant mentioned that finding an ideal level of penetration will introduce a healthy level of competition to the utility. This is advantageous to the consumer and country as a whole, as now there will be more of a prompt to provide cheaper electricity and improve upon the existing infrastructure, because *"the utility will be more competitive in terms of delivery, they will look at delivery and the best type of energy that will be there, whether it's using the existing infrastructure or they are improving their infrastructure, their maintenance… The competitiveness brings about a better product" (P5, 74:74).*

By finding an ideal penetration level, utilities can change their business models to ensure that the integration of solar does not negatively influence their revenues. Three out of the five participants agreed with this notion. Participant 14 further elaborated that "*big companies which were successful in capturing disruptive business models by spinning out subsidiaries that have a low-cost structure in themselves that then allows them to make money at those lower margins" (P14, 115:115).* Participant 5 then expressed the view that finding an ideal penetration level will be beneficial to the utility as it will be able to incorporate agreements *"on a possible way of getting the benefit from both ends" (P5, 78:78).*

Overall, from the findings and discussions with the solar installers, it can be concluded that finding an ideal penetration level will greatly help the utility because they can plan and prepare for the future of energy generation.

5.8.4 Grid parity

In an attempt to understand the situation of 'grid parity' from a South African context, as well as to see whether it could be looked at as a possible driver to find an ideal penetration level, the researcher asked the participants what they thought about the concept of 'grid parity'. Two main sub-themes were picked up from the results, i.e. the participants thought that grid parity was either 'achieved' or was 'yet to be achieved'.

5.8.4.1 Utility

The sub-theme 'yet to be achieved' ranked the highest with a total frequency count of three, as shown in Table 43.

Table 43: Utility's opinion on grid parity

Rank	Sub-Theme	Participant code	Frequency
1	Yet to be Achieved	P13, P16, P17	3
2	Achieved	P9, P10	2

Participants 13, 16 and 17 commented that grid parity is far from being reached, as investing into solar technology involves a lot of costs, hence it is going to take a while before the costs balance out or become cheaper than the price of electricity which is provided by the utility. Participant 17 highlighted that the cost of solar is still relatively higher than the price of electricity, and mentioned that *"in the cost of PV, you need to factor in the cost of batteries…" (P17, 92:92).* Similar sentiments were shared by participant 16, who said that "*generation costs have gone up and maybe they will be a point and renewables will start to make a lot more sense when electricity crosses and the PV costs are coming below the generation costs" (P16, 151:151).*

Contrary to what the majority of participants had to say, participants 9 and 10 were of the opinion that grid parity has been reached already, since the price of electricity from the utility has been escalating while that of solar has been decreasing. According to these participants, *"with our rising cost of our utility going up every year, and the price of solar going down every year, it is a price war out there.... Typical supply and demand scenario, as the demand for panels go up, the cost is coming down. It's going to catapult eventually… in fact grid parity has been reached" (P9, 201:201). "There are a lot of people saying it has reached grid parity and that's based on what's being shown… It is going to depend on your uptake. I will try and forward you another study showing the scenarios, there's a median higher gross study as well as shows you the impact quite nicely. Its shows you the high penetration levels" (P10, 122:122).*

The other participants did not have much to say on this topic. From the discussions with the participants from the utility, it can thus be deduced that grid parity is not yet an issue, especially with the current prices of solar technology.

5.8.4.2 IPP

Once again, the main sub-theme picked up was 'yet to be achieved', with a total frequency count of six.

Table 44: IPPs' opinion on grid parity

Rank	Sub-Theme	Participant code	Frequency
1	Yet to be Achieved	P2, P4, P6, P7, P15, P18	6
	Achieved		0

When compared to the responses received from the utility participants, the members interviewed from the IPPs seemed to be hoping that grid parity can be reached. *"Grid parity is what we want. We want for renewable sources to be the same cost as the existing sources and we are getting to a stage where that is possible, we have seen that is happening. And what that means is that the consumer shouldn't see a change in their bills overtime because we have achieved grid parity" (P6, 281:281).*

Participant 7 was of the opinion that *"the utility has to be depoliticised" (P7, 89:89),* adding that the escalating price of electricity charged by the utility is due to *"political meddling" (P7, 89:89).* This implies that the strict management of utilities could actually decrease the price of electricity and therefore eliminate the looming threat of grid parity.

On the other hand, participant 2 hinted at the utility's ignorance and said that *"if they don't acknowledge it they can't do anything about and as the more people go off grid the quicker they demise" (P2, 87:87).* From Participant 15's point of view, the utility is already conscious of the problem of grid parity, so *"they are already trying to get into that space. Whether that helps them with their CO_2 emission mitigation or not, I am not sure. I think they see it as is something that will help them reduce the cost of running these coal power plants" (P15, 109:109).*

Participant 18 was of the opinion that by embracing and incorporating solar onto their systems, the utility could make electricity prices cheaper and thereby eliminate the threat of grid parity as a whole; *"Instead of building new coal fired plants, grow through solar power, and then, what they might save there, they invest in new improved technologies in their current plants. So, they push the price down there. If there is more solar power, there is less demand on coal, if you decrease demand, your price should decrease, operations decrease, which should make production cheaper as well" (P18, 219:220).*

5.8.4.3 Solar installers

Similar to the other two groups, the sub-theme ‘yet to be achieved’ was the highest ranked with a frequency count of five.

Table 45: Solar installers’ opinions on grid parity

Rank	Sub-Theme	Participant code	Frequency
1	Yet to be Achieved	P3, P5, P11, P12, P14	5
	Achieved		0

Discussions with solar installers on the concept of grid parity did not bring up as many sub-themes as the researcher expected. Most of the discussions were centred around the current price of electricity provided by the utility, and the price at which solar can be generated. Participant 14 brought up the topic of levelised cost of electricity, arguing that grid parity has not been reached as yet because of the high prices of renewables and low carbon tax penalties. They added that *“grid parity simply means that the cost of the current…let’s say coal against the renewables then it means ideally now you no longer have to incentivise because they can sell their own, they can compete, in terms of costs. But then we have another problem, coal is still subsidised anyway. So, it’s through cost. Renewables are costly today.” (P14, 121:121)*. Participant 5 remarked that utilities need to *“work on agreements, engagement and agreements or something like that…” (P5, 98:98)* to prevent grid parity from being reached.

Overall, the solar installers did not seem convinced that grid parity has been reached as yet, and also mentioned that there are ways in which the utility can avoid the threat. This was contradictory to many of the statements that were given by the members of the IPP, who believed that grid parity has already been reached.

5.8.4.4 Conclusion

It is evidenced from the findings that grid parity has not yet been reached in the South African context. This sub-theme ranked the highest with a total of 17 frequency counts. It was interesting to note that the solar installers and participants from the IPP both hope that grid parity will be reached soon. Another finding was that there is only one factor limiting grid parity from being reached, and that is the current cost of solar.

5.9 Overall Conclusion

From the results, it was evident that majority of participants shared similar views in terms of the economic impact of captive solar technology, and as well as whether or not an ideal penetration level can be found.

From Research Question 1 it was seen that energy consumption does have a positive relationship on economic growth, i.e., positive energy consumption leads to positive growth of the GDP. At the same time, since South Africa is a high coal user, it was evident that higher energy consumption leads to more carbon emission, which is not good for the economy. This according to many participants could be decreased by the addition of cleaner sources of energy. Furthermore, most participants were in agreement that it is possible to find an ideal penetration level, and many similar responses were given as drivers that motivate the need to find an ideal penetration, such as the threat that over penetration may cause to utility, the effect of feed in tariffs and net metering, and costs. The similarities in views and opinions expressed by the respondents could indicate that it would be possible to incentivise all stakeholders or role players to drive adoption of solar without role players working against each other.

Chapter 6: Discussion of Results

6.1 Introduction

The purpose of this research is to provide a better understanding of the economic impact of captive solar PV penetration onto the grid, the need for an ideal penetration level, as well as to look into the drivers that influence the need to find this ideal penetration level. In this chapter, the findings that were established in chapter 5 will be analysed and discussed in relation to the literature reviewed in chapter 2. The insights discovered from the investigations are compared and contrasted to what is offered in current literature, in an attempt to answer the research questions presented in chapter 3. The chapter is then divided into subsections that relate specifically to the research questions and objectives presented in chapter 3.

6.2 Discussion regarding the Current Electricity Situation

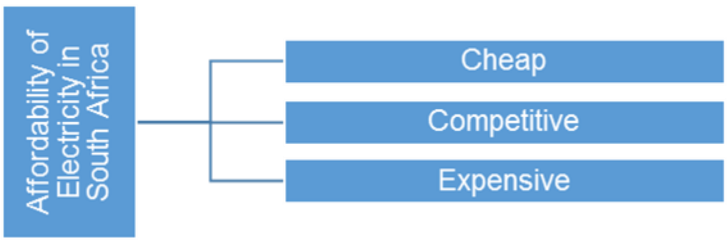
Conventional fossil fuel plants are sufficient to meet electricity demands, however as a result of climate change implications and environmental concerns, this method of electricity generation is being questioned (Obi & Bass, 2016). Countries across the world have thus begun to incorporate renewable energy sources onto their grids (Loomis, Jo, & Aldeman, 2016). The researcher first sought to investigate the current electricity situation in the country, as it was a way for him to motivate the need for this study to the participants. In addition, the researcher thought that these findings would help add value and put the answers that were provided during the discussions into perspective. The majority of the participants felt that the energy price is relatively cheap and affordable compared to international standards, even though there has been a vast escalation over the past few years due to the energy crisis. Furthermore, the participants remarked that although the utility's infrastructure is aged and outdated, the utility is still able to meet the current demand.

As elaborated upon in section 5.5, this discussion enabled the researcher to access key information and get an in-depth understanding of the current electricity situation in order to answer the three research questions in context.

6.2.1 Affordability

Table 7 in section 5.5.1 presents the three main themes that were picked up when the participants were asked whether the electricity price in South Africa is affordable. The data were analysed based on frequency and aggregated counts. The highest ranked theme, with a frequency count of six, was that the electricity price is 'cheap' compared to other countries. The second highest construct was that the electricity price is 'competitive'. These aspects are supported by studies such as the ones by Pollet, Staffell & Adamson (2015, p.16687), who said that "in terms of production RSA is one of the most coal dependant countries in the world, using it for 85% of electricity generation". Since coal is a cheaper commodity compared to generation through renewable energy resources, it can be concluded that the electricity prices are affordable. The main themes that were picked up from the discussions are as shown in Figure 9.

Figure 9: Affordability of electricity in South Africa

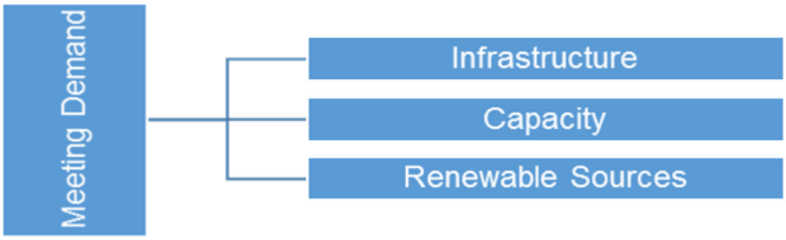


6.2.2 Meeting demand

In addressing whether or not the demand for electricity is being met, the theme that ranked the highest with a frequency count of seven was that of 'capacity'. The majority of participants commented that the main reason that the demand is being met is because an additional two plants have come online, providing extra capacity. However, it is evidenced from the findings that the economy has not grown at the expected rate, with many energy intensive industries such as mining not working at their full potential. The second highest ranked theme was that of infrastructure; the respondents, mainly from the utility, commented that the refurbishment and maintenance of the existing infrastructure is the reason why there is enough supply. Although the utility has sufficient infrastructure to meet current, respondents have mentioned that if the economy had grown, with all main energy intensive sectors were in operation, it would have been difficult to meet demand (SA, 2016). Renewable sources ranked third, with a frequency count of four, however this seems contradictory because South Africa plans to spend

US$ 50 billion on clean energy in the coming years (Pollet et al., 2015), as it has been seen that the introduction of cleaner energy is also helping the utility meet the electricity demand.

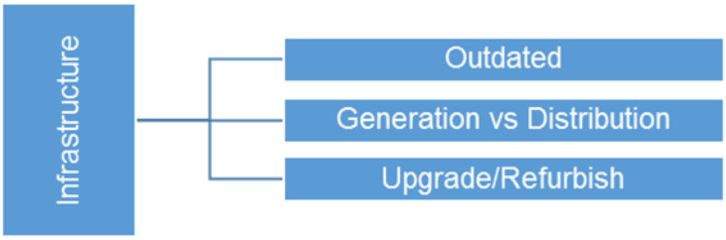
Figure 10: Meeting demand



6.2.3 Infrastructure

As seen from section 5.5.3, the highest ranked theme was that the utility's infrastructure is 'outdated'. Many participants were of the opinion that the utility has good distribution infrastructure in place, however the generation infrastructure was seen to be quite outdated and old. The theme ranked first, with a frequency count of nine.

Figure 11: Infrastructure



6.2.4 Conclusion of pre-questions

The pre-questions were an attempt by the researcher to understand and contextualise the purpose of the study, as well as to set the tone for the main research questions. Understanding the current electricity situation not only helped the researcher, but also helped the respondents open their minds to the problems facing the energy sector. From the findings, it can be concluded that the majority of the respondents believe that the electricity price is indeed affordable in South Africa, compared international electricity prices. Similarly, with new investments into cleaner technologies, it can be concluded that currently the electricity demand is being met by the traditional utility. Finally, the infrastructure, although old and outdated, seems able to meet the current demand.

The questions pertaining to the current electricity situation allowed participants to come to a conclusion, that the utility alone that has met demand, but uses the help of renewables. At the same time, the participants acknowledged that the South African economy has not being growing with many heavy energy users such as mines being offline.

Overall, the results indicate that the current price of electricity is affordable, compared to international prices. However, the infrastructure is outdated and old, and focus has been placed on generation with refurbishments that are being done, consequently increasing electricity prices (Mayr, Schmid, Trollip, Zeyringer, & Schmidt, 2015), and making electricity more difficult to afford.

6.3 Discussion of Results of Research Question 1

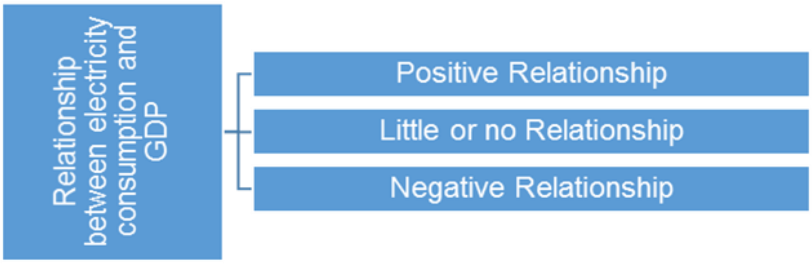
Research Question 1: What are the perceptions of the utility, solar power producers and solar installers with regards to the economic impact of captive solar technology?

Energy is an “important catalyst for economic growth” (Pollet, Staffell, & Adamson, 2015, p.16688). Research Question 1 sought to identify and understand the perceptions that the utility, IPPs and solar installers have with regards to the impact that captive solar PV technology could have on the economy. Numerous studies show the relationship between energy and the economy, such as one by Caraiani, Lungu & Dascalu (2015), however it was necessary to identify whether the increasing penetration of captive solar PV technology (Hurtado Munoz, Huijben, Verhees, & Verbong, 2014) would have a positive or negative impact on the economy. This was done by confirming if factors such as electricity consumption, carbon emissions and FDI are influenced in any way by increasing solar penetration.

6.3.1 Electricity consumption

From the discussions, the researcher picked up that there were three main themes, i.e. there is a positive, or a negative, or little to no relationship, between electricity consumption and economic growth.

Figure 12: Relationship between electricity consumption and GDP



The themes that ranked the highest, with a frequency count of seven for the utility, four for the IPPs and four for solar installers was that there is a 'positive relationship' between electricity consumption and economic growth. According to Caraiani, Lungu & Dascalu (2015), there is a bi-directional relationship between economic growth and electricity consumption. This means that an increase in electricity is an indication that the economy is growing positvely, and vice versa. Furthermore, seeing as South Africa is a developing country and depends on primary and secondary industries, it is more electricity intensive (Pollet et al., 2015), thus a reliable and secure supply of electricity is necessary for economic growth. Moreover, it has been seen that energy consumption is lower when there is lower economic growth, thus the utility is able to meet the electricity demand more easily, implying that there is decreased consumption of electricity.

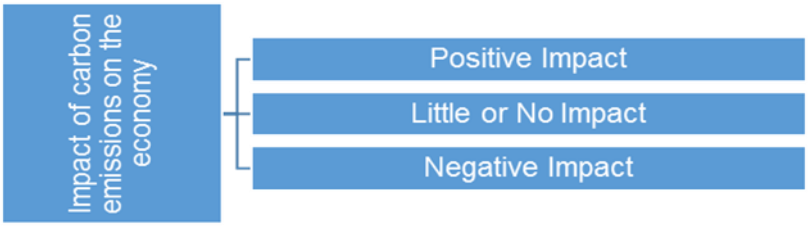
The second ranked theme was that there is a 'negative' relationship between electricity consumption and economic growth. According to Pollet, Staffell & Adamson (2015), South Africa's electrification rate has been higher (85.3%) than the world average (80.5%), however the growth in the economy is slower than ever. Two respondents from the IPPs were of the opinion that cheaper prices for electricity actually led to a wastage of energy, i.e. there was high electricity consumption but no positive growth in the economy. This is in-line with Menegaki's (2014) findings, i.e. an inefficient use of energy affects the growth of a country's GDP negatively.

Overall, the findings of the study reveal that most respondents feel that there is a positive relationship between electricity consumption and economic growth.

6.3.2 Impact of carbon emissions on the economy

As in the previous section, three main themes emerged from the discussions; there was either a positive relationship between carbon emissions and the economy, a negative relationship, or none at all. From the frequency counts shown in section 5.6.2, it is evident that there is a positive relationship between carbon emissions and economic growth.

Figure 13: Impact of carbon emissions on the economy



Most respondents believe that an increase in CO_2 emissions is an indication that energy is being consumed. Seeing as the primary source of energy in South Africa is coal (Pollet et al., 2015), more electricity consumption leads to more carbon emissions. Moreover, since regulations such as carbon taxes and other such penalties have not been put in place strictly, especially in developing countries such as South Africa (Breyer, Koskinen, & Blechinger, 2015), there is a notion that high carbon emissions, as a result of high electricity consumption, results in greater economic growth in a coal-based economy.

However, CO_2 emissions have a negative impact on the economic growth of a country; according to a study by Saidi & Hammami (2014), a 1% increase in carbon emissions leads to a 0.04% decrease in the growth of an economy. This implies that although an increase in energy consumption is good for the economy, as explained in section 6.3.1, an associated increase in carbon emissions will eventually lead to a decline in economic growth. Furthermore, a study by Breyer, Koskinen & Blechinger (2015) stated that South Africa produces the highest amount of CO_2 per kWh of energy generated, but pays the lowest taxes in the world. This implies that if a stricter implementation of laws in terms of carbon penalties and carbon taxes comes into play, it will have adverse impacts on the economy. The same demand should thus be met using cleaner sources of energy, so the amount of carbon emissions emitted is reduced drastically.

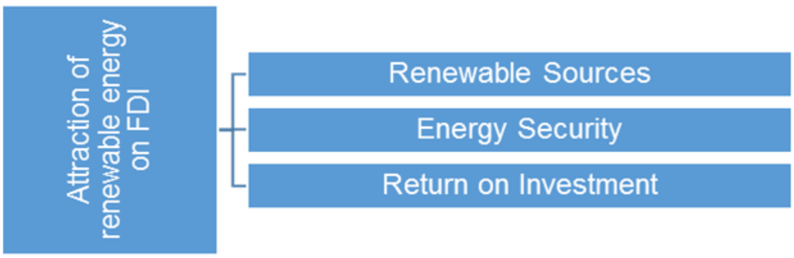
Countries such as South Africa that were not industrialised by the 1990s do not have any binding GHG targets, and as a consequence may not feel the need to limit or mitigate their carbon emissions (Almer & Winkler, 2017). Zakkour et al. (2014) stated that the UNFCCC can be an important catalyst for “supporting project investments, capacity building and technology transfer” (p.6956). This framework should thus be used to support project investments that will mitigate carbon emissions (Zakkour et al., 2014).

Finally, since South Africa is a coal generating country, higher energy consumption is linked to higher carbon emissions. However, as seen in some studies (Saidi & Hammami, 2014), carbon emissions have a negative impact on the economy. For this reason, it can be concluded that the positive impact noted was referring to an increase in carbon emissions, which are associated with more energy consumption. Therefore, overall it can be concluded that high carbon emissions have a negative impact on the economy, so bringing in solar will decrease these emissions and lead to a more positive impact on the GDP.

6.3.3 Impact of renewables on FDI

As stated by Tang & Tan (2014), FDI is an important source of capital that is making an increasing contribution to export activities, transferring technologies and the creation of job opportunities in developing countries. As FDI has a positive impact on an economy, the researcher attempted to find out whether more renewables as a means of electricity generation would lead to more investment. The aggregated interview data ranked the construct 'renewable sources' the highest, with frequency counts of five, three and five for the utility, IPPs and solar installers respectively. This is in-line with current literature, thus this finding was not by any means unexpected. Pollet et al. (2015) indicated that South Africa plans to spend US$ 50 billion on clean energy in the coming years, as energy is seen as an important catalyst in economic growth. The constructs that ranked second and third were 'return on investment' and 'energy security' respectively.

Figure 14: Influence of renewables on FDI

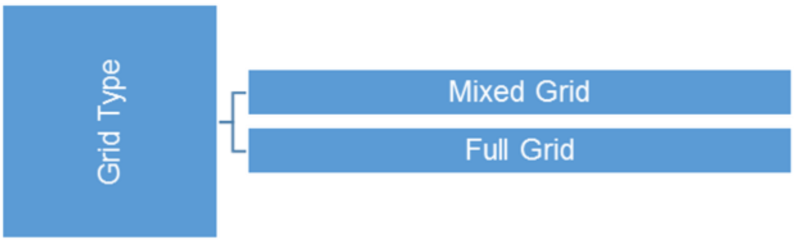


From the utility's perspective, in addition to renewable sources, return on investment, energy security and reliability of supply are additional drivers that will ensure FDI. This implies that the addition of renewables could help increase energy security, as PV technologies are considered to be of high potential because the sun provides "10 000 times the planet's energy demand" daily (Hurtado Munoz, Huijben, Verhees, & Verbong, 2014, p.179). On the other hand, as seen in section 5.6.3.2, participants from the IPPs were convinced that nothing matters more than getting a cheap supply of energy so that business is carried out profitably. They also remarked that renewables will become an important driver when there are stricter enforcements placed on carbon taxes, as well as when there are more regulations in place that force companies to go green.

6.3.4 Type of grid

The researcher wanted to understand what the participants thought was the best or most ideal type of network configuration for electricity supply, which would consequently have the most positive impact on GDP. From the discussions, it was clear that off-grid network configurations are not an option; the researcher thought that this was a valid point because the technology for storage is still quite expensive and complicated (Singh, et al., 2016). The two main themes identified from the discussions were mixed grid and full grid.

Figure 15: Most ideal grid type



There was unanimous agreement across all three samples that the ideal network configuration would be the mixed-grid or grid tied configuration. In fact, mixed grid ranked the highest with a total frequency count of 17. This is in agreement with existing literature on the subject (Obi & Bass, 2016); and (Singh, et al., 2016). According to their studies, grid-tied systems are advantageous because they are able to supply power back to the grid when excess electricity is produced. Consequently, customers save money as a result of better efficiency rates. Although South Africa does not have any systems in place to allow feed-in of excess energy produced, the participants still maintained that the mixed grid is the best configuration system in terms of energy security and reliability of supply.

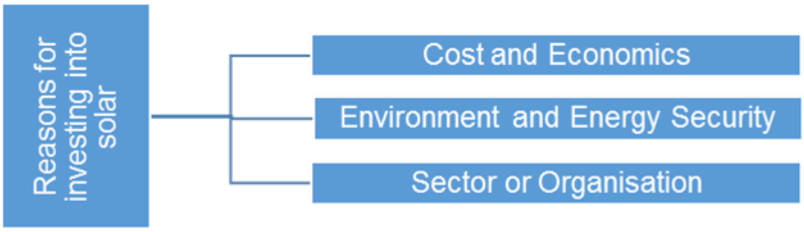
On the other hand, one of the participants was of the opinion that if energy security was not an issue, then full grid would be considered the best network configuration. This makes sense because energy security is defined as "diverse energy resources in sustainable quantities and at affordable prices" (Strydom, 2015, p.12). If the utility or full grid system could provide affordable and reliable energy there would be no need for any sort of integration onto the grid. However, since the 2008 energy crisis, the utility has been under stress to meet the country's electricity demand. Furthermore, inadequate investment in infrastructure has led to power shortages and calls for new capacities (Mayr, Schmid, Trollip, Zeyringer, & Schmidt, 2015). Energy security is thus still an issue, so the mixed grid configuration as mentioned was taken to be the best.

Overall, it can be concluded that the mixed grid is the best network configuration type as it is able to provide a reliable supply of energy.

6.3.5 Investing in solar

The researcher sought to investigate the factors that influence investment into solar. The main themes picked up are shown in Figure 16.

Figure 16: Investing into solar



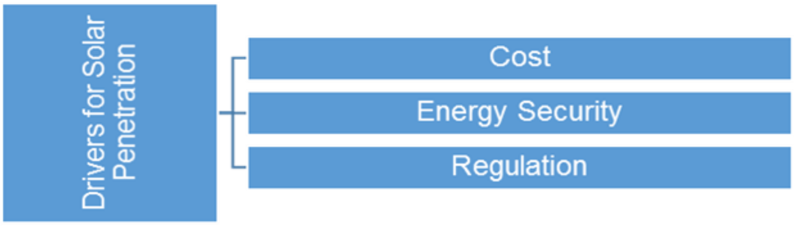
According to Cole, Haley, Sigrin & Margolis (2016), the price of solar technology has decreased by over 50% over the past few years. These decreasing prices have consequently promoted the growth of rooftop solar (Kappagantu, Danel, & Venkatesh, 2015). In line with what was said in these studies, some respondents identified power generation through solar energy to be a cheaper form of electricity generation than buying it from the utility. Cost and economics ranked as the main driver for investing into solar, with a total of 18 frequency counts.

The theme that ranked second was that of energy security and environment, which was in line with existing studies. The main attraction of solar PV systems is that they produce electric power without harming the environment (Singh G. , 2013). Concurring with this theme, the participants said that the impact that coal fired power stations have on the environment is reason enough to promote the use of renewable technologies such as solar. Furthermore, the respondents said that the health impacts of emissions should be further incentive for more people to invest into solar. This was also illustrated in studies like the one by Brown, Henze, & Milford (2017), which say that direct impacts of air pollution include diseases like asthma and even death.

6.3.6 Drivers for solar penetration

From section 6.3.4 it was seen that the mixed grid was selected as the best network configuration, hence the researcher sought to identify the factors that influence the penetration of solar onto the grid. The main themes that emerged from this discussion are as shown in Figure 17.

Figure 17: Drivers for solar penetration



The main driver that was identified across all three sample groups was cost, with a total frequency count of 19. Many respondents mentioned that the increase in electricity prices are motivating movement onto solar; in fact, the cost of new investments, combined with traditionally low electricity prices, caused an underfunding of the utility, which eventually resulted in a sharp rise of electricity rates over the last 10 years (Mayr, Schmid, Trollip, Zeyringer, & Schmidt, 2015). This, coupled with the decreasing costs of solar PV technology (Cole, Haley, Sigrin, & Margolis, 2016), has promoted growth in solar PV penetration.

The effect of regulations and policies was also mentioned as a reason for more investment into solar, and was ranked second with a total frequency count of five. In light of the regulations and goals set out in COP21 with regards to a reduction in carbon emissions, it can be agreed that regulations are a driver for more captive solar penetration.

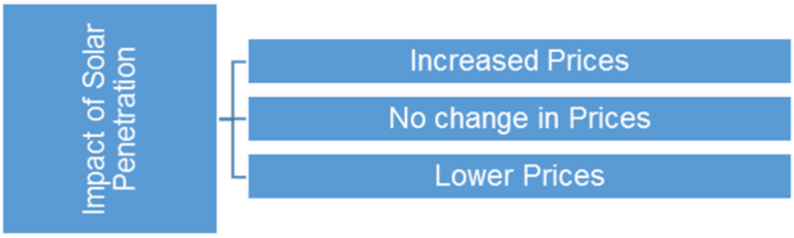
Although not noted as the highest ranked, many participants mentioned energy security to be a driver as they felt that a need for a reliable supply of electricity is a major driver promoting solar penetration. A major contribution to this was the energy crisis that the country faced in 2008 (Mayr, Schmid, Trollip, Zeyringer, & Schmidt, 2015). As mentioned by Strydom (2015), systems with lower risks or interruptions are more secure, and supply security is often discussed in terms of the availability of energy sources and their commodity price risks. The findings of this study show that a primary reason to invest in solar is the need for energy security. Since the 2008 energy crisis, energy security or the reliability of supply has made consumers think about investing into other methods of energy generation to ensure that they are not subjected to things like blackouts.

From the data gathered, it was evident that many respondents felt that adding solar onto the grid can help the utility to lower demand, and consequently ensure cheaper prices of electricity. Further, since people are able to generate their own power, excess that can be sold back to the grid will assist the utility to meet demand at lower costs. Additionally, a number of participants mentioned that increasing captive solar technology creates job opportunities, especially for solar installers. This is in line with what Loomis, Jo, & Aldeman (2016) mentioned.

6.3.7 Impact of increasing captive solar penetration on utility customers

The researcher sought to identify the impact that increased captive solar penetration would have on customers who remain on the utility instead of moving onto solar rooftop. This question was asked in order to determine whether more penetration of solar would drive the utility to increase its prices or not, as a result of revenue loss.

Figure 18: Impact of solar penetration on those who remain on the utility



From the rankings, it was evident that the utility and IPP members felt strongly that an increase in captive solar PV penetration will lead to increased prices for those customers who remain on the utility (see Table 25, Table 26, and Table 27 in section 5.6.6). This, however, contradicts the law of supply and demand, which states that more demand increases prices (Outcomes, 2011). On the other hand, Sander (2016) suggested that uncertainty is a factor that affects transaction costs. This implies that the uncertainty around solar PV penetration may cause the utility to hike its prices in order to ensure that it makes its revenues.

However, respondents from the solar installers felt strongly that there will be no impact of more people moving to solar on those who are left behind on the utility. One participant mentioned that the price would actually go down to prevent more people from moving away from the utility. However, if the utility was to lose too much revenue, it will result in a utility death spiral (Graffy & Kihm, 2015), so the utility would increase their prices to generate more revenue. No new themes emerged from the discussions with the participants from the solar installers.

From the discussions, it can be concluded that those who remain on the utility will have to pay higher prices for their electricity, if too many people move onto solar and the utility is not able to sustain itself.

6.3.8 Conclusive findings for Research Question 1

It can be concluded that there is indeed a positive relationship between energy consumption and economic growth, i.e. more energy consumption is an indication that the GDP is growing positively. At the same time, more energy consumption leads to more carbon emissions, especially in coal-based generation countries like South Africa. However, as discussed in section 6.3.2, carbon emissions have a negative impact on the economy, so more captive solar penetration will ensure that the same demand is met, together with lowered carbon emissions.

Renewables are a factor that is considered for FDI, in addition to other motivators such as ROI and the need for energy security. Even more consideration will be given to renewables if strict carbon laws are in place. Furthermore, as evidenced in section 5.6, energy security is a primary motivator for more captive solar penetration and the choice for investment. This implies that more renewables mean improved reliability of supply, thus the economic impact that captive solar technology has on the economy is a key positive relationship that is growing stronger day by day.

From the findings for research question 1 it is evident that the utility, IPP and solar installer perceive the increase in captive solar penetration to have an overall positive impact on the economy. Thus, the researcher concludes that research objective 1 as set out in chapter 3 has been met.

Figure 19: Main findings for RQ1

Economic Drivers for more captive solar technology

Motivators:

Less CO_2 emissions

Increasing Prices of Electricity

Energy Security

Demotivators:

Prices of solar PV technology

6.4 Discussion of Results of Research Question 2

Research Question 2: Is it possible to find an ideal penetration level that is beneficial to both the utility and customers?

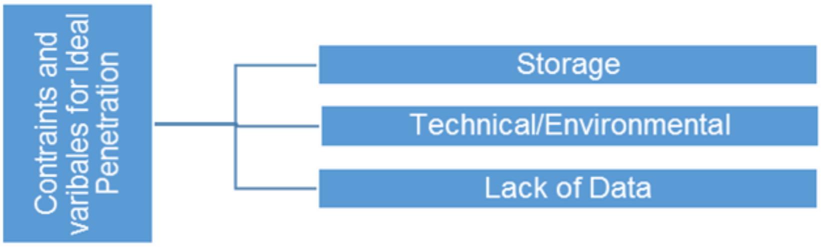
From Research Question 1, the researcher was able to deduce that if the costs of technology were affordable, the ideal choice of network configuration would be a mixed grid, i.e. a solar and utility hybrid. However, many studies, including those by Costello & Hemphill (2014) and Graffy & Kihm (2014), speak of the "death of utilities", which could be caused by the uncontrolled penetration or over penetration of solar onto the grid. The researcher thus sought to investigate whether it is possible to find the ideal penetration of solar that will be beneficial to the customer, while at the same time not harming the utility in any way.

The researcher questioned the participants on the possible constraints of finding such an ideal penetration level and the steps that could be taken to achieve this penetration level. This question required a “yes” or “no” answer, with elaboration on why the specific answer was given. If the interviewees only answered either “yes” or “no”, the researcher probed them to expand more.

6.4.1 Constraints and variables

All 18 participants agreed that it is possible to find an ideal penetration level, and in an attempt to uncover what must be done in order to find this level, the researcher prompted them to mention what they thought were some constraints or variables associated with finding this. In this research a constraint is described as a limitation or restriction, while a variable refers to a factor that is likely to change or vary. The main themes that were picked up from the discussions are shown in Figure 20.

Figure 20: Constraints and variables for finding an ideal penetration level



The three sample groups had mixed opinions about which variables and constraints were the most important, however the construct ‘technical and environmental’ ranked the highest with a total frequency count of 11 from all three stakeholders. This is in line with the current literature. Breyer, Koskinen & Blechinger (2015) focused on environmental concerns and emphasised that the ecological limit is being reached, thus motivating movement onto cleaner energy such as solar. An additional environmental factor that was picked up was weather patterns; as weather patterns and solar levels change from place to place, the output of solar power produced varies, hence this is also considered a variable which needs to be considered in the model to find an ideal penetration level.

When considering the technical aspects, the respondents said that it is impossible to pinpoint one specific ideal penetration level because the system is dynamic. This can be related to a number of things that have been mentioned in the literature, for instance a study by Cole, Haley, Sigrin & Margolis (2016) illustrated that the price of solar technology is decreasing year by year. This implies that every year there should be an increase in the number of people moving onto solar, thus the ideal penetration level will change. The price of solar technology is therefore taken to be a variable.

Another important constraint that emerged from the findings was the lack of historical data on variables. This factor got the second most frequency counts, as seen in section 5.7.3. According to some of the participants it is actually a lack of data that is limiting the finding of this ideal penetration level. Although studies such as the ones by Graffy & Kihm (2014) and Minnaar (2016) spoke of the positive and negative impacts of finding an ideal penetration level, these studies provided little to no information on whether it is possible to find an ideal penetration level. There is thus also a lack of theory in the exisiting literature on the subject of ideal penetration and what influences it.

Finally, the storage of energy created through solar is an issue, as is the actual placement of the load centres for distribution. This factor ranked third among the other themes that were brought up. Storage is a constraint as batteries are still expensive and complicated to use (Singh, et al., 2016), so even if an ideal penetration can be found, storage will be a constraint in implementing it.

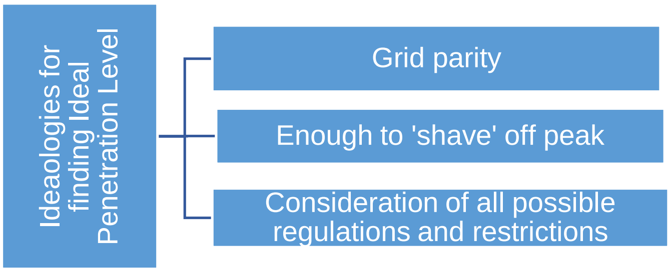
Additional factors picked up was the construct ‘regulation’. The South African government has recognised that energy is an “important catalyst for economic growth” (Pollet, Staffell, & Adamson, 2015, p.16688), so if governing bodies decide to put regulations on carbon emissions or limit the amount of solar penetration onto the grid, this will force another shift in the ideal level of penetration. For this reason, according to the researcher, carbon emissions can be considered to be variable in finding an ideal penetration level.

From the results it was evident that the participants felt very strongly that an ideal penetration level could be modelled considering the variables and constraints mentioned. One participant also mentioned that the demand required by the country is constantly changing, hence the required demand can also be considered a variable. Like demand, the supply from the utility is a variable, depending on which power stations are available for supply.

6.4.2 Potential steps to find an ideal penetration level

Through the discussions, the participants offered insights and possible steps that could be taken in order to identify an ideal penetration level. The approaches that the researcher found to be the most valuable are shown in Figure 21.

Figure 21: Approaches for finding an ideal penetration level



Most respondents mentioned that the ideal penetration level will be a point at which there is a sustainable supply of electricity and the demand is always met. For some respondents this meant that an ideal level of penetration onto the grid is when solar energy can be used to help ‘shave’ off the peak demands. This implies that the utility is constantly running at a base load, and the energy from solar supplies the extra demand that is required. Unfortunately, as mentioned in section 6.4.1, storage is still the major concern with this suggestion, as solar energy still needs to be captured and used during peak times, which usually occur after daylight hours.

A very interesting point that was brought up was that the ideal penetration level can be related to grid parity. The respondent commented that the maximum penetration of solar allowed onto the grid can be identified as the point where grid parity is reached, i.e. the cost of electricitity produced through solar is equal to the cost of electricity supplied by the utility. At this point, the decreasing cost of electricity from a renewable energy technology due to its technological advances intersects the cost of electricity generated from conventional fuels (Hurtado Munoz, Huijben, Verhees, & Verbong, 2014). This means that if the cost of solar decreases beyond the point at which grid parity is reached, then the utility will incur losses as a result of more and more solar penetration. Using the LCOE framework, the economic viability of the solar PV systems can be determined, which can help the utility identify the point at which the cost of solar becomes lower and provides a higher return on investment than conventionally generated electricity.

Another suggestion was to incorporate all restrictions, both technical and environmental, as well as policies and regulations that are in place, in relation to solar energy integration onto the grid, and model an ideal penetration level that is accomodating to all stakeholders concerned. This means that an ideal penetration level is where there is no harm to the utility, e.g. grid instability or loss in revenues, and the carbon emission targets as set out in COP21 can be met.

6.4.3 Conclusive findings of research question 2

Irrespective of which sample group the participants belonged to, there was a common understanding among the participants that an ideal penetration level can be found, however since the system is dynamic in nature there will not be only one specific ideal penetration level, but this level will vary depending on the variables that are taken into consideration when modelled. From the results it is evident that the participants felt very strongly that an ideal penetration level could be modelled considering the variables and constraints mentioned. Variables included carbon emissions, the decreasing price of solar technology, weather patterns, and the demand and supply of energy by the utility. The main constraints that were mentioned included the lack of historical data on variables and lack of storage.

Some approaches were proposed, as discussed in section 6.4.2, for how the ideal penetration level could be found. These included 'shaving' off the peak demands using solar, and using solar to help the utility meet demand.

Overall the researcher concluded that an ideal penetration can be found, however the variables and constraints that were analysed and discussed in section 6.4.1 need to be considered when modelling this ideal penetration level. It was also realised that an in-depth study should be done to find further variables and constraints that were not mentioned by the participants, but may still influence the ideal penetration level.

Figure 22: Main Findings for RQ2

Can an Ideal Penetration Level be found?

Motivators:

Supply meets demand

"Shave" off peak demands

Demotivators:

Weather patterns

Lack of historical data

6.5 Discussion of Results of Research Question 3

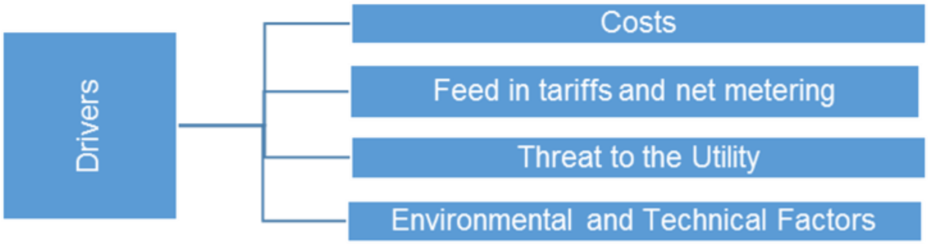
RQ3: What drivers influence the need to find an ideal penetration level?

Seeing as there was unanimous agreement that an ideal penetration can be found, the researcher sought to reinforce why it is necessary to find an ideal penetration level by asking the participants which drivers influence this need.

6.5.1 Need for ideal penetration

The three main drivers that influence the need to find an ideal penetration level were found to be costs, threat to utility, and environmental and technical factors.

Figure 23: Drivers influencing the need for ideal penetration



6.5.1.1 Feed-in tariffs and net metering

Feed-in tariffs and net metering ranked the highest among the IPPs and solar installers, but was ranked second by the respondents from the utility. Overall this theme had the highest rank, however, with a total frequency count of 13. Per the results from the respondents, it was evident that introduction of feed-in tariffs and net metering would be a motivating factor for more people to move onto captive solar technology, as it would provide rebates for people who produce extra energy through solar. However, feeding into the grid is still illegal in South Africa (Fritz, 2013) because it may cause voltage fluctuations and instability of the grid (Janko, Arnold, & Johnson, 2016). This implies that because there are no smart grids in place (i.e. feed-in tariffs and net metering), feed-in tariffs and net metering is actually a driver demotivating the need to find an ideal penetration level.

6.5.1.2 Costs

Costs was identified as another driver that could help find an ideal penetration level. This driver ranked second with a total of 10 counts, so was taken as one of the main themes that emerged throughout the discussions.

Costs were mainly looked at from a technical perspective; participants from the utility talked about the costs of the operation of the utility and the associated revenue implication of this. An increase in electricity generation by private individuals would decrease the demand for electricity from utilities, and consequently lead to an erosion in their revenues (Satchwell, Andrew, & Barbose, 2015). The respondents mentioned that identifying an ideal penetration level can help the utility operate according to the electricity demand requirements.

Participants from the IPPs looked at the costs from the customers' point of view. According to these respondents, the cost of solar technology is a driver in finding the ideal penetration level. As identified by Seldon, Penjor, Puri & Lhendup (2016), completely off-grid systems are still relatively expensive, so the cost to customer becomes an excellent driver for finding the ideal penetration level, i.e. the ideal penetration level will have to be such that the customer benefits from integrating captive solar PV technology.

According to Satchwell, Andrew & Barbose (2015), utility sales are closely tied to volume of sales and capital investments. Now, however, advancements in technology and public policies which drive the growth of alternative sources such as solar are reducing sales and opportunities for capital investments.

6.5.1.3 Threat to the utility

Although this driver was not noted as one of the top three themes, the researcher felt that this should have been represented as the one of the main drivers for ideal penetration. Looking at the variance in the data gathered in section 5.8.2, there was a clear divide in the opinions of the respondents from the utility. Half of the respondents concurred that there should be an ideal penetration level otherwise the utility will see a drastic decline in its revenue, which will eventually lead to the utility becoming obsolete. This is in line with Graffy & Kihm (2014) study, which said that rooftop solar is a "mortal threat" or "radical threat" to utilities (p.6). On the other hand, a number of respondents from all three sample groups remarked that rooftop solar PV does not pose as big a threat as utility scale PV. According to Purohit, Purohit, & Shekar (2013), utility scale PV technologies are generally used by independent power producers (IPPs), which are private entities that use their own facilities to generate electrical power for sale to utilities and end users to generate electricity using solar energy on a large scale. The uptake of utility PV has increased however it is still not at a potential whereby the utility sees it as a threat.

The major impacts of solar PV integration include voltage variations and unbalance, current and voltage harmonics, grid islanding protection, and other power quality issues, such as flicker and stress on distribution transformer (Karimi, Mokhlis, Naidu, Uddin, & Bakar, 2016). This implies that over penetration will lead to grid instability, which is in line with what was said by Karimi, Mokhlis, Naidu, Uddin & Bakar (2016).

Furthermore, the construct 'regualations and policies' was also mentioned by a number of paticipants. Regulations and policies are also considered a factor promoting the growth of PV, which could lead to the ultimate demise of the utility.

6.5.1.4 Environmental factors

According to the utility interviewees, environmental and technical factors were seen to be the major driver influencing the need to find an ideal penetration level, however the respondents from the IPPs and solar installers categorised these drivers as secondary. Participants mentioned that solar levels and the location of solar panels are a driver that motivate the need to find an ideal penetration level. According to Cole, Haley, Sigrin, & Margolis (2016), certain areas receive more sunshine than others. Furthermore, many participants mentioned that finding an ideal penetration level could help identify the amount of carbon emissions that will be mitigated, because as identified by Breyer, Koskinen, & Blechinger (2015), GHG emissions have been identified as a major threat by way of "the collapse of globalised human civilization in this century" (p. 610), which has steadily increased over the past decade.

6.5.2 Grid parity

A driver that was mentioned in many studies was that of grid parity. According to Hurtado Munoz, Huijben, Verhees, & Verbong (2014), the concept of 'grid parity' has emerged as the dominant benchmark for competitiveness, while some even argue that it will determine the point in time after which the PV industry will boom. The researcher thus sought to identify whether grid parity should be taken as a threat or not. The themes that emerged the most was that grid parity has been 'achieved' or is 'yet to be achieved'. All three sample groups were in agreement that grid parity is 'yet to be achieved', as seen in section 5.8.4. This is in line with existing literature. Fokaides & Kylili (2013) stated that manufacturing costs, the selling price of energy produced and the performance of PV systems are all conditions that must be met in order for grid parity to be achieved. Therefore, as suggested by the participants, grid parity is yet to be achieved because although the costs of technology are getting cheaper, captive PV technology is still quite expensive. According to the researcher, grid parity could be considered a driver for finding an ideal penetration, however since it is 'yet to be achieved', it is not one the main motivators.

6.5.3 Advantages and disadvantages of finding an ideal penetration level

This question was posed in an attempt to conclude whether finding an ideal penetration level was an advantage or disadvantage to the utility, IPPs and solar installers. From the frequency counts (refer to section 5.8.3) it was seen that finding an ideal penetration level was an advantage to all three. Only two participants from the utility mentioned that it could be a disadvantage. The main advantage that was mentioned was that finding the ideal penetration will allow for better planning and management. This, according to (Strydom, 2015), is one way to ensure that there is energy security. Furthermore, identifying these penetration levels could help the utility to adapt their business models to ensure that they incorporate solar. This would be an advantage, because as mentioned by Richter (2013), utilities struggle to offer attractive and economically sustainable products and services in the field of distributed PV generation, which could result in more and more people moving into private PV systems and thus the utility's profitability would decline.

6.5.4 Conclusive findings for research question 3

From the findings, it was evident that the major impact of over-penetration will be primarily felt by the utility, i.e. finding an ideal penetration level should be driven by the utility. The primary driver for finding an ideal penetration level was the threat that over-penetration poses to the utility. As evidenced from a number of studies and discussed in section 6.5.1.1, if an ideal level of solar penetration is not found, it will lead to the utility losing revenue and technical problems such as grid instability. The cost of solar is another motivation to find an ideal penetration level, as once this level is identified, installations can be made to specification.

Furthermore, it has been seen that finding an ideal penetration level will be beneficial as it will allow for better planning and management, as well as the adaptation of the utility's business models to ensure that they are sustainable. Also the findings showed that drivers such as threat to utility (Graffy & Kihm , 2014), and feed in tariffs and net metering (Poullikkas, 2013) motivated the need to find an ideal penetration level, thus it can be concluded that the research objective 3 set out in chapter 3 has been met.

Figure 24: Main Findings for RQ3

Need

Motivators:

Costs

Environment

Threat to Utility

Planning and Management

Demotivators:

Feed-in tariffs

6.6 Overall Conclusion

From the analysis of the findings in chapter 5, it is evidenced that the study has met all three research objectives that were set out in chapter 3. The findings indicated that there is indeed a positive relationship between the integration of captive solar technology on the economy. All participants remarked that it is possible to find an ideal penetration level. Furthermore, the majority of participants mentioned drivers which motivate the need to find an ideal penetration, which are similar to those found in the literature review.

Chapter 7: Conclusions and Recommendations

7.1 Introduction

In an attempt to summarise and highlight the main findings of this study, as presented in chapter 5 and discussed in chapter 6, the researcher presents and discusses a conceptual 'Ideal Penetration' model in this chapter. This chapter also assesses the limitations of this research and suggests recommendations for future research. The research objectives formed the basis for the research questions. The first contribution of this study is the identification of the perceptions of the utility, IPPs and solar installers on solar PV penetration and its impact on the economy. The second contribution is the establishment of whether or not it is possible to find an ideal penetration level, while the final contribution is the identification of the drivers that stimulate the need to find an ideal penetration level.

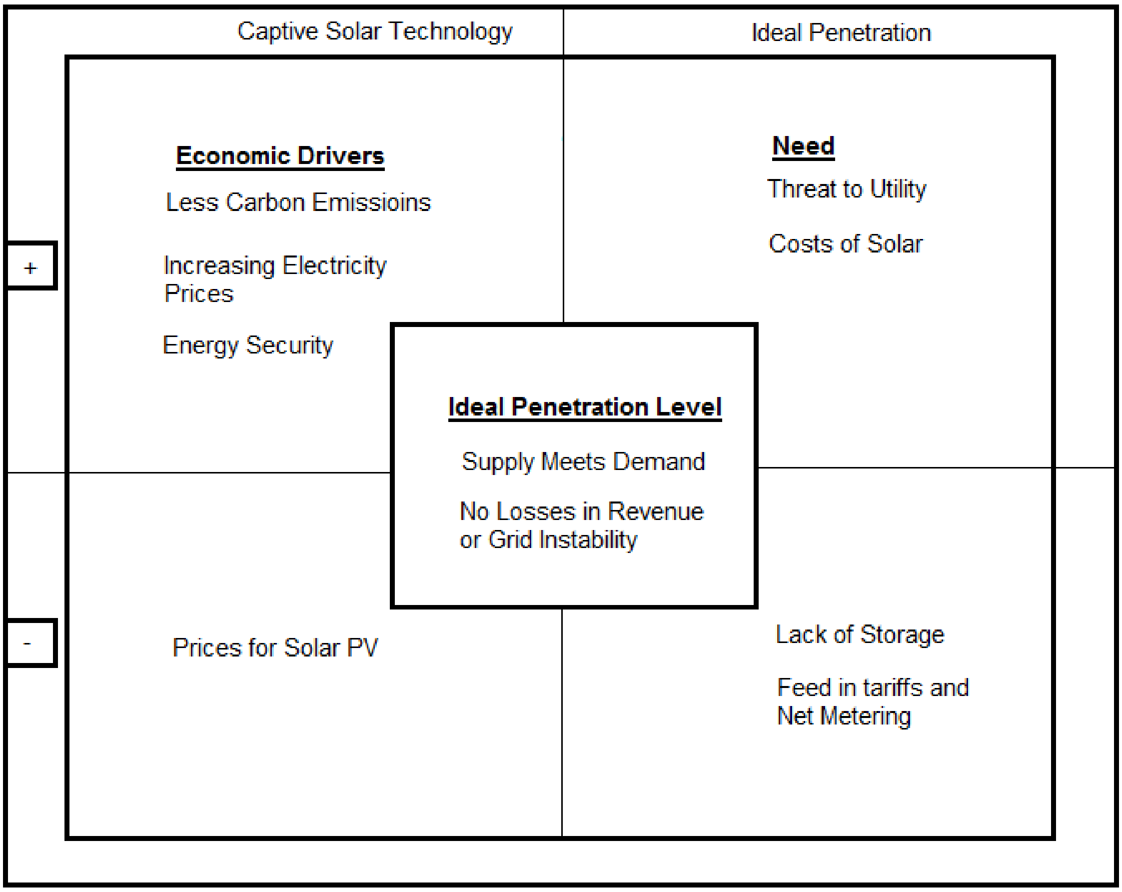
7.2 Main Findings

The primary objective of this study was to understand the perceptions of three stakeholders, namely the utility, IPPs and solar installers, of the economic impact of captive solar penetration. Additionally, the researcher sought to identify whether it was possible to identify an ideal level of solar penetration onto the grid, as well as to understand the factors or drivers that influence the need to find an ideal penetration level.

7.2.1 The 'Ideal Penetration' Model

From the main themes that were identified in chapter 5 and after careful integration of these themes and analysis of the findings, a conceptual model was developed. The model identifies the main drivers and effects of solar PV penetration and links it back to the economic impact, the drivers and the possibility of finding an ideal penetration level. The researcher refers to this model as the 'Ideal Penetration Model', which attempts to communicate a possible way to relate the findings of this study to an ideal penetration level.

Figure 25: Conceptual framework for solar PV penetration



7.2.2 Explanation of the model

The model looks at two main aspects, namely the motivators and demotivators of the following:

1) Economic drivers for captive solar technology (findings of research question 1).
2) The need to find an ideal penetration (findings of research question 3).

The model is made up of four quadrants and a centre block. The top left quadrant lists the economic drivers that motivate captive solar technology. The main drivers include the mitigation of carbon emissions and increasing electricity prices. The bottom left quadrant lists the economic drivers that demotivate captive solar technology, which include factors such as the location of load centres if PV is installed and the current prices of solar PV.

In the right-hand quadrants, the researcher focuses on the motivators and demotivators for finding an ideal penetration level. An increase in captive solar technology has a positive influence on GDP (Inglesi, 2010), however an over-penetration of the technology could have negative impacts on the economy as well (Graffy & Kihm , 2014). The top right quadrant focuses on the drivers that motivate the need to find an ideal penetration level. From the discussions, it came across that costs of solar, threats to the utility and job creation were all factors that motivated the need to find an ideal penetration level. The bottom right quadrant, on the other hand, listed the drivers that demotivate the need to find an ideal penetration level. This included factors such as a lack of storage (Rose, Stoner, & Perez-Arriaga, 2016) and net metering and feed-in tariffs (Poullikkas, 2013). These factors were the main findings linked to research question 3.

Finally, the centre block lists the possible ways that were mentioned to find an ideal penetration level. These were the main approaches that the researcher picked up from section 6.4.1 and 6.4.2. The centre block is an integration of Research Question 2 and 3. From the findings of Research Question 1 it is seen that increasing captive solar technology means an increase in GDP, however over-penetration of the technology could have adverse effects on the economy as well. From this finding the researcher deduced that the ideal penetration is a point at which the supply of energy meets the demand. Furthermore, this should be a point at which carbon emissions are mitigated to try and meet the requirements stipulated in the COP21 summit, while at the same time the utility should not face any threat, either in terms of revenue or grid instability. This, to the researcher, was best captured by the term ‘energy security’, i.e. the ideal penetration level is the point at which there is a reliable supply of electricity at affordable costs.

7.2.2.1 Economic drivers

In the top left hand corner of the model the researcher grouped together the main findings from Research Question 1. As seen in section 6.3.1, there was general consensus that there is a positive relationship between electricity consumption and economic growth, however more energy consumption means more carbon emissions, which negatively impacts the growth of the economy, i.e. for a 1% increase in pollutant emissions, economic growth decreases by 0.04% (Saidi & Hammami, 2014). Thus, the mitigation of carbon emissions is a motivator for more captive solar technology. Furthermore, as seen in section 6.3.6, the increasing price of electricity was found to be another major driver for people to move onto solar (Mayr, Schmid, Trollip, Zeyringer, & Schmidt, 2015). From the perceptions of the participants, as more people move onto solar there will be price hikes for those who remain on the utility. High electricity prices were thus also considered to be a factor that motivates captive solar penetration. Overall, less carbon emissions and the provision of cheaper electricity will have positive impact on the economy (Dai, Xie, Xie, & Liu, 2016), so these are considered the main motivators for more captive solar technology.

The main drivers that deter captive solar technology is the price of solar technology. Although prices have dropped drastically over the past few years it is still quite expensive (Cole, Haley, Sigrin, & Margolis, 2016), which could limit more penetration of captive solar technology.

7.2.2.2 Need for ideal penetration

Although a number of reasons were mentioned in section 6.5.1 as to why there is a need to find an ideal penetration level, the researcher identified the primary reason to be the effect that uncontrolled penetration of solar will have on the utility. As mentioned by the participants and as seen from the literature, over-penetration could lead to losses in revenue for the utility as less customers depend on them for supply. This integration could also cause instabilities within the grid which could cause damage to equipment. This could eventually lead to the utility “death spiral” (Graffy & Kihm , 2014). This was thought to be sufficient reason to motivate a need to find an ideal penetration level. Another primary motivator is the price of solar; although costs have decreased drastically over the past few years, solar technology is still quite expensive. Finding an ideal penetration level could help customers that are moving onto solar identify how much solar is needed to ensure that they are within the ideal range. This implies that customers will not have to pay more than necessary for rooftop solar panels, as they will be aware of how many solar panels they should install to reach the ideal penetration level.

A major deterrent is the lack of storage systems and feed-in tariffs and net metering (Fritz, 2013). As seen from the discussions in section 6.5.1, although there are storage systems available, the technology is still too expensive to make it a worthwhile investment. This implies that there is no need to find an ideal penetration of solar technology, as there will be no way to store this energy to feedback when needed; the utility will always be needed to supply the demand when there is insufficient sunlight. This implies that the utility will not be in any way threatened by solar penetration. The lack of net metering and feed-in tariffs also discourages the utility from finding an ideal penetration, because people are not motivated to produce excess solar power which they can then sell back onto the grid.

From the discussions, the researcher came to an understanding that the need for an ideal penetration level is mainly the priority of the utility, as it is primarily affected by an increase in solar penetration.

7.2.2.3 Ideal penetration level

The researcher placed this in the central block because it is an integration of the findings from both research questions 1 and 3. A common theme that was brought up during the discussions was that of energy security (sections 6.3.3, 6.3.4, and 6.3.6). This, to the researcher, implies that the ideal penetration level will be the amount of solar that will enable the utility to meet supply without any problems or the building of new power plants. At the same time, this level should be capped before the point at which grid parity is reached, otherwise the utility will face a loss in revenues. According to the researcher, the ideal penetration level lies at:

1) a point at which there is enough energy to meet or ‘shave’ off the peak demands and storage is no longer a driver demotivating the need to find an ideal penetration level;
2) a point where the supply meets the demand, which is a point of energy security for the consumer and cheaper electricity prices; and finally,
3) a point where there is no threat to utility, however there is enough solar to mitigate CO_2 emissions (meeting regulations and policies) and bring down the energy price (positive drivers for the economy).

Although there seems to be variations as to how the ideal penetration level can be identified, it should be noted that all groups of respondents seem to agree that there is an ideal penetration level, and that it can be determined. Such a common understanding could be an indication that it would be possible to incentivize all role players to drive adoption of solar without role players working against each other.

7.3 Implications for management

This research has implications for the utility and the industry:

- Managers from the utility should rework and remodel their current business models. It is evident that many participants felt that the utility should focus on the transmission and distribution of energy by leveraging off the current network rather than generation. This suggests that the utility management may have to redefine their business models such that they hand over generation to other power producers, especially those who produce power using renewables.
- All participants suggested that the best type of network configuration that will be ideal for energy generation is the mixed grid. This implies that energy management systems and government policies should be reworked such that they allow for the integration of solar energy.
- Over-penetration of solar energy could potentially lead to a loss of revenues for the utility, as well as grid instability.
- It was identified that there is a common understanding on the ideal penetration level among participants. This implies that management can focus on establishing policies that encourage develop a broad industry supported approach to promoting PV adoption.

7.4 Limitations of the Study

Qualitative research is subjective and at risk of being affected by biases (Saunders & Lewis, 2016). The limitations of the study are as follows:

- The study is exploratory in nature so could have been subject to researcher bias. Since the researcher worked in the energy sector as an engineer previously, some of the discussions in the interviews became quite technical in nature. This could have placed too much emphasis on a particular theme or biased some of the responses given by the participants.
- The sample was only represented by individuals from the Gauteng area, and thus the results could be subject to geographical bias.

- The sample selected consisted of subject matter experts from three different sectors within the energy industry, namely the utility, IPPs and solar installers. The researcher did not attempt to establish the opinions of customers or every day users of electricity, as the researcher thought of each of the participants as customers themselves.

- The coding of the interviews could be subject to researcher bias as it was primarily done by the researcher. The researcher attempted to eliminate this bias by aligning the codes as closely as possible to the research questions and sub-questions. This ensured that all the relevant answers were captured.

- The predominant theme of this study focussed on electricity from coal-based and solar generation, and did not take into consideration other forms of renewable energy even though they were brought up during the discussions.

7.5 Recommendations for Future Study

The purpose of this study was to investigate the impact of captive solar PV technology on the economy, as well as to identify whether there is any way to find an ideal level of solar penetration onto the grid. The principle findings of this study relate to other areas for future research, such as:

- There is a need for quantitative research to be conducted into the variables that affect the ideal penetration level of solar onto the grid, possibly leading to the development of an accurate mathematical model for ideal penetration.

- Research needs to be conducted on energy storage systems and how these can be made more economically viable, thereby allowing more large scale solar electricity generation.

- Since it was identified that determining the point at which grid parity is an indication of the maximum level of solar penetration that should be allowed on the grid, research should be done on grid parity and the factors that influence it in relation to the utility and solar.

7.6 Closing Remarks

This chapter presented addressed the research questions regarding the economic impact of captive solar PV technology, and ideal grid penetration. This chapter concludes by mentioning the limitations of this study, as well as recommendations for future research.

From the findings, it was seen that there is a strong link between the drivers that motivate more captive solar PV penetration and the drivers that motivate the need to find an ideal penetration level. Participants mentioned a few approaches to how the ideal penetration level may be found. One approach, as depicted in the model, could be to align the motivators for solar penetration, and the motivators for the need to find an ideal penetration and ensure that the one does not overly influence the other, i.e., they need to meet at a neutral point. Moreover, it can be deduced that the ideal penetration will be at a point where the economic benefits are high. From this it can be concluded that the aim of the study, which was specified in the beginning of this thesis, has been met.

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APPENDIX A: Interview Guide

Introduction – Background Information

This section will gather some data about the participant.

1.1 What is your highest qualification?

1.2 What is your background?

a) Engineering
b) Commerce
c) Environmentalist
d) Other

If other, please specify:

1.3 What is your current role in the industry?

a) Decision maker
b) Decision recommender
c) Subject matter expert
d) Other (please specify)

1.4 How many years do you have experience in your current industry

2. Current Electricity Supply

2.1 In your opinion is the electricity price in South Africa affordable?

a) Yes

b) No

2.2 Do you think South Africa is able to meet the electricity demand currently?

a) Yes

b) No

Please justify.

2.3 In your opinion what do you think of the electricity supply infrastructure in South Africa?

3. Economic Impact

Research Question 1: What are the perceptions of the utility and solar power producers with regards to the economic impact of captive solar technology?

3.1 In your experience what is the relationship (both positive and negative) between electricity consumption in South Africa and its growth in terms of Gross Domestic Product (GDP)?

3.2 Do you think that there is a link between carbon emissions and economic growth?

a) Yes

b) No

Please explain.

3.3 What are the consequences of Foreign Direct Investment (FDI) into a country that has more renewable energy such as solar incorporated into their energy sector than those that do not?

3.4 Which grid type in your opinion (Full-grid, off grid, and mix of solar and grid) is most conducive for economic growth? And why is this the case?

3.5 From an economic point of view, what drivers could motivate or demotivate the increase in captive solar PV penetration onto the grid?

3.6 If the people that can afford solar energy decide to use this technology instead of electricity provided by utility, what impact would that have on those who cannot afford to move onto solar, i.e. those people still depending on the utility for power supply?

4. The Need for an Ideal Penetration Level

Research Question 2: Is it possible to find an ideal penetration level beneficial to both utility and customer?

4.1 In your view, should businesses and the public invest into solar technology or continue using electricity supplied by traditional utilities?
4.2 How do you see the growth of the Solar PV industry in South Africa, and what are the potential threats of this growth, if any, that this technology poses to the utility ?
4.3 In your opinion is it possible to find an ideal level of solar penetration onto the grid?
4.4 What are the constraints of finding an ideal solar penetration level onto the grid for South Africa?
4.5 If these constraints are bridged what steps should be followed to achieve an ideal level of solar penetration into the grid?

5. Drivers for Ideal Penetration Level

Research Question 3: If an ideal penetration level can be found, what drivers influence it?

5.1 In your opinion, what factors do you think highly influence the penetration level of solar onto the grid?
5.2 How will identifying an ideal penetration level be an advantage or disadvantage, to South Africa, the utility, and solar installers?
5.3 From a financial point of view how will the utilities and supporting solar power producers (IPP) be affected in South Africa with increasing captive solar penetration onto the grid?

5.4 What do you think is the most profitable way in which solar power can be incorporated into the utility's business model?

5.5 What are the technical risks in South Africa with implementing net metering and feed-in tariffs?

5.6 How should the utility tackle Grid Parity (the decreasing cost of electricity produced through Solar PV)?

APPENDIX B: Consent Form

Gordon Institute
of Business Science
University of Pretoria

Research Project: Consent Form

Topic: Economic Impact of Captive Solar Technology and an Ideal Grid Penetration Level

Dear Participant,

I am a student at the Gordon Institute of Business Science, University of Pretoria. I am currently conducting research on the economic impact of captive solar technology and an ideal grid penetration level.

The purpose of this study is to better understand the economic impact of captive solar PV penetration onto the grid, in reference to its effects on gross domestic product (GDP), job creation, foreign direct investment (FDI), as well as environmental impacts, such as meeting carbon emission targets. The study also investigates if it is possible to determine an ideal level of solar onto the grid, and if so, what are the drivers that allow this ideal penetration level to be identified.

The interview duration is about an hour. Your participation in this research study is voluntary. You may choose not to participate, and may withdraw at any time without penalty. All information obtained from the interview, and your identity will be kept confidential throughout and after the study.

If you have any queries regarding the research study, please contact Nithin Isaac or Dr. John Wentzel.

Researcher Name: Nithin Isaac

Email: 27100032@mygibs.co.za

Phone: +27 84 560 4435

Research Supervisor: Dr. John Wentzel

Email: jwentzel@tsebo.com

Phone: +27 11 577 8630

Signature of researcher: ____________ ___________ Date: __28/08/2016______________

Signature of participant: _______________________ Date: _________________________

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APPENDIX C: Atlas.ti Codes

0-Current Electricity Situtation	1-Utility	1-Affordability	Cheap
	2-IPP		Expensive
	3-Solar installers		Competitive
	1-Utility	2-Meeting Demand	Capacity
	2-IPP		Infrastructure
	3-Solar installers		Renewable sources
	1-Utility	3-Infrastructure	Outdated
	2-IPP		Refurbishment
	3-Solar installers		Generation vs Distribution
1-Research question 1	1-Utility	1-Energy consumption	Positive relationship
			Negative relationship
			Neutral/No impact
		2-Carbon emissions	Positive relationship
			Negative relationship
			Neutral/no impact
		3-Attraction of renewables on FDI	ROI
			Renewables
			Energy security
		4-Grid type	Mixed grid
			Full grid
			Off grid
		5-Drivers for solar penetration	Cost
			Energy security
			Regulation
			Increase in prices

		6-Impacct of solar penetration	No change
			Lower
	2-IPP	1-Energy consumption	Positive relationship
			Negative relationship
			Neutral/No impact
		2-Carbon emissions	Positive relationship
			Negative relationship
			Neutral/no impact
		3-Attraction of renewables on FDI	ROI
			Renewables
			Energy security
		4-Grid type	Mixed grid
			Full grid
			Off grid
		5-Drivers for solar penetration	Cost
			Energy security
			Regulation
		6-Impact of solar penetration	Increase in prices
			No change
			Lower
	3-Solar installers	1-Energy consumption	Positive relationship
			Negative relationship
			Neutral/No impact
		2-Carbon emissions	Positive relationship
			Negative relationship
			Neutral/no impact
		3-Attraction of renewables on FDI	ROI
			Renewables

			Energy security
		4-Grid type	Mixed grid
			Full grid
			Off grid
		5-Drivers for solar penetration	Cost
			Energy security
			Regulation
		6-Impact of solar penetration	Increase in prices
			No change
			Lower
2-Research question	1-Utility	1-Reason for investing into solar	Cost and Economics
			Environment and Energy Security
			Type of Industry
		2-Constraints and variables	Storage
			Technical/Environment
			Lack of Data/Awareness
	2-IPP	1-Reason for investing into solar	Cost and Economics
			Environment and Energy Security
			Type of Industry
		2-Constraints and variables	Storage
			Technical/Environment
			Lack of Data/Awareness
	3-Solar Installer	1-Reason for investing into solar	Cost and Economics
			Environment and Energy Security
			Type of Industry
			Storage

		2-Constraints and variables	Technical/Environment
			Lack of Data/Awareness
3-Research question	1-Utility	1-Need for ideal penetration	Costs
			Environment/Technical
			Feed in Tariffs and Net Metering
		2-Threat to utility	Revenue Loss and Death Spiral
			Grid Instability/ Regulation
			No Threat
		3-Advanatages and Disadvantages	Advantages
			Disadvantage
		4-Grid parity	Achieved
			Yet to be Achieved
	2-IPP	1-Need for ideal penetration	Costs
			Environment/Technical
			Feed in Tariffs and Net Metering
		2-Threat to utility	Revenue Loss and Death Spiral
			Grid Instability/ Regulation
			No Threat
		3-Advanatages and Disadvantages	Advantages
			Disadvantage
		4-Grid parity	Achieved
			Yet to be Achieved
	3-Solar installers	1-Need for ideal penetration	Costs
			Environment/Technical

			Feed in Tariffs and Net Metering
		2-Threat to utility	Revenue Loss and Death Spiral
			Grid Instability/ Regulation
			No Threat
		3-Advanatages and Disadvantages	Advantages
			Disadvantage
		4-Grid parity	Achieved
			Yet to be Achieved

APPENDIX D: Ethical Clearance Form

Dear Mr Nithin Isaac

Protocol Number: **Temp2016-02048**

Title: **Economic impact of captive solar technology and an ideal grid penetration level**

Please be advised that your application for Ethical Clearance has been APPROVED.

You are therefore allowed to continue collecting your data.

We wish you everything of the best for the rest of the project.

Kind Regards,

Adele Bekker