The Mega-Project Paradox: Is the “New-Build Programme” the last mega-project South Africa will see this century?

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ABSTRACT

Projects are constructed daily across the globe. However very few of these are mega-projects. These mega-projects are deemed grand in scale and are designed to serve millions of people. Over the years a trend has emerged where these projects are having increasing problems related to time and cost overruns – despite issues related to labour, poor project management, reduced return on investment, poor design and non-completion – increasingly mega-projects are being built. Therein lies the mega-project paradox.

Mega-projects are now facing major external market disruptors such as the spread of solar photovoltaics, economic growth in sub-Saharan Africa, diversifying the energy mix, changing consumer dynamics and market structure. One of the biggest threats to utilities is the changing regulatory reform and the move to 'prosumers'. Given Eskom's delayed and expensive New Build programme, the question then arises – will South Africa embark on another mega-project build in this century.

This study utilised both primary and secondary data for analysis by means of mixed methods. Primary data from online surveys as well as analysis of secondary data from the Infrastructure Journal were used. Sixty percent (60%) of survey respondents said that South Africa would embark on another mega-project.

This study reveals that mega-projects have sublimes which perhaps influence investment in them – political, economic, technological and aesthetic sublimes. In addition to these sublimes the social pacts these mega-projects bring are one of the biggest drivers for their investment. Furthermore, the future utility model has changed and Eskom will not survive the utility death spiral unless it adapts.

Key words: Mega-project; New Build, Sublimes, Eskom; Mega-project paradox

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LIST OF ACRONYMS/ABBREVIATIONS

BRICS	Brazil, Russia, India, China, South Africa
CAPEX	Capital Expenditure
CCGT	Closed Cycle Gas Turbine
CFL	Compact Fluorescent Light
CO2	Carbon Dioxide
COP	Conference of the Parties
DAM	Day Ahead Market
DBSA	Development Bank of Southern Africa
DFI	Development Finance Institution
DOE	Department of Energy
DPE	Department of Public Enterprise
DRE	Distributed Renewable Energy
EAPP	East African Power Pool
EAF	Energy Availability Factor
EDM	Electricidade de Mozambique
EIB	European Investment Bank
ESCOM	Established in 1923 as the Electricity Supply Commission (ESCOM). It was also known by its Afrikaans name Elektrisiteitsvoorsieningskommissie (EVKOM).
ESI	Electricity Supply Industry
ESKOM	The acronyms ESCOM and EVKOM were combined and the company was renamed to ESKOM in 1986
EV	Electric Vehicles
GDP	Gross Domestic Product
GHG	Green-house Gas
GNP	Gross National Product
IDC	Industrial Development Corporation
IEP	Integrated Energy Plan
IGCC	Integrated Gasification Combined Cycle
IPP	Independent Power Producer
IRP	Integrated Resource Plan
ISMO	Independent System Market Operator
IWPP	Independent Water and Power Plant
LED	Light Emitting Diodes
MIT	Massachusetts Institute of Technology

MLA	Mandated Lead Arranger
NERSA	National Energy Regulator of South Africa
NT	National Treasury
OCGT	Open Cycle Gas Turbine
OPEX	Operational Expenditure
PPP	Public Private Partnership
PV	Photovoltaic
RE	Renewable Energy
REDs	Regional Electricity Distributors
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
ROI	Return on Investment
SAPP	Southern African Power Pool
Solar PV	Solar Photovoltaic
SSA	Sub-Saharan Africa
WAPP	West African Power Pool

1. CHAPTER

INTRODUCTION AND RESEARCH ORIENTATION

1.1. INTRODUCTION

Every country needs mega-projects as they are a permanent and necessary requirement for economic growth (Mišić & Radujković, 2015). Mega-projects are defined as those whose capital investment amount is in excess of $1 billion (Priemus et al, 2008). They are broadly defined as projects of a substantial capital cost that attract a significant level of public and political interest because of the massive direct and indirect impacts on the community, fiscus and environment (Priemus et al, 2008). The word “mega” also implies the size of the task involved in developing, planning, and managing projects of this magnitude. The risks are normally substantial. Cost overruns of 50% are common, and overruns of 100% are not uncommon (Mišić & Radujković, 2015). Similarly, substantial benefit shortfalls trouble many mega-projects (Flyvbjerg, 2014). In some of the instances, regional development effects and environmental impacts often differ from what proponents had initially promised (Flyvbjerg et al., 2003; Douglas, 2005; Mišić & Radujković, 2015). Regardless of these shortfalls, more and bigger mega-projects are being planned and built despite their poor performance record in terms of costs and benefits to the economy (Flyvbjerg, 2015).

However, mega-projects have significant economic, environmental, and political risks, which include risks to countries, lawmakers, developers and lenders. These risks can be attributed to their long planning horizons and very complex interfaces (Flyvbjerg, 2006). Similarly, substantial benefit shortfalls trouble many mega-projects (Flyvbjerg, 2014). In some of the instances, regional development effects and environmental impacts often differ from what proponents had initially promised (Flyvbjerg et al., 2003; Douglas, 2005; Mišić & Radujković, 2015).

However, mega-projects should be serving a greater purpose than just utilisation of assets to generate incomes for project developers (Flyvbjerg, 2014). Mega-projects can build communities, grow economies and promote social justice and regeneration (Bornstein, 2010; Jia, 2011; Hannan, 2015; Mišić & Radujković, 2015). It is within this context that a paradox arises because there are markedly conflicting outcomes. Increasingly and throughout the world, mega-projects are being built, more and more, and larger and larger (Altshuler & Luberoff, 2003; Priemus et al,. 2008; Flyvbjerg, 2014; Mišić & Radujković, 2015; Flyvbjerg, 2015). More money is being spent on mega projects as a percentage of the global Gross Domestic Product (GDP) although the outcomes have been dismal. The paradox associated with mega project is not only occurring globally but is also observed in the Sub-Saharan African region and in the South African landscape of infrastructural investments.

1.2. GLOBAL CONTEXT FOR MEGA-PROJECTS

Since the signing of the Paris Accord aimed at reducing greenhouse gas emissions, the global energy outlook has shifted dramatically. According to the (IEA, 2018) publication World Energy Outlook for 2018, the world is building a different kind of energy system. There is a move away from brick and mortar infrastructure to a more technology based energy solution. IEA (2018) cite three key pillars which are impacting on the sustainability of energy projects going forward. The first being affordability, the rising costs of oil combined with the declining cost of solar PV is changing how technology is viewed and whether fossil fuel based investments are still necessary (IEA, 2018). The second pillar is the risk surrounding reliability of oil and gas supply. Given that one eighth of the world's population doesn't have electricity there is a need to have reliable but flexible power that is free from cyber threats (IEA, 2018). Finally, after three flat years, energy-related carbon dioxide (CO_2) increased by 1.6% in 2017. This indicates that while commitments to reduce emissions have been undertaken, the reality is that both developing and developed countries are requiring reliable power that is both flexible and cheap (IEA, 2018).

This green-house gas (GHG) increase correlates with the European Union who over the 2016/7 period experienced a 0.6% increase in GHG emissions, largely as a result of the transport sector (European Environment Agency , 2018).

This phenomenon was predicted by (Shearer, et al., 2014) that the use of natural gas was promoted in the United States in order to decarbonise their economy. The decommissioning of coal plants and commissioning of gas plants had a lagged emission effect, which now seems to have an increase on GHG emissions.

In the (IEA, 2018) new policy scenario, a rising middle class accompanied by an increase in population of 1.7 billion people expected in 2040 is one of the major demand factors that will see global energy demand increase by 25%. Global energy demand will increase however it is uncertain if this demand will be met by conventional fossil fuel technologies, renewables or a hybrid.

1.3. SUB-SAHARAN (SSA) CONTEXT FOR MEGA-PROJECTS

Projections reflect that by 2035 Africa will account for 21% (1.8 billion) of the world's population - up from 16% in 2016 (British Petroleum, 2016). Tied to this, is an increase in energy demand by 88% between 2014 and 2035 in this region, much higher than the global average of 34% (British Petroleum, 2016). However, the majority of people without access to electricity are found in the Sub-Saharan (SSA) region (International Energy Agency, 2015). With the anticipated economic growth and energy demand, more investments in energy generation will be required to address this development need (International Energy Agency, 2015). And because of this growing energy demand, SSA is increasing its generation capacity to meet this anticipated demand (ESI Africa, 2017). This projected capacity is comprised of solar, hydro, gas, wind and coal generation technologies. Furthermore, there is a growing trend whereby state utilities are being replaced by independent power producers in the generation business (Chimbaka, 2017; Waldron & Nobuoka, 2017; International Energy Agency (IEA), 2017). Investment trends also show that power generation is shifting away from fossil fuels to renewables (International Energy Agency, 2017). At the same time, the traditional energy power market in SSA is evolving and is experiencing regulatory changes to allow a greater share of independent power producers as well as micro grids and solar rooftop technologies (PricewaterhouseCooper (PwC), 2015; International Energy Agency (IEA), 2017). With this background it is clear that the SSA region is in need of energy investments, of which South Africa will be an important supplier, thus raising the rationale for more mega projects not only in the SSA region but also in South Africa.

1.4. SOUTH AFRICAN CONTEXT FOR MEGA PROJECTS AND THE RESEARCH PROBLEM

South Africa has a rapidly growing population, currently estimated at 54.9 million people (Statistics South Africa, 2015). However, South Africa's economy has been stagnant or declining, especially in the first quarter of 2016 because it declined to an annualised low of 1.2% (Gumede & Mbatha , 2016). Among the consequences of this economic downturn has been a decline in energy demand (Eskom, 2016). This has in-turn affected the new-build programme[1], causing both time and cost overruns (Kretzmann, 2017). Although there are economic challenges in South Africa, more mega-energy projects are being planned because of rising energy demand in the SSA region. This increased impetus for more of such projects is occurring despite their poor performance record in terms of costs and benefits (Priemus et al, 2008). For instance, South Africa has committed to further mega-projects such as Thabametsi (coal IPP), Khanyisa (coal IPP), gas and nuclear technologies as per the Integrated Resource Plan (2010). However the future of these projects is uncertain given the environmental as well as financing constraints. On the other hand, mega-projects have the potential to increase economic growth, create jobs, improve social equity, and provide political and economic stability (Apergis & Payne, 2009a; Alam et al., 2012; Dlamini et al., 2013; Creamer, 2016). With these mixed outcomes, there is now a mega project paradox.

The paradox follows that, while there is intensified increase in building mega-projects, their pre- and post-construction performance does not justify their existence (Flyvbjerg, et al., 2003)

[1] Eskom New Build Programme – Construction of Medupi, Kusile and Ingula

(Flyvbjerg, 2014) (Priemus et al, 2008). Given this paradox, the value of these mega-projects in terms of economic and social benefits remains questionable and underexplored in the scientific research literature. In a report by Korytárováa & Hromádkaa, (2014), the social and economic impacts of mega-projects are explored. Other scientific research is not focused on the energy sector alone as it is cross-sectoral in addition is primarily project management focused (Flyvberg et al. 2003; Flyvberg, 2006; Priemus et al., 2008; Flyvberg, 2014). In the light of the above context of mega projects and their questionable sustainability, this dissertation has examined the viability of these projects in the Sub-Saharan region and South African context. This dissertation aims to define the mega-project paradox in relation to investment uncertainty given the challenges and risks associated with these projects. It will look at the extent and state of funding of mega-projects being built across the SSA region as well as in South Africa. The major research objectives addressed by this dissertation can be stated as follows:

Objective 1: To characterise the investment uncertainty of mega-projects given the risks & challenges associated with them

Objective 2: To establish whether mega-projects are being built and in which countries given market disruptions

Objective 3: To determine who are the funders of mega-projects

1.5. STRUCTURE OF THE DISSERTATION

Chapter one introduces the research focus, rationale for the study and the research problem and guiding research question. In the same chapter, a global as well as a South African context of mega projects is given. Chapter two is a literature review and delves in to the reasons (sublimes) why mega projects are being built while giving an introduction to global mega-projects. This chapter examines the challenge of funding these mega-projects and the technology disruptions that have been encountered in the energy power sector. Information provided on research methodology is provided in chapter three which addresses the survey design, data collection methods and possible shortcomings. Chapter four presents and discusses the survey results relating to objective 1. Chapter 5 presents and discusses the empirical data gathered from the Infrastructure Journal related to objectives 2 and 3. In the last chapter (Chapter 6), the conclusions and recommendations are provided.

2. CHAPTER

LITERATURE REVIEW

Chapter 2 introduces some of the challenges of investing in mega-projects. These are the challenges that global utilities and countries face when deciding on mega-projects. This chapter also reviews the nature of technology disruptions in the power sector, a mechanism that could herald a paradigm shift in how utilities are viewed.

2.1. INTRODUCTION

Mega-projects are growing larger in size, growing in currency value and they are also being built in larger numbers. According to the McKinsey Global Institute it is estimated that, between 2013 to 2030, infrastructure spending is projected to be USD 3.4 trillion per year which will mainly be delivered as large scale infrastructural projects (Jennings, 2012). According to "*The Economist"*, there was never a time when huge finances were spent on mega infrastructural projects when quantified as a share of world GDP than it is today.

In fact, the McKinsey Global Institute estimates that global expenditure should reach $57 trillion on infrastructure projects by 2030 to unlock the expected degrees of economic growth globally. Two thirds of this amount should be earmarked for developing countries where there is an increased population, a rising middle class, rapid urbanisation and economic growth in the double digits (Garemo et al.; 2015).

Flyvbjerg (2014) postulates that if industries were to become mega-projects as the main delivery tools - such as oil and gas, mining, energy - then the global mega-project market is estimated at USD 6 to 9 trillion per year, or nearly 8% of the whole global GDP. As a way of comparison, the mega-project market is tantamount to spending five to eight times the accumulated debt to China, every year. With much effort being spent on superior and an increasing number of mega-projects, there was never a time when the funding and the management of these projects was more important than is the case now (Flyvbjerg, et al., 2003). The anticipated rewards of building the correct projects in a timely and cost effective manner can only be matched by designing ill-conceived projects or delivering them with an array of faults (Flyvbjerg, et al., 2003). It has become equally important to select projects with the correct mix of economic, social and environmental impacts (Noorbakhsh & Ranjan, 1999) (Hendrickson, 1998). Until recently, not enough importance has been placed on systematic and knowledge of mega-projects in order to direct policy and public discourse in the expensive business associated with mega-projects and government (Flyvbjerg, et al., 2003).

2.2. CONTEXTUALISING THE NATURE OF MEGA-PROJECTS

Mega-projects have been the preferred energy infrastructure design as opposed to smaller projects (Deloitte, 2014). This has been the trend in China, Korea, United States of America, Sub-Saharan Africa and India (Kent, et al., 2017). This trend was fuelled by rampant industrialisation, increased output in Africa's natural resource sector and economic growth particularly in Southern Africa (Deloitte, 2014).

Priemus et al. (2008) state that an increased number of larger mega-projects are being planned and built despite their poor performance record in terms of costs and benefits to society and the economy. However, mega-projects have significant risks, which include the risk to countries, lawmakers, developers and lenders. Mega-projects possess an inherent risk due to extended planning requirements and challenging interfaces (Flyvbjerg, 2006).

These diverging views form the mega-project paradox which has created a conundrum for all proponents of mega-projects. Are mega-projects sustainable and feasible in the long run and do they deliver value and benefit to the economy, country and its people?

Despite the preference for mega-projects, the status quo is evolving. Project developers are no longer established utilities or governments with sizeable balance sheets; they are being replaced by public private partnerships (PPP) particularly in developing countries (Kent, et al., 2017). Market and regulatory reform is being experienced in the electricity sector which is unsettling for large utilities; whilst technical and market disruptions are more prevalent and are gaining widespread acceptance.

Subsequently, lenders have grown cautious of mega-projects in recent years (Deloitte, 2014). Significant time and cost overruns experienced by mega-projects provides an explanation as to why lenders are changing how they do business (Deloitte, 2014). This and the fact that power purchase agreements (PPAs) with credible offtakers are difficult to obtain; this is a critical project risk which guarantees tariffs and the financial sustainability of projects. The uncertainty of obtaining PPAs in a changing regulatory environment poses a risk for lenders who have to take long term investment decisions (Deloitte, 2014).

Mega-projects are associated with challenges such as financing and technical issues. According to a study conducted by (Flyvbjerg, 2014) given the vastness of resources that are allocated to mega-projects, their management and sustainability has never been this critical. The research of mega-projects is critical in allocating financial, physical and technical resources efficiently.

Whilst there is vast research on mega-projects, this research is limited to the project management of these projects. This dissertation aims to define the mega-project paradox as it relates to energy projects, if and where these mega-projects are being built; who still has interests in funding these mega-projects and what the implications of building them could be on the Southern African region and Eskom in particular.

2.3. INVESTING IN A WORLD OF SUBLIMES

According to Flyvbjerg (2014), the driver of the mega-project boom as well as the attractiveness of these mega-projects can be found in the “Four Sublimes”. A sublime is defined as a reason why decision makers undertake mega-projects (Frick, 2008; Flyvbjerg, 2014; Verreynne, et al., 2017).

The first sublime is technological in nature; a trend ascribed to the positive historical acceptance of technology in the 19^{th} and 20^{th} centuries. This technological sublime was first introduced by Frick (2008) to describe “the rapture engineers and technologists get from building large and innovative projects with their rich opportunities for pushing the boundaries for what technology can do, like building the tallest building, the longest bridge, the fastest aircraft, the largest wind turbine, or the first of anything (Flyvberg, 2017 pg. 7).” Frick (2008) first applied this concept when working on a case study of the multibillion dollar New San Francisco Oakland Bay Bridge project. Frick concluded that the technological sublime had a huge impact on the project design and its outcomes, public debate and in the particular case of the Oakland Bay Bridge, on the lack of accountability for the project’s cost overruns (Frick, 2008). This technological sublime is witnessed with the construction of Medupi and Kusile. Eskom engineers pride themselves in building structures that are among the top 5 biggest coal fired power stations in the world (Eskom, 2015). Kusile will also be the first South African power plant to incorporate flue gas desulphurisation (FGD) technology (Eskom, 2015).

The second sublime is a political one. This is referring to the rapture that politicians get when constructing infrastructure in their honour, tenure or for their causes (Flyvbjerg, 2014). Mega-projects by their very nature attract huge attention, praise and a sense of accomplishment and legacy making (Kennedy, 2015). Moreover, mega-projects attract media attention which is particularly enjoyed by politicians especially during election years, such openings and commissioning of new projects come with ribbon cutting and naming ceremonies as well as praise and public exposure which sometimes make re-elections possible (Flyvbjerg, 2014). A prime example of this is when the idea of a high speed passenger train was conceptualised in Gauteng; the project was dubbed the “Shilowa Express” named after the then Premier of Gauteng, Mbhazima Shilowa (Cox, 2002). This name was later changed to the Gautrain.

The third sublime is the economic sublime, which is what brings pleasure to business people and trade unions. It creates jobs, grows the economy and profit sharing is incumbent of these mega-projects. Mega-projects by their nature have expansive budgets which span billions of Rands; implying ample funds for project developers, engineers, lawyers, accountants, bankers, land owners, architects, consultants, construction companies all other participants in the value chain (Flyvbjerg, 2014).

Lastly, the aesthetic sublime is the joy that designers and people who generally enjoy good design get when looking at buildings that are thought to be 'iconically beautiful'. A global example, is perhaps the Sydney Opera House or the Eiffel Tower (Flyvbjerg, 2014) (Donaldson, et al., 2017).

Flyvbjerg (2014) believes that all four sublimes play a pivotal role in determining the scale as well as the frequency of mega-projects. He believes these sublimes give impetus to mega-projects despite their flaws. He goes further to say, when mega-projects are merged they enhance strong alliances amongst stakeholders who stand to derive benefit from them and thus are willing to engage in more of such projects.

Given the discussion on sublimes, it is imperative to highlight that during the first half of the 20th century, Eskom's build programme was determined by the economic sublime. The growth in mining, job creation, industrialisation and economic growth spurred the building of power plants (Steyn, 2006). From the late 1960's this sublime ceased to be a driving force. Instead the race for nuclear and hydro technologies was related to national security, nuclear proliferation and energy mix diversification (Steyn, 2006). From the 1980's, the mandate had shifted and security of supply became a major feature along with a technological sublime; it was during this period that Eskom constructed their biggest power stations with elaborate designs (Steyn, 2006). Since the 1990s, mega-projects have been viewed with an economic sublime however with a social angle. The investment in power projects both Eskom and IPPs have been driven by job creation, local content, industrialisation, ownership, social benefit and economic impact. Mega-projects have continually evolved over the course of history in their nature, magnitude, occurrence and their perceived doles and shortcomings (Parrock, 2015).

Flyvbjerg (2014 p.7) asserts that for policy makers, investments in mega-projects are desirable because if executed properly, they have the following benefits:

- Creates sustainable employment,
- Contains a higher element of domestic inputs as compared to imports,
- Improves productivity and competitiveness by lowering producer costs, &
- Consumers enjoy higher quality services,

Despite challenges with mega-projects they continue being built in larger numbers; this is due to a number of benefits in particular the stated sublimes. The benefits of mega-projects are favourable to most investors and governments. Implemented correctly, mega-projects can have a positive and sustainable impact on a country.

2.4. THE CHALLENGE OF FUNDING MEGA-PROJECTS

Mega-projects are where the best in the industry work, where the elite engineers and project managers are awarded (Parrock, 2015). Over the years, working on mega-projects has led to a specialised group of transcontinental players that dominate the industry and are used as benchmarks for others elsewhere (Frick, 2008) (Flyvbjerg, 2014). As esteemed as these mega-projects may be, they are not without their challenges. Table 2.1 lists typical challenges encountered when funding mega-projects (Othman, 2013) (Moola, 2017) (Mabuza, et al., 2013) (Garemo, et al., 2015) (PwC, 2014):

Table 2.1: List of Challenges of Mega-projects.

Othman	McKinsey	PwC	National Energy Regulator of South Africa	Investec
Engineering	Over optimism	Lack of private sector funding	Credit rating	Lack of private sector investment
Human Development	Over complexity	Insufficient funding	Cost overruns	No credible offtakers
Managerial and political	Poor execution	Changing funding models	Consumer affordability	Affordability of consumer
Sustainability	Weakness in organisational design	Political risk and corruption		Long term funding
	Lack of capabilities	Project delays		
		Budget overruns		
		Project management		

These challenges range from project management, regulatory, financing, human capital, consumer and industry changes. To be able to address most of the issues raised in a concise manner, these issues will be grouped into the following categories and discussed in detail:

- Time and cost overruns,
- Funding requirements, &
- Project management and Human capital

2.4.1. Time and Cost Overruns

Mega-projects are highly coveted amongst industry leaders, with only the best specialists having the opportunity to work on them. The implementation of mega-projects requires a greater level of leadership with superiority in managing them and dealing with cost overruns and schedule delays (Jones, 2008).

Overruns relating to time and cost in mega-projects have over the years become difficult to manage for project managers (PwC, 2014). This is due to the impetus placed on projects by governments, funders and project owners pushing for a quality product produced in the shortest amount of time and within budget (PwC, 2014) (Hart, 2016). The overrun risks associated with mega-projects are well documented. According to Flyvbjerg (2014) and Frick (2008) 90% of mega-projects attract cost overruns; while overruns of more than 50% are not uncommon. Table 2.2 lists famous global mega-projects and their cost overruns:

Table 2.2: Cost Overruns on Mega-Projects Source: (Flyvberg, 2017 p.20).

Project	Cost Overrun (%)
Suez Canal, Egypt	1,900
Scottish Parliament Building, Scotland	1,600
Sydney Opera House, Australia	1,400
Montreal Summer Olympics, Canada	1,300
Concorde supersonic aeroplane, UK, France	1,100
Troy and Greenfield railroad, USA	900
Excalibur Smart Projectile, USA, Sweden	650
Canadian Firearms Registry, Canada	590
Lake Placid Winter Olympics, USA	560
Medicare transaction system, USA	560
National Health Service IT system, UK	550
Bank of Norway headquarters, Norway	440
Furka base tunnel, Switzerland	300
Verrazano Narrow bridge, USA	280
Boston's Big Dig artery/tunnel project, USA	220
Denver international airport, USA	200
Panama canal, Panama	200
Minneapolis Hiawatha light rail line, USA	190
Humber bridge, UK	180
Dublin Port tunnel, Ireland	160
Montreal metro Laval extension, Canada	160
Copenhagen metro, Denmark	150
Boston-New York-Washington railway, USA	130
Great Belt rail tunnel, Denmark	120
London Limehouse road tunnel, UK	110
Brooklyn bridge, USA	100
Shinkansen Joetsu high-speed rail line, Japan	100
Channel tunnel, UK, France	80
Karlsruhe-Bretten light rail, Germany	80
London Jubilee Line extension, UK	80
Bangkok metro, Thailand	70
Mexico City metroline, Mexico	60
High-speed Rail Line South, The Netherlands	60
Great Belt east bridge, Denmark	50

Particularly for power plant and transmission projects, a study by Sovacool, et al., (2014) shows that there are cost overruns in three out of every four projects. An analysis of more than 400 power plant and transmission projects in 57 countries has revealed that only 39 projects amongst all did not experience cost overruns or underruns; that is a total of 9.73%. In their experience the intensity of these overruns are influenced greatly by geography, along with the size of the plant as well as the fuel source (Sovacool, et al., 2014).

Time and cost overruns are caused by multiple factors and a single issue related to labour, procurement or systems may influence a project negatively (Condon & Hartman, 2004) (Flyvbjerg, et al., 2003). However, one of the leading indicators of cost overruns is usually time overruns (Ameh & Osegbo, 2011). Figure 2.1 depicts the mean time overrun as well as percentage of projects with cost overruns.

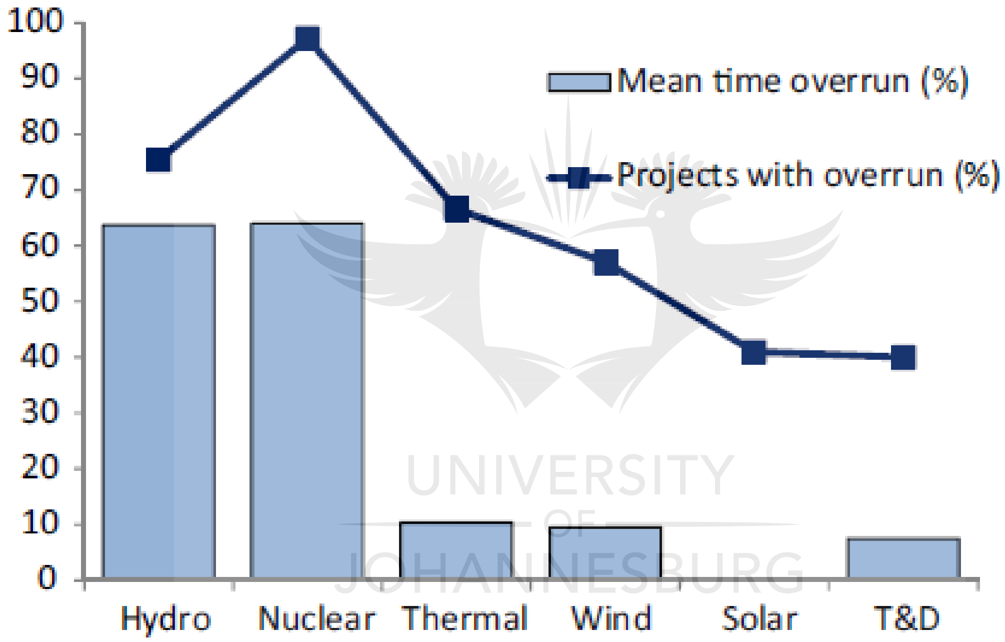

Figure 2.1: Project Overrun per Technology Source: (Sovacool, et al., 2014).

Figure 2.1 for instance in the case of nuclear, shows that time overrun was 64% whist the cost overrun was close to 100%. A plausible rationale for this disparity between project and cost overrun trends may be due to the fact that costly attempts were undertaken to expedite schedules with a goal of minimising delays. These mismatches could have emanated from exorbitant salaries along with overtime costs, which are used to entice workers, thus leading to a decline in lead times as well as a rise in overall expenditure (Sovacool, et al., 2014).

On the one hand, cost overruns are not always accidental because they can be strategic in origin. In this instance, project managers can overestimate the real costs and benefits that are linked to a project; the goal being to keep stakeholders interested, committed and involved (Sovacool and Cooper, 2013). Energy and transport projects with significant infrastructural implications are approved solely because of underestimated costs, exaggerated revenues, underestimated environmental effects, and overestimated economic development impacts (Flyvbjerg, et al., 2003; Flyvbjerg, 2013; Söderlund, et al., 2017).

Given the distortion of information, poor risk assessments are under undertaken while the true risk of projects is hidden from investors, taxpayers, and regulators, only to be revealed very late in the project when it is too late to abandon the failing project (Flyvbjerg, 2013). The contractors who are keen to legitimise their projects may produce unreasonably optimistic projections at the beginning of these projects, which may take long to be detected (Flyvbjerg, et al., 2003). In addition, contractual penalties that are levied against unusually positive assessments are usually lower than the potential profits derived by misrepresentation. This provides a deceptive incentive for these agents to exploit the weaknesses of the system although they can be found accountable later (Söderlund, et al., 2017) (Flyvbjerg, 2006). According to Flyvbjerg, the solution is to make strong demands on accountability. It is therefore necessary to attribute or to apportion financial blame on those who make over optimistic forecasts (Flyvbjerg, 2005).

Eskom has in the past delayed construction of its plants such as Majuba and Duvha, this was deemed a strategic overrun. This was due to low demand during the early 90s and a reluctance by Eskom to create 'white elephants'. As a result, construction was delayed in order to monitor demand and build at a commensurate pace (McRae, 1997).

2.4.2. Funding Requirements

Mega-Projects by their very definition cost in excess of $1 billion (Söderlund, et al., 2017). This money is often raised through the financial markets as very few companies have a balance sheet that can absorb this cost (PwC, 2014). Even if they did, resource and capital allocation would rather place this money in other interests and have lenders share in the risk (Den Haan & Covas, 2012). Mega-projects often have a group of global lenders clubbing together to make a deal possible.

In addition to this funding requirement, there is often a debt equity mix which comes from lenders, private equity, government borrowing and private debt; all of this is blended to provide an equitable return on investment (ROI) to all participants (Den Haan & Covas, 2012). Figure 2.2 depicts the debt equity ratios which lenders applied during financial close between Q4 2015 till Q4 2016, the emerging trend could be that banks are requiring a higher equity contribution as the global finance market stagnates and uncertainty abounds. It is anticipated that a global recession is less than two years away (Martynova, 2015) (Vale, 2011). Other schools of thought however, believe that due to the limited pipeline of Greenfield projects, equity contribution has risen as sponsors require operational assets. These are seen to be safer and guarantee a steady income (PwC, 2011) (OECD, 2013).

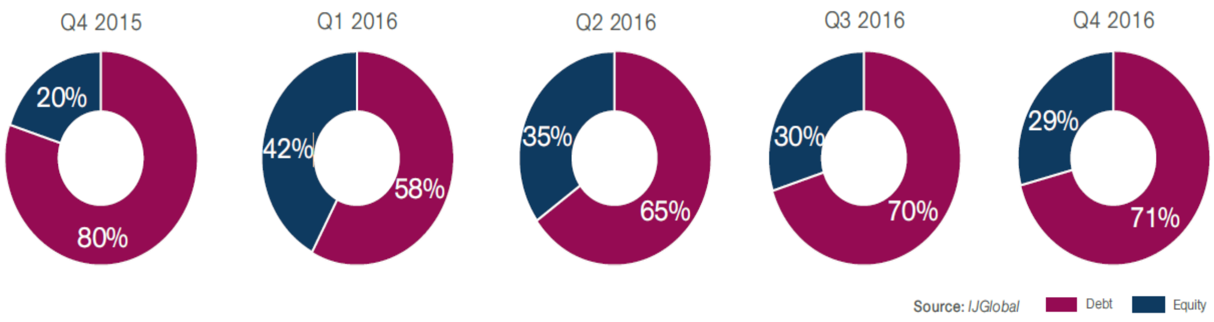

Figure 2.2: Infrastructure Finance Debt-Equity Ratios Source: Infrastructure Journal.

Figure 2.3 breaks down global infrastructure financing by the source of funding, however further expands on the type of debt being used.

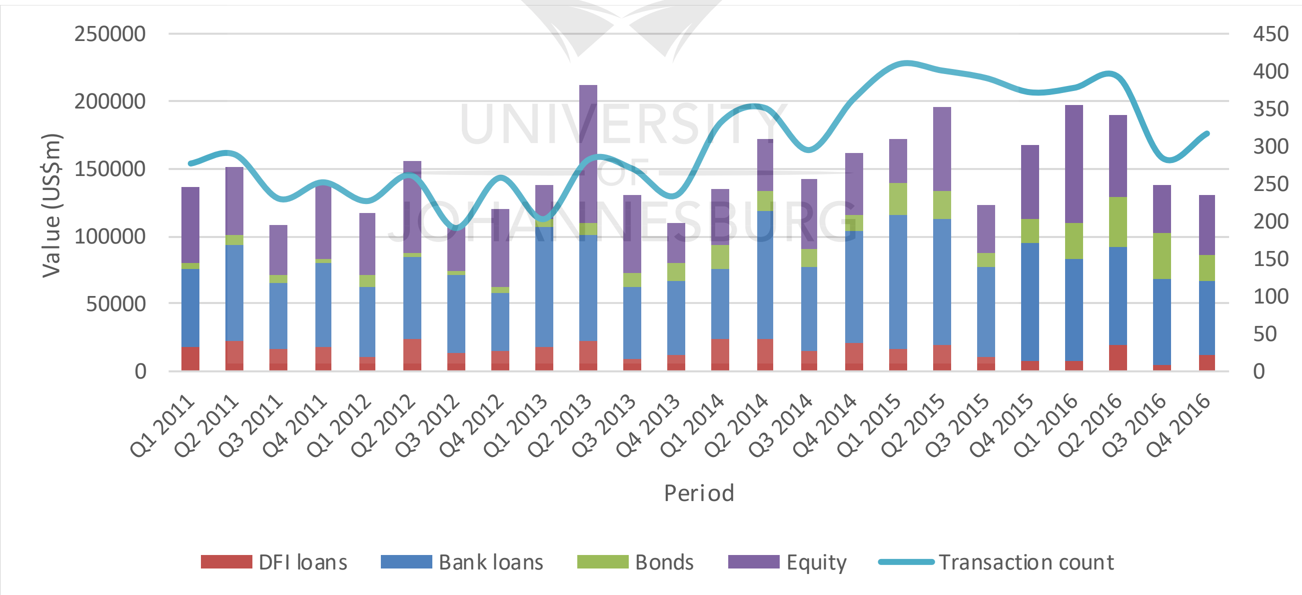

Figure 2.3: Global Infrastructure Equity-Loans-Bonds-DFI Breakdown Source: Infrastructure Journal.

An analysis of Figure 2.3 reveals that DFI loans contribute to a small percentage of total funding required, the bulk is taken up by commercial bank loans and equity; with bank loans of course far surpassing the equity contributions. Bonds have over the last 5 years become popular for funding, these bonds are also raised through capital markets and are starting to have a larger share than DFIs. Apart from 2Q2013 when funding breached the $200 000 million threshold, over the last 3 years funding has been oscillating just below this amount.

The funding tenor exhibited in Figure 2.4 is also seeing a gradual decline indicating perhaps reduced risk appetite or the need to syndicate loans sooner. It is important to note that this debt tenor refers to senior banks and not necessarily DFIs, this is perhaps one of the advantages of funding with DFIs, a longer tenor of up to 18 years or longer in certain instances is offered (International Finance Corporation, 2017).

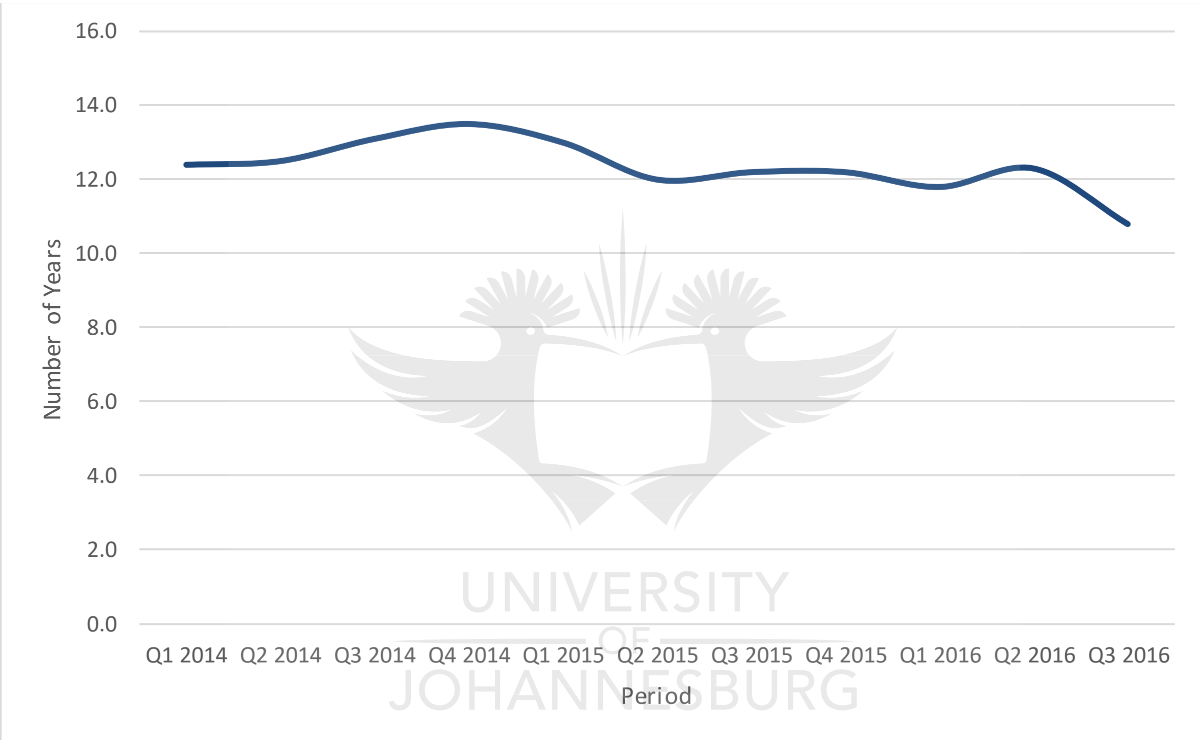

Figure 2.4: Commercial Senior Bank Tenor Source: Infrastructure Journal.

Funding constraints are multi-layered. Certain technologies are not funded by some banks, for instance, it is very difficult to secure funding for a nuclear or coal project (Sweet, 2016). The World Bank as well as European banks such as KfW, Agence Francaise de Developpement (AFD) and the European Investment Bank (EIB) for instance do not fund coal fired plants unless under exceptional circumstances (Centre for International Climate Research, 2017). This is a hindrance for many countries considering coal as a base load solution. European countries and their banks are more amenable to renewables because they have a technology agenda which aims to spread renewables globally.

In addition to obtaining capital, comes the additional burden of securing the preferred and favourable cost of capital. Certain Development Finance Institutions (DFIs), like those in South Africa charge an interest premium because they have been downgraded. Owing to their credit downgrades, they borrow money at a higher cost from other lenders and thus pass this premium down to their borrowers (Huang & Kuo, 2014) (Adelino & Ferreira, 2014).

2.4.3. Project Management and Human Capital

Project management is a critical resource in executing mega-projects (Ameh & Osegbo, 2011) (Garemo, et al., 2015) (PwC, 2016). Project management skills abound globally, however specialised skills and experience are required to lead mega-projects (Othman, 2013). Project management can be a fatal flaw during project implementation if there are no underlying tenets (Othman, 2013). A few of these characteristics will be listed below:

- Projects are often led by planners and managers who will change over the construction life of the project; this means that over time institutional memory and experience are eroded – this leaves project leadership weak (Flyvbjerg, 2014 p.8)
- Decision making, planning and management are typically multi-actor processes involving multiple stakeholders, public and private, with conflicting interest (Aaltonen, et al., 2010)
- Significant changes in scope and project ambition will occur over time (Ameh & Osegbo, 2011)
- Managing cross-cultural teams with very diverse backgrounds (Foan & Parslow, 2006)
- Employing a separate project management company to manage an EPC contractor

Key to everything, project management will be the first line of defence against time and cost overruns; capital adequacy and technical accomplishment (Ameh & Osegbo, 2011) (Othman, 2013). The key to being a successful project manager will be based on many factors, some of which, being the ability to be a social architect who understands the interaction of political and business ambitions. A project manager who can balance productivity and rewards as well foster a climate of active participation that is devoid of dysfunctional conflict (Ameh & Osegbo, 2011) (Othman, 2013).

2.5. TECHNOLOGY DISRUPTIONS IN THE POWER SECTOR

Disruption in the energy sector can be defined as evolution of markets through the emergence of disruptive technologies. In the short term these technologies may result in bad performance of the industry. However in the medium term, these technologies can be competitive and start to dominate and shape the market (Linnankoski, 2017).

Deloitte (2015) in their Deloitte Africa Power Trends Report gives six disruptors that have emerged in the power sector, these are:

- African economic growth
- Shifting the energy mix
- Renewable technology
- Changing role of customers
- Smart grids, smarter utilities[2]
- Changing market structures and dynamics

The following section will focus on five disruptors that have emerged in the energy sector over the last decade and have played a huge role in shaping policy and will affect utilities and how they operate for years to come.

2.5.1. Economic Growth in Sub-Saharan Africa

Between 2009 and 2015, South Africa has experienced a stagnant economy which is forecast to grow an average of 2.4% between 2015 and 2019 (Deloitte, 2015); however this growth has not been commensurate with electricity demand growth. Electricity demand is at its lowest (Eskom, 2016) and the trend does not show signs of improvement.

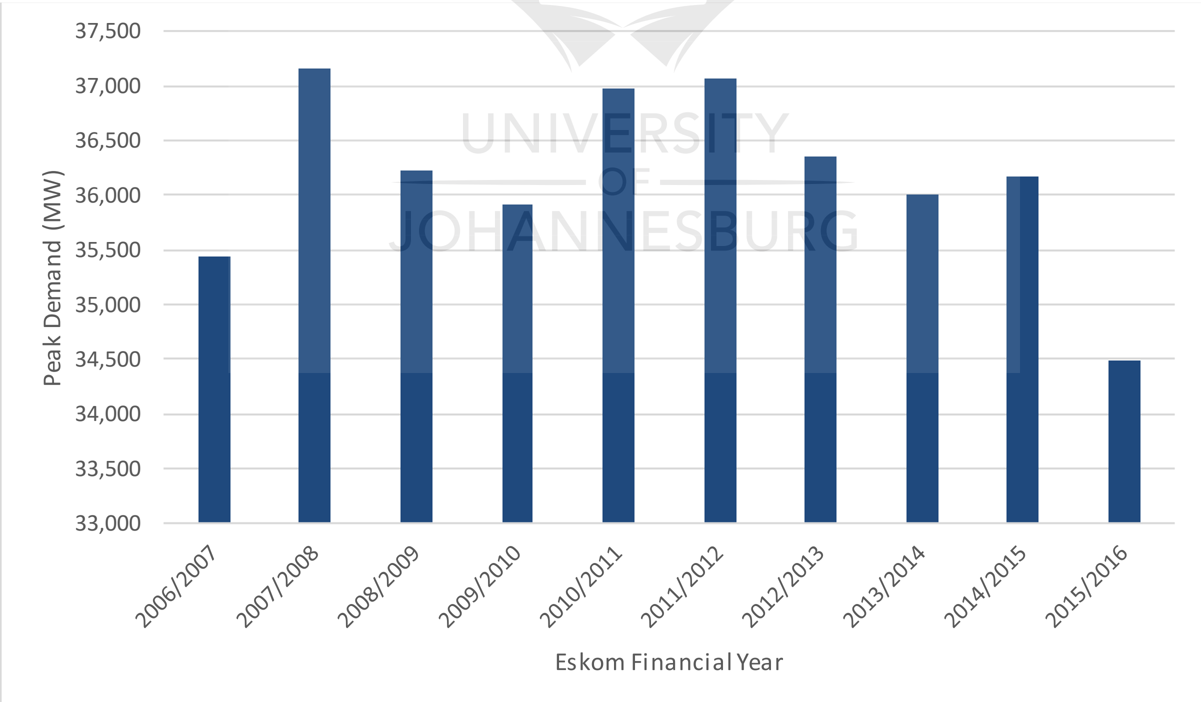

Figure 2.5: Peak demand on integrated Eskom system, including load reductions and non-Eskom generation (MW) Source: (Eskom, 2016).

[2] This disruptor will not be looked at due to a lack of credible and sufficient sources

The peak demand pertaining to the integrated Eskom system is illustrated in Figure 2.5. The peak was experienced during the 2007/08 financial year when South Africa was experiencing high economic growth, in 2008 this all came crashing down with the global financial markets. Electricity demand declined due to a slowing economy but more importantly because electricity demand had surpassed supply (Deloitte, 2017).

Since 2008 numerous interventions were implemented to reduce demand through technology interventions such as solar water heaters, heat pumps and PV installations. Adding to these were measures to use power more efficiently such as reducing consumption, LEDs[3] and CFLs[4] as well as pool timers (Inglesi-Lotz & Blignaut, 2011).

The initial thinking was to reduce demand in order to prevent loadshedding and to give Eskom enough time to commence the New Build programme. Inadvertently, it seems the measures were implemented robustly and successfully, however failed to take into account new generation which was being built (Inglesi-Lotz & Blignaut, 2011).

Between 2006 and 2016 March, Eskom increased its generating capacity from 42 618MW to 45 075MW and there was an additional 3 392MW added by Independent Power Producers (IPPs) (Eskom, 2016); that is an increase of 5 849MW in South Africa's generating capacity, however demand has declined sharply to below 34 500MW; from an average of 36 000MW.

This is a worrying trend because the country continues to increase its generating capacity however demand is on a decline because of the slowing economy and demand management (Deloitte, 2017). The advent of disruptive technologies has altered this belief in economic growth and electricity growth being correlated (Inglesi-Lotz & Blignaut, 2011). Historically such economic slumps were met with increased generation capacity. Due to there being no competition with the grid, customers would inadvertently return to the grid once the economic situation improves. For the first time in history, utilities face a stark reality, the customers lost may never return to the grid as they have found alternative means of energy production. This could mean the investing and construction of mega-projects that will not have consumers to offtake the power generated.

Sub-Saharan Africa is experiencing unprecedented growth, it is one of the fastest growing regions with an average GDP growth rate of 6% over the past 15 years (Deloitte, 2015); and as a result have a high energy demand. On average, the inhabitants of the African continent are utilising lower energy than is the case for England more than a hundred years ago

[3] Light Emitting Diode
[4] Compact Fluorescent Light

(Davidson & Sokona, 2002). The difference between electricity consumption amongst African countries with the developed world or even among African countries is disturbing. As it stands, in excess of 600 million people living in Sub-Saharan Africa do not have access to electricity (Castellano, et al., 2015).

To compound matters, as the worlds electricity per capita consumption has been increasing during the last three decades, Sub-Saharan Africa's consumption per capita has been on a declining trend. The electricity per capita consumption of Sub-Saharan African countries (excluding South Africa) declined from 132.6kWh in 1980 to 112.8kWh in 2000 (Wolde-Rufael, 2006 p.1107).

As a result of this shift in economic growth and declining demand, many Sub-Saharan African countries have opted to increase their generating capacity through build programmes, albeit not in the grand scale of Eskom's New Build Programme. Table 3 lists all the projects planned within the Southern African Power Pool (SAPP) region; these projects range in size from 88MW to 4 320MW for Grand Inga with the last commissioning date being in 2025. The East African Power Pool as well as the West African Power Pool are planning 12 070MW (Mwangi, 2012) and 10 267MW (WAPP, 2011) of additional generation capacity respectively.

Table 2.3: Southern African Power Pool Masterplan Source: SAPP.

Country	SAPP	Technology	Capacity (MW)
Namibia	Kudu	Gas	880
Namibia	Baynes	Hydro	600
Zambia	Lunsemfwa Lower	Hydro	255
Zambia	Kafue Gorge Lower	Hydro	750
Zambia	Kalungwishi	Hydro	247
Zambia	Lusiwasi	Hydro	88
DRC	Zongo 2	Hydro	150
Tanzania	Rumakali	Hydro	520
Zambia	Mpata Gorge	Hydro	543
Malawi	Lower Fufu	Hydro	100
Tanzania	Ruhudji	Hydro	480
Zimbabwe	Hwange 7 & 8	Coal	600
Zimbabwe	Kariba South Extension	Hydro	300
Mozambique	Temane	Gas	400
Mozambique	CTM – Maputo	Gas	100
Mozambique	Chirodzi	Coal	150
Mozambique	HCB North Bank	Hydro	1245
Mozambique	Mphanda Nkuwa	Hydro	1500
Zambia/ Zimbabwe	Batoka Gorge	Hydro	2400
DRC	Grand Inga Phase 1	Hydro	4320
DRC/ Zambia	Mambilima & Mumbotuta Falls	Hydro	1200
		Total	**16 828MW**

With all these countries generating power, there may come a time where countries which lie within the Southern African Power Pool (SAPP) will no longer rely on Eskom for power imports. This will have huge repercussions for Eskom whom according to pronouncements by their executives, fear that this may come to fruition.

South Africa's energy demand situation continues to deteriorate whilst generation capacity increases monthly through new generation and system efficiencies. Eskom in South Africa has suggested the development of an integrated African power pool to help facilitate more electricity cross border trade while arguing for more investments involving generation plants (Creamer, 2016). During a presentation at the Africa Energy Indaba in February 2016, the Group Executive for transmission, Thava Govender, made the point that the continent is in need of enhanced interconnectivity, along with efficient transmission infrastructure to boost cross-border sales to areas in need of electricity (Creamer, 2016).

This will do good to ward off excess supply in South Africa whilst the rest of the continent is starved of power, ultimately making Eskom a large exporter of power within SAPP. However looking at planned generation in all three power pools and Eskom's own generation, combined with declining demand there could very well be a situation of oversupply in future. Leading to untold problems for the utilities who borrowed large sums of money to finance their generation expansion.

2.5.2. Diversified Energy Mix

During the last 90 years, South Africa's energy mix has been heavily reliant on coal; Eskom's coal capacity as a percentage of total generation historically has been in excess of 90% of the total installed capacity (Statistics South Africa, 2015). This is true even today. This mix however has started to change with the advent of renewables, which places coal reliance at 82% of total grid capacity[5] (Eskom, 2016). The 18% of other capacity is made up of hydro, pumped storage, gas turbines, wind energy, nuclear, solar and wind.

The diversification of the energy mix brings with it new participants such as IPPs, private companies and entrepreneurs. It also changes the face of banking, as traditional entities such as Development Finance Institutions (DFIs) make way for commercial banks who are interested in the high returns and risk averse investments especially in competitive renewable bids (Eberhard, et al., 2014).

Solid relationships between the private and public sector have become pivotal in ensuring the success of the future energy model, this has impacted on policy and funding models (Eberhard, et al., 2014). The diversified energy mix has also brought with it the need to plan and integrate on a regional level and to provide solutions that will meet country specific needs whilst ensuring regional success (Montmasson-Clair & Deonarain, 2017).

The changing energy mix has also invited notable players from the United States, China and Europe who provide a range of funding models that include government loans, equity and private investment. This has had a major impact on banks operating within the region, it has catapulted these regional banks into providing innovative solutions that can compete with international funds (Montmasson-Clair & Deonarain, 2017). Figure 2.6 graphically represents

[5] Total Integrated Eskom Grid (incl. IPP purchases, wheeling and energy imports)

the percentage of project participation in Sub Saharan Africa (SSA) power infrastructure projects by funders, builders or owners.

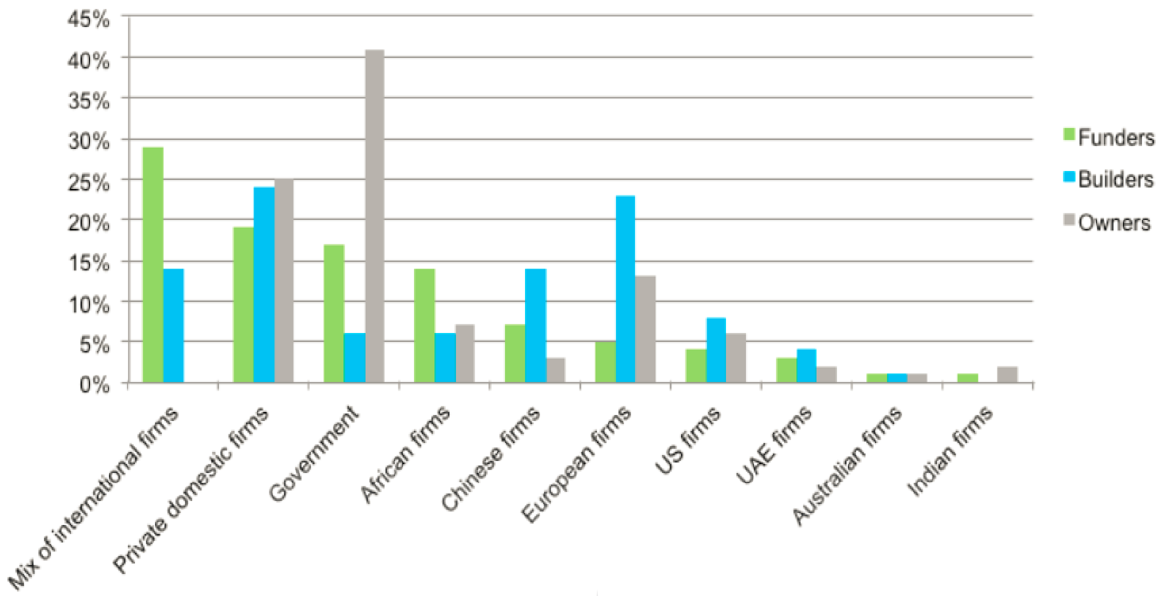

Figure 2.6: Funders, Builders and Owners of SSA Power Infrastructure Projects (2014 p.6)[6].

Figure 2.6 indicates that at least 77% of funding for power projects in SSA comes from a mix of international firms, private domestic firms, government and Africa firms (Deloitte, 2015). This is still impressive given the onslaught of funding from the East and West. The builders are typically private domestic firms, Chinese firms as well as European companies; they account for over 75% of those building power projects in the SSA region. However there is a stark contrast with who owns the asset and who builds it, government typically owns most assets due to their large capital outlay and strategic importance. Government is followed by the private domestic sector who together own 66% of all power infrastructure being built in SSA.

2.5.3. Renewable Technology

While (Deloitte, 2015) alluded to renewable technologies in the disruptors list, the focus will be on solar photovoltaic technology as it has enjoyed large scale deployment and has the potential to have the greatest impact in Africa (Castellano, et al., 2015).

[6] Source: Deloitte on Africa: African Construction Trends Report, 2014.
Note: The sampling basis for identifying and mapping infrastructure construction projects in the power sector, was based on projects to be a minimum value of US$50 million and to have broken ground, but not been commissioned, by 1st June 2014.

Solar photovoltaic (PV) although thought to be a new technology has been in development since 1839 with commercial development since the 1970's (Fraas, 2014). Since the year 2000, there has been large scale adoption of PV owing to huge price decreases in the technology. Schleicher-Tappeser (2012) contends that the average growth rate annually of PV between the 2006 - 2010 period was 80% mainly due to the volume and the rapid growth of the global PV market. He goes on further to say that the unprecedented price decline in the PV market is due to growing markets and competition. During the December 2010/11 period, PV modules from China/Taiwan experienced a price decline of about 48% (Su, 2013).

In 2012, the PV grid parity for households was reached for Germany and in South Africa; this was achieved in 2014 for grid tied systems (Schleicher-Tappeser, 2012). The reasons solar has had such disruptive influence are listed below (Schleicher-Tappeser, 2012):

- PV technologies are scalable
- PV cells enjoy economies of scale and steep learning curves due to mass production
- They are compact, have no moving parts and don't require fuel
- Innovation cycles are much shorter for PV than for conventional power plants, planning is also much shorter

According to (Schleicher-Tappeser, 2012) the global PV market grew in excess of 5900% between 2000 and 2010; in 2015 the industry hit a record installation of 51GW[7] of solar PV for that year, marking an increase of 24% from 2014 (Hill, 2016).

The cumulative global installations however, stand at a staggering 223GW. Figure 2.8 shows global installations and their growth over the 10 years between 2006 and 2015, a growth in excess of 3000% (International Renewable Energy Agency, 2016), aided largely by "the rapid deployment of solar PV, working in combination with high learning rates (for every doubling of cumulative installed capacity PV module costs decline by 20-22%) has led to dramatic cost declines in the last 10 years.

Crystalline silicon (c-Si) PV module prices have fallen by over 65% over the last two years alone. This is driving reductions in installed costs. Utility-scale solar PV projects can now have lower installed costs than for wind in some markets and have lower installed costs than for coal-fired power stations in virtually all OECD countries" (International Renewable Energy Agency, 2016).

[7] The Figure of 51GW is subject to a correction factor of 10% in both directions as not all countries report on their solar PV installations

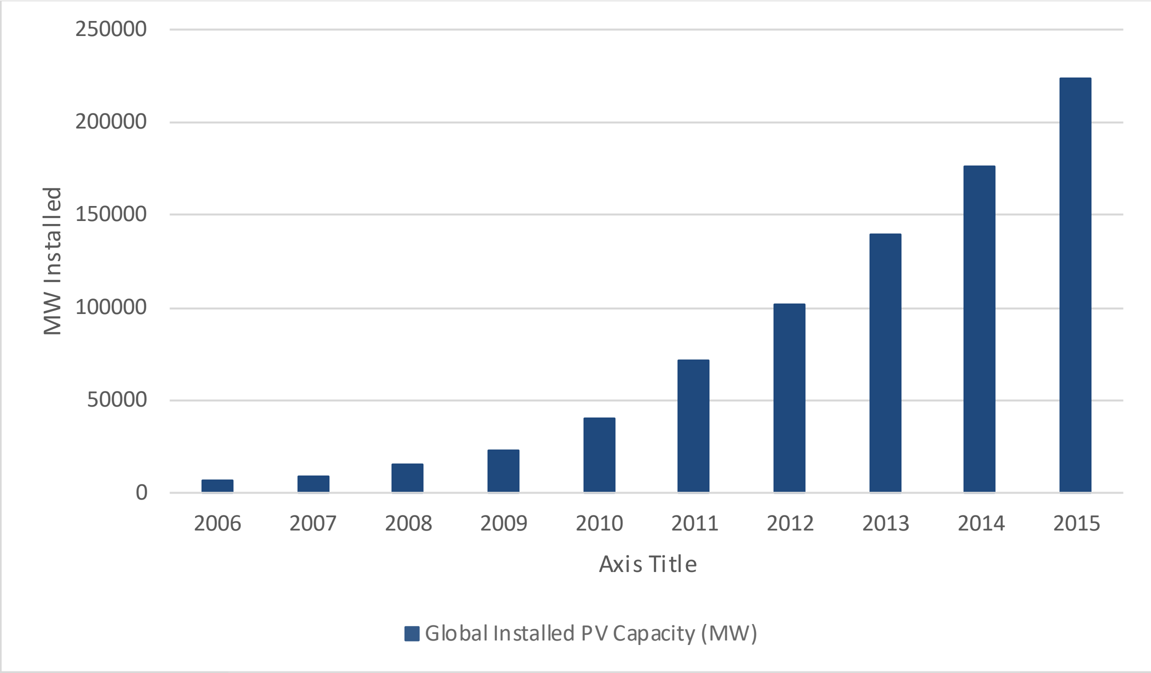

Figure 2.7: Global Installed PV Capacity Source: (International Renewable Energy Agency, 2016).

Figure 2.8 depicts how South Africa has spurred Africa's solar PV increase, accounting for over 60% of Africa's installed PV capacity; Africa's installed PV capacity is just over 2000MW.

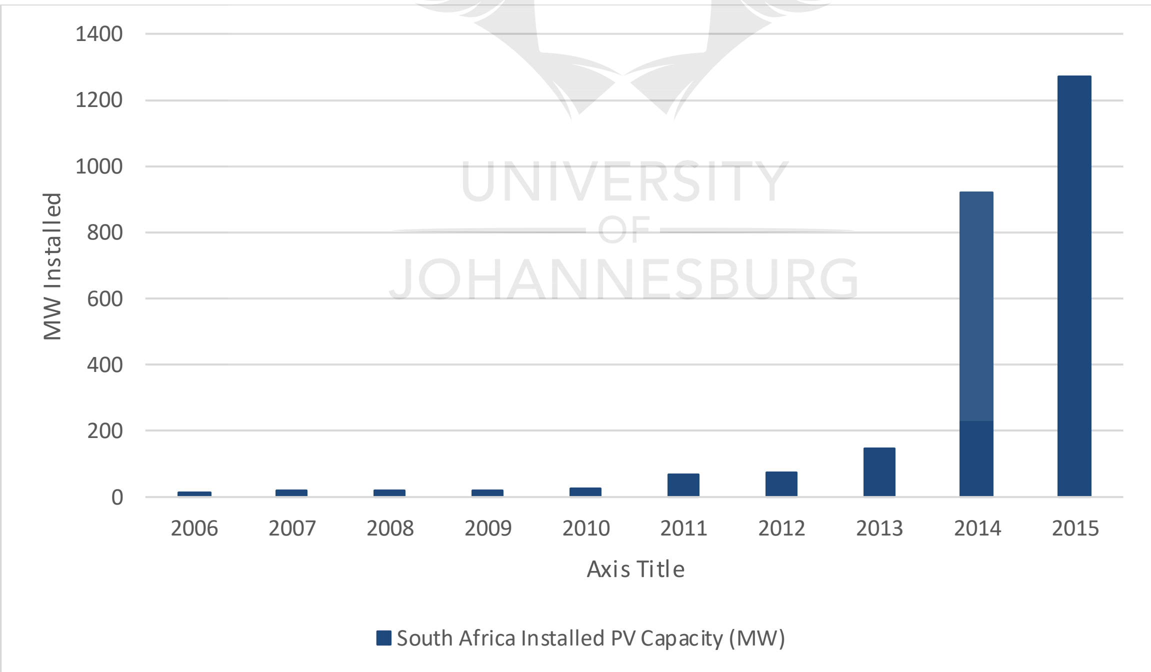

Figure 2.8: South Africa Installed PV Capacity Source: (International Renewable Energy Agency, 2016).

South Africa has through the Renewable Energy Independent Power Producer Procurement (REIPPP) programme alone added more than 2000MW of solar onto the grid in 4 years. This does not take into account small scale residential or commercial installations which are estimated to be 159MWs (Vos, 2016). PV has made electricity generation a reality for consumers, who are now being called "prosumers" – a term for consumers who can also produce their own power (PwC, 2017). A decade ago it would have been unfathomable to request net metering, however this requirement is becoming a necessity as a result of the numerous prosumers in the market (PwC, 2017). These are customers who for all intents and purposes will never return to full time reliability on the grid and may even go off the grid entirely. The customer base is being reduced (Eskom, 2016) and may never return as it has found a competing product. As this trend continues it should worry utilities who are still investing in large infrastructure as well as the funding institutions that lend them money.

2.5.4. Consumer Dynamics

Over the last decade the consumer has become more educated and hence playing a more active role in making their energy choices. This consumer is also keen to "go green" and may as a result start moving away from energy options that are uneconomical and environmentally unfriendly (Deloitte, 2015). The diversified energy mix mentioned above is changing the structural make-up of consumers. Whereas traditionally there was just a consumer who bought power from a single utility or municipality; this has been replaced with commercial customers such as MTN and ABSA[8] who generate their own power from gas and have excess capacity which they could sell to the grid (Eicker, 2011). Coupled with the change in the commercial customer, the residential customer now uses gas for cooking and space cooking, solar for water heating and possibly electrification. There are consumers who now generate their own electricity and even have capacity for supply to the grid. The new types of consumers are being branded "prosumers" due to their dual nature (Deloitte, 2015).

The rural customer now also has access to electricity in their homes, although perhaps not grid tied. This has been beneficial to the rural customer who may not be able to attain grid access due to the costs associated with transmission nor afford the exorbitant electricity costs (Wamukonya, 2007).

As the consumer changes, their behaviour becomes unpredictable and thus difficult to rely on for future projects and generation requirements. Typically when financing a power project what is key is the offtaker and their demand profile, once this profile becomes unpredictable, projects are brought into disrepute and their validity questioned.

[8] MTN and ABSA head offices use trigeneration plants to generate power

2.5.5. Changing Market Structure and Technology Shifts

The advent of the REIPPP programme heralded a massive structural reform for South Africa's energy landscape (Creamer, 2016). Energy generation had multiple new entrants that all had to be accommodated on the grid; all supplying varying amounts of energy from different sources and from remote locations. It has necessitated a flexible grid that has renewable tracking functionality which unfortunately Eskom does not possess (Eberhard & Naude, 2016).

Adding to these woes is the commercial and residential customer who is now producing their own power and has excess capacity to sell to the grid, this customer requires net metering which is currently not an option apart from a pilot project in the Western Cape (Engineering News, 2012). This needs policy and regulatory reform in the form of an Independent System Market Operator (ISMO), who will facilitate the buying of electricity from utilities and manage the grid (Parliamentary Monitoring Group, 2013).

Many SSA countries have started the road towards utility privatisation and have unbundled their utilities to reflect the regulatory reform that will be required from a 21st century utility that still wants to remain relevant (Ivo, 2008).

The market reform also calls for a cost reflective pricing regime which is transparent and recovers all prudent costs (Promethium Carbon, 2016). This has been a contentious issue between NERSA and Eskom regarding what can be recovered, depreciation methods and what is prudent. In addition to the changing regulatory environment is the ever changing technology shifts which require new legislation and policies, these shifts relate to smart meters, smart grids and smarter utilities (Promethium Carbon, 2016).

Smart grids are electricity supply networks that utilise digital communications technology in the analysis, detection and reaction to local changes. These smart grids are being incorporated into a number of utilities within the SSA region. The other benefits of smart grids apart from utility management, will be to optimise asset utilisation and operational efficiency (Deloitte, 2015).

With the emergence of 'prosumers', renewables, off-grid rural solutions and smart grids, Deloitte (2015) believes that opportunities lie in the incorporation of these technologies to feed the smart grid system such that generation of power, its consumption, payment and revenue management are possible from a single device. The integration of technology and smart solutions in the energy sector is a conversion to efficient, revenue enhancing and smart infrastructure (Deloitte, 2015).

2.6. REGULATORY REFORM

Electricity market reform is a global phenomenon that finds it roots in being a way to address major barriers in the Electricity Supply Industry (ESI). Since the 1980s, market liberalisation has become prevalent, today it is perceived as being an answer to many global problems. Some of these problems include obsolete infrastructure, limited access to capital for new generation capacity as well as a technical environment that is changing rapidly (Promethium Carbon, 2016).

The market for electricity in the Southern African region is associated with aging infrastructure, electricity supply challenges, rising tariffs, increasing GHG emissions and a growing exposure to climate change. The current state of the market is exacerbated by growing but decreased electricity demand as well as human and institutional challenges (Promethium Carbon, 2016). Currently, the unavailability of electricity in the region is hampering the business environment and subsequently is limiting economic growth. Market liberalisation that brings increased market competition can lead to a mechanism for encouraging investment and promoting efficient electricity pricing (Promethium Carbon, 2016).

In South Africa, Eskom with an installed capacity of over 42GW is the main electricity utility (Eskom, 2016). This utility is no longer the sole provider of electricity since the emergence of the independent power producers (IPPs) however; it is still holding a dominant market position for the supply of bulk electricity at a time when new IPPs are slowly developing their respective market shares. The emergence of these IPPs was facilitated by the Integrated Resource Plan of 2010 which gives indication of South Africa's energy demand as well as energy sources to meet this demand (Promethium Carbon, 2016).

The section below explores the current regulatory environment in South Africa and its enablers, it also looks into regulatory failures and picks up global utility reforms. A discussion is then provided on the utility of the future and concluding on what Eskom would need to do in order to survive this changing regulatory and technical environment.

2.6.1. Current Regulation that Enables Eskom

The ESI in South Africa has multiple interactions comprised of institutional and regulatory frameworks, the progress of which has been altered partly by political power dynamics and competing industry interests over the last 10 years, which had a direct impact on the cost and availability of power in South Africa (Njikelana, 2014).

South Africa's ESI reform has been "slow and modest". Eskom is still controlled by the state and there appears to be no political decisiveness to completely disaggregate or unbundle its operational structure. There is no denying the important role Eskom has played in South Africa meeting its developmental goals by ensuring universal access. Despite several increases, electricity prices in South Africa remain amongst the lowest in the world (Eberhard, 2004).

Analysts have over time pointed out market opportunities for creating a less monopolistic and highly efficient environment for new investment plans. These suggestions are still not broadly understood or accepted by most stakeholders even within government. In 1998, an Energy Policy White Paper paved a track of "managed liberalisation"; nevertheless, at that time the urgency of securing new power generation frustrated any plans of reform (Eberhard, 2004).

The evolution of South Africa's current ESI configuration dates back to 1998 with the promulgation of the White Paper on Energy; the paper focused on restructuring the framework of the energy sector. Below is a list of some of the major points emanating from the paper that were supposed to ensure the success of ESI reform (Department of Minerals and Energy, 1998 p.42)?

- Customers have the right to choose their electricity supplier
- Introduction of competition, particularly in generation
- Open and non-discriminatory access to the transmission network
- Encouraging private sector participation in the industry

Cabinet approval of the blueprint report included the restructuring of the electricity distribution and the introduction of Regional Electricity Distributors (REDS). The repeal of the Electricity Act in 2003 was anchored on the following (Njikelana, 2014 p.2):

- Multi market model which was proposed to allow for competition in electricity generation
- The need for alignment with the White Paper on Energy
- Restructuring of Eskom generation to allow for competition in electricity generation

Subsequent to the proposal being tabled, there was disapproval to the multi market model as it hinged on the restructuring of Eskom generation (Njikelana, 2014). The ESI regulation is crucial in developing an effective South African electricity market. Thus the role of governments is to design and implement stringent institutional arrangements, adequate policy frameworks and an independent regulator, including policies and directives showing how IPPs, Eskom and municipal distributors should be administered and how they will be held responsible to the state (Njikelana, 2014 p.3).

Key ESI players are:

- Eskom
- Municipalities
- Independent Power Producers

The current institutional stakeholders of the ESI include:

- Department of Energy (DoE)
- Department of Public Enterprises (DPE)
- National Treasury (NT)
- National Energy Regulator of South Africa (NERSA)

2.6.2. Regulatory Failure

Since the late 1990s and early 2000s, the traditional utility model of a publically owned, vertically integrated ESI has been surpassed by the unbundled, efficient and largely privately owned industries. Reform has become unavoidable however Eskom remains; the question becomes has it remained unchanged due to a developmental need or political expediency (Eberhard, 2004).

Eskom's current financial position presents a high-risk level to investors and future base load programmes i.e. coal and gas mega-projects. Investors are likely to be anxious with Eskom's ability to honour the PPAs; this could possibly lead to further guarantees being required by lenders from National Treasury. The continued haemorrhaging of Eskom does not augur well for lenders, shareholders as well as IPPs (Njikelana, 2014).

2.6.3. Global Utility Trends

There has been a growing trend of increased embedded generation and mini-grids in the industry globally. The ESI finds itself in the precarious position the telecoms industry found itself in more than two decades ago with the advent of wireless telephony in a world of fixed lines. The future is uncertain and Eskom may find itself relegated to the role of providing back up power when embedded generation is not available (Njikelana, 2014). This possibility may seem far-fetched but companies such as ABSA, Wesbank, BMW and MTN with their 'off-grid' or co-generation facilities are proving that the future is here. This new utility trend may force lenders to take shorter tenors to guarantee their payback and enter into risk averse PPAs which may be detrimental to the utility.

The technology shift has had a detrimental impact on utilities in Europe and in the United States. The prices of electricity in Germany have reached lows of negative 320 Euros per megawatt hour and it is common for them to remain negative for hours at a time. Three of

Germany's largest utilities – E.ON, RWE and EnBW – have lost approximately 45% to 66% of their share price between 2011 and 2016. As a collective, utilities in Western Europe have lost hundreds of billions of dollars of market value in the past decade (MIT Energy Initiative, 2016).

"Numerous US states are experiencing similar challenges with curtailment and negative electricity prices. Certain renewable generators in the Electric Reliability Council of Texas experienced negative prices in nearly 18% of generating hours in 2011, and many California Independent System Operator units faced negative prices for nearly 6% of generating hours in the same year" (MIT Energy Initiative, 2016, p.6). There remains a challenge in integrating large volumes of renewable energy; however, the pattern shows that renewable energy is no longer an option for utilities but rather a fixed and growing feature to the grid.

Numerous utility models are being pondered, and numerous utilities are opting to either scale down or diversify towards renewables. Companies such as RWE of Germany, claim that "conventional power generation, quite frankly, as a business unit, is fighting for its economic survival" (MIT Energy Initiative, 2016, p. 9). Theodore Craver Jr, CEO of Edison International notes that "It would be foolish to dismiss the potential for major changes in the utility business model" (MIT Energy Initiative, 2016, p. 9). It is in this same light that utilities like E.ON have opted to separate their fossil fuel business and their renewable business. From January 2016, E.ON and Uniper have been operating as separate companies. It was decided that E.ON would focus on renewables, networks, and customer solutions while Uniper guarantees the security of energy supply through its baseload generation and energy trading businesses (E.ON, 2016). They are not the only ones, companies like Enel, RWE and ENBW have followed suit by splitting their operations as a means of further liberating the sector and diversifying their companies to ensure survival.

2.6.4. Future Utility Model

The power sector is in reform and so are its utilities suggests the Massachusetts Institute of Technology (MIT Energy Initiative, 2016). They state that the power system is becoming more distributed with more entrants playing who are sometimes grid-tied or off-grid. These are small generators as well as large generators. This distributed energy is taking multiple shapes such as demand response, electric vehicles as well as conventional power generation.

The (MIT Energy Initiative, 2016) goes on further to assert that the power system is increasingly digitalised, enabling a more active and price responsive demand market. Digitalisation combined with new generation technology is permitting networks to be more actively managed, this has a potential to end the passive customer paradigm where utilities provided for the peak demand to passive customers. In addition to becoming more fragmented, global demand is slowing. Electricity growth as a percentage has declined, where it was 10% in 1950 it is less than 1% currently.

The energy resource mix is evidently more intermittent and renewable, data analysed from "Renewables 2016 Global Status Report" indicates a shift from conventional sources of power to renewable sources such as PV, wind, large hydro, geothermal and marine energy. In Germany for instance, distribution has changed so radically that more than 70% of the grid is connected to the low voltage grid (MIT Energy Initiative, 2016). China in the first half of 2017 has installed in excess of 24GW (PV Magazine, 2017) of solar energy indicating a massive paradigm shift in the countries energy mix.

"Five headline-catching events from within the span of a few months in 2016 alone highlight the significant impact of renewable resources on power systems. (1) From May 7 to May 11, Portugal met its electricity demand entirely with renewable energy sources. (2) Costa Rica generated 100 percent of its electricity from renewable sources, including hydropower, geothermal, and wind energy, for 76 straight days beginning June 17 (ICE 2016). (3) Renewable power sources (including large hydropower plants) provided 40 percent of electricity demand in California in the United States on May. (4) For a brief period on May 15, renewable resources met nearly 100 percent of electricity demand in Germany, Europe's largest economy. (5) Finally, solar PV plants produced more electricity for one week in May 2016 than coal-fired power plants in the United Kingdom, one of the birthplaces of coal-fired electricity production" (MIT Energy Initiative, 2016). These incidents might be listed as anomalies however there is no denying a shift towards renewable technologies globally.

MIT Energy Initiative (2016) further asserts that power systems are decarbonising due to climate change commitments made since the Paris agreements. They further state that power systems are increasingly assimilated with other important sectors as well as critical infrastructure. This trend speaks to the increased inter connectivity and interindependence of electricity and other important sectors and infrastructure such as telecommunications, natural gas, temperature and transportation. The prevalence of combined cycle gas turbines using natural gas can be attributed to the electricity industry as well as the use of electric vehicles; this is also true for the market growth in mobile telecoms devices.

The "Energy Union Package" which defines the European Unions electricity strategy over the next ten years, the European Commission asserts that to achieve the EUs energy goals the EU must divest from a fossil fuelled economy, an economy where the supply of energy is based on a centralised, supply-side approach and which uses old technologies and obsolete business models (MIT Energy Initiative, 2016).

This is but one example of decision and policy making entities anticipating a renewable and distributed generation future, one in which energy consumers play a role in the operations and investment decisions of the power sector.

In a world where the ESI is evolving, where the role of the traditional utility is diminishing, a world with “distributed storage, distributed generation, electric vehicles as well as many diverse and sophisticated forms of demand response, metering, energy control devices, and communications and computational capabilities, both centralised and distributed” what is to become of the utility (MIT Energy Initiative, 2016)?

In a 1978 article titled “Power Systems 2000”, the late MIT Professor Fred Schweppe postulated a theory that went against conventional wisdom at the time. Schweppe imagined the power system as the equilibrium point of supply and demand, where supply and demand play equal roles and together produce a homeostatic equilibrium (MIT Energy Initiative, 2016).

Currently most electricity users in South Africa are gid-connected through a vertically integrated power system where a single central utility makes all decisions concerning the operation of system asets and investment in energy supply (Linnankoski, 2017). (MIT Energy Initiative, 2016) tells us however that in recent decades there has been a paragdigm shift and this centralised model has begun to deteriorate as a result of competitive generation. (MIT Energy Initiative, 2016 p.37) asks how this paradigm might begin to evolve with the introduction of Distributed Energy Resources (DERs), on the next page the possible impacts are listed:

- A distributed provision of services from new players, sectors, industries and residences that need to be coordinated
- Diversity in patterns of power flow, control signals and origin of services. This moves away from a top down utility approach to a bottom up paradigm
- The enabling role of information and communications technologies
- The need for further restructuring of the power sector which will mean integration of the activities of distribution and transmission system operators
- The rise of empowered consumers
- Grid defection, self-generation and implications for tariff design

All these have serious implications for Eskom and its current design, policies and financial outlook. Adaptability is key and any utility lagging behind may become obsolete. DER integration will require an overhaul of common practices and expectations on the functioning of the power system and its regulation.

MIT Energy Initiative (2016) goes on further to suggest a possible framework for the emergence of DERs and how policy makers can adjust for an efficient and evolving power system. Their framework is underpinned by four critical factors listed below:

1. Enhance distribution network
2. Rethink industry structure to minimise conflicts of interest
3. Allow DERs to participate in wholesale markets
4. Carefully evaluate the economic opportunities and costs of DERs

The section below will expound on these critical success factors to enable industry reform of South Africa's electricity sector. It will speak to what was attempted previously, what transpired and what the challenges were to achieve liberalisation of the sector.

2.6.5. Electricity Industry Reform

Most analysts describe at least three broad drivers that drive power sector reform globally. First there is the desire to improve efficiencies in both investment and operations that hinder the performance of state owned utilities which are typically monopolistic in nature. Second is the need for massive increased generation capacity which places pressure on the public purse; this then ingratiates the sector to private participants. Third, unbundling and privatisation creates the opportunity for reallocating the fees and assets of the electricity supply industry and for increasing economic growth or reducing state debt. A fourth could be the need to follow the trend of ESI reform that has powerfully gripped most power sectors globally (Eberhard, 2004).

The Budgetary Review and Recommendation Report (BRRR) of 2011/2 included the restructuring of the electricity industry; this had to be juxtaposed against the potential impact of the restructuring on the socio economic impact of South Africans. As a result, the Independent System Market Operator (ISMO) Bill was born (Njikelana, 2014 p.7). The following recommendations were made by the portfolio committee on energy:

The 5th Parliament ensures that the Minister of Energy:

a) Conducts a due diligence study in order to determine the feasibility and implications of the transfer of transmission assets and to submit a final report to the National Assembly
b) Conducts a cost benefit analysis of the possibility of incorporating the transmission assets into the Independent System and Market Operator (ISMO)
c) Further conducts a cost benefit analysis of establishing a Transmission System Operator (TSO), or any other arrangement suitable to the South African situation.

d) Ensures that the restructuring of the entire electricity sector be addressed as matter of urgency.

An emphasis was placed on the understanding of the outcome for each of the sub-industries in the electricity sector. It is expected that the 5th Parliament will ensure a comparative analysis as well as providing lessons learnt from other countries through a number of interventions such as study tours and workshops to be facilitated for the future Portfolio Committee on Energy (Njikelana, 2014).

Some of the challenges faced by the industry as a result of a lack of clear and concise direction on regulatory reform are listed below (Njikelana, 2014) (Promethium Carbon, 2016) (Deloitte, 2015):

– Uncertainty with regards to policy in the regulatory framework of the ESI have led to harmful impacts on the sector and the economy as a whole
– The unsettled policy environment puts Eskom's demand and financial planning under intense pressure thus increasing its risk profile and access to affordable finance
– The roles of the institutional stakeholders such as the DoE and NERSA have over time become clouded; this is further exacerbated by the information symmetry which leans heavily on the Eskom side
– There is a clamour to ensure cost reflective pricing due to the price path followed in the early 1990s as a result of political decisions
– Periods of rotational blackouts in 2008 and 2015 which affected investor confidence, economic growth and introduced new entrants and disruptors into the ESI

2.7. BRIEF OVERVIEW AND HIGHLIGHTS

Given South Africa's sordid apartheid past and the need for social development post democracy, it was unavoidable that the energy policy would be converted from one focused on defensive energy security to one more focused on promoting social participation and improving economic competitiveness as South Africa reintegrated with the rest of the world. Despite calls for ESI reform in the 1990s, the need to promote social equity and extend infrastructure services to the majority of people forced Eskom and larger municipalities to react to the challenge of electrification first (Eberhard, 2004).

The development of market liberalisation has been unhurried and hampered by the complexity political interests at local and national government level as well as the dread of loss of control of a pivotal infrastructure service with huge income flows (Eberhard, 2004).

Market liberalisation in South Africa is not very advanced even with the introduction of new market participants in the form of IPPs. However, the process towards reform continues through government's commitment to increasing the competitiveness of the economy and expanding the economic participation of black people in South Africa. The impetus for reform is informed by various ebbs and flows in the ESI but is largely led by the White Paper on Energy; in conjunction with various analysts who introduced the international experiences of power sector reform. In 2004, (Eberhard, 2004) had already made assertions that South Africa was at the peak of its low electricity prices and that sharp increases were on the cards – this was to be proven in 2008.

In a bid to remedy this, in a 2013 briefing to the Portfolio Committee on Energy regarding the ISMO Bill, the DoE stated that IPPs have not been forthcoming in significant volumes (Njikelana, 2014 p.8) due to:

- Eskom has several conflicts of interest
- Perception that government is not committed to reforming the industry
- Uncertainty about long term viability of present ESI structure
- Lack of clear policy specifically for IPPs
- Lack of an enabling legal and regulatory environment to facilitate IPPs

Arguments continue being made that a vertically incorporated, state-owned, monopolistic industry, even if made 'corporate' is unlikely to make proficient investment decisions. Government still experiences ambivalence regarding the decision of fully unbundling Eskom, increasing competition and introducing privatisation. Eskom is still viewed as an important instrument of government policy that supports governments' social and economic programme (Eberhard, 2004).

2.8. LITERATURE REVIEW SUMMARY

The literature review was conducted, as presented in this section and throughout this dissertation, to understand how the mega-project paradox emanates and what are some of the challenges utilities, engineer and bankers face when considering building or financing them. Chapter 2 has unpacked some of the key consideration when considering investing in a mega-project.

Chapter 2 commences by drawing our attention to how some mega-project decisions are made, in particular those that do not find their basis in economic drivers. It infers that these mega-projects make use of sublimes that could explain the 'irrational' decision making. These sublimes explain why South Africa has been constructing complex, massive and expensive coal fired plants for the last ten years with no respite in sight.

The added complexity of time and cost overruns leads the list of challenges in funding mega-projects. Given that at this juncture we are unsure of whether mega-projects are being funded or not, this cost analysis is important in understanding why they may or may not be funded. It also enables the understanding of funding shortfalls and why some mega-projects remain incomplete.

The challenge of project management and human capital also presents a massive problem for mega-projects. These two inputs relate to adequate resource efficiency and allocation. Objective 1 seeks to address the challenges of sublimes, overruns, human capital and project management experience as well as disruptions by determining whether or not mega-projects are feasible given the risks and challenges associated with them.

An important aspect of this dissertation is determining whether mega-projects are being funded and by whom; this is addressed in Objective 2 and 3 respectively. Literature was reviewed on the finding requirements and constraints in the capital debt market and how such constraints impact on which projects are financed. Depending on the risk, higher equity may be called for and funding limited to certain types of funders. One of the key findings of the funding constraints section is the limitation of certain funding to certain power technologies. This does not bode well for most countries and may impact their ability to borrow as this may be seen as interference. The prevalence and growth of the renewables sector also indicates a flow of funds away from conventional technologies to renewables which are sometimes seen as disruptors.

Finally, regulatory reform ties back to objective 1 in that given the regulatory changes and challenges, what impact does this have on the feasibility of mega-projects. Given the shift to a deregulated market with foreseeable unbundling what does the future utility model look like for Eskom? This is an important aspect to consider because given rising electricity costs in a deregulated market with increased competition, we could be building stranded assets.

3. CHAPTER

RESEARCH DESIGN AND METHODOLOGY

3.1. INTRODUCTION

This chapter discusses the research design and different methodologies followed to address the research problem, questions and objectives. Section 3.2 explains the research design while section 3.3 discusses the research methods, data collection, and analyses. Section 3.4 explains the sampling techniques used while section 3.5 analyses the questionnaire design. The data analysis techniques are explained in section 3.6 and while research limitation and ethical considerations are explained in section 3.7 and 3.8 respectively.

3.2. RESEARCH DESIGN

The research design provides the overall strategy for integrating the different components of research in a coherent and logical manner, thereby, ensuring that the research problem is addressed systematically and a structure that provides guidelines for data collection, measurement and analysis (De Vaus, 2001). In the current research, a mixed method research design was used. Creswell (2013) defines mixed methods as a research approach whereby researchers are involved in the collecting, analysing and integration of both quantitative and qualitative data in a single study in order to address their research questions. To warrant mixed-method approach, a number of fundamental questions needs to be addressed and these are summarised as follows (Creswell, 2013: 32):

- Is the use of qualitative research or quantitative research alone insufficient to fully understand the problem?
- Is there a qualitative database?
- Is there a quantitative database?
- Is there a need to integrate all of these data sources?

Since this research complies with all of these questions in the affirmations side, the mixed methods design was espoused. Mixed method approach is also regarded as a triangulated research design because during the analysis stage there is a combination of qualitative and quantitative data to help understand the different ramifications of the research problem.

3.3. RESEARCH METHODS

Various research methods and data sources were used in the current study and these entailed close ended and open ended questionnaires to generate primary data (Table 3.1). Such primary data was sourced by means of surveys. In addition, secondary data was generated from existing literature on the sustainability of mega projects. This secondary data was obtained from searching for keywords on the internet (Google scholar and journals) and obtaining journal and research articles that were cited by other researchers. Table 3.1 provides a summary of the research objectives and which methods were used to interrogate and analyse them. For example, the patterns and trends (**Research objective 1, 2 & 3**) emerging from the building of mega-projects were determined from the analyses of secondary data from the IJ Global Project Finance and Infrastructure Journal (www.https://ijglobal.com). The Infrastructure Journal is an online data repository of most infrastructure projects globally and it is the foremost database with relevant information pertaining to individual projects. The repository is constantly being updated and as such it is not static. However, **research objective 1** was addressed by conducting surveys involving industry professionals who have worked for Independent Power Producers (IPPs), Development Finance Institutions (DFIs), private companies, commercial banks and electricity utilities.

Table 3.1: Research Methodology.

Research Objective	Method	Analysis	Presentation
Objective 1: To characterise the feasibility of mega-projects given the risks & challenges associated with them	Open-ended questionnaires	Content analyses & Thematic mapping	Themes & Ideas
	Closed ended questionnaires	Quantitative analysis Likert scale Trend analyses Descriptive statistics	Tables, Bar charts, Pie charts
Objective 2: To establish whether mega-projects are being built and in which countries given market disruptions	Literature scanning; Quantitative data sourced from secondary sources **(Infrastructure Journal Global Project Finance)**	Summarised the patterns and trends emerging from mega-projects; and analysing the number of countries investing in mega-projects, emerging trends and the rationale for investing	Pivot Tables & Graphs
Objective 3: To determine who are the funders of mega-projects	Literature scanning; Quantitative data sourced from secondary sources **(Infrastructure Journal Global Project Finance)**	Analysed the funders who are investing in mega-projects, who they are and where are they located	Pivot Tables & Graphs

3.4. SAMPLING TECHNIQUE

A convenience sampling technique was used. Convenience sampling is also described as haphazard or accidental sampling. Ilker , et al., (2016) defines it as a type of non-probabilistic or non-random sampling where members of the targeted population that adhere to certain criteria such as proximity, ease of access, availability and willingness to participate in a study are selected.

A convenience sample is considered to be affordable and easy as the subjects are readily available. A convenience sampling technique is used in both quantitative and qualitative data. The cons of such a technique however, are that the study is subject to selection bias and thus a high level of sampling error (Ilker , et al., 2016). Due to the nature of this dissertation and the related questionnaire, only energy professionals could have participated and given meaningful input. Thus selection bias can be ruled out because the alternative would have been skewed data due to a wider and uninformed sample size.

This survey was completed by 25 respondents from a selected group of 50, thus represented a response rate of 50%. The survey respondents are anonymous, therefore, age, race, gender or designations are unknown. The respondents were selected as a result of their significant work experience (more than ten years) in the energy sector, globally and within South Africa. The respondents are employed in government, utilities, and research organisations, institutions of higher learning, consulting firms and funding institutions.

3.5. QUESTIONNAIRE DESIGN

To obtain primary data, questionnaires with both close-ended and open-ended questions were utilised. Following a systematic process of evaluating questionnaires from similar studies, a revised set of questions was prepared. The structure of the questionnaire is attached as Appendix A. The structure of the questionnaire used in this survey is attached as Appendix A. The questionnaires were comprised of several questions such as the following ones:

- Are time and cost overruns a deterrent to building mega-projects?
- Are funding constraints a deterrent to investing in mega-projects?
- Is the advent of disruptive technologies, e.g. solar PV and embedded generation, a deterrent in investing in mega-projects?
- Are credit downgrades a deterrent to investing in mega-projects?
- How likely South Africa is to build mega-power projects in this century?
- How likely is South Africa to invest in mega-power projects given fiscal tightening?

- How likely is South Africa to invest in mega-power projects given the experiences with big projects such as Medupi and Kusile?
- How likely is South Africa to invest in mega-power projects given funding constraints?
- How likely is South Africa to invest in mega-power projects given current credit ratings?
- How likely is South Africa to invest in mega-power projects given current demand forecasts?
- How likely is South Africa to invest in mega-power projects given perceived/real corruption surrounding nuclear energy?
- Will South Africa's decision to invest in mega-power projects be influenced by a technical sublime?
- Will South Africa's decision to invest in mega-power projects be influenced by a political sublime?
- Will South Africa's decision to invest in mega-power projects be influenced by an aesthetic sublime?

A total of 25 responses were received out of 50 web-based questionnaires that were sent to prospective respondents by means of the Survey Monkey © software. With this software, it was possible to distribute and analyse the various responses received. The questionnaires utilised had two sections – Section 1 (open-ended questions) and Section 2 (closed ended questions). The open-ended questions were based on the experiences; investments; market and regulations; and project management aspects that are related to mega projects. The close-ended questions involved similar aspects but the questions were based on a Likert Scale. Whereas the primary data obtained via open-ended questions were analysed through content analyses and some thematic mapping, the data from close-ended questions were analysed through quantitative procedures. These procedures were in the form of calculating percentages or number of occurrences that were mentioned by respondents. These were presented in tabular and graph format to illustrate the responses.

3.6. DATA ANALYSIS

The secondary data was sourced from a number of repositories such as journals, research reports, academic papers and presentations, audio and conference proceedings. There is an inherent bias because all these publication were produced for a certain purpose. This data was triangulated with both survey results as well as contrary or opposing information to give a balanced view. Data reliability was ensured by quoting from credible sources in mostly peer reviewed journals as well as credible industry experts and publications.

The secondary data was analysed by summarising the patterns and trends emerging from mega-projects, country data, investment rationale, funding and funders using pivot tables and graphs. This secondary data was also utilised to give impetus to the primary data which is subjective by nature of it being obtained by questionnaire.

The graphs used in the discussion of results are either data extracted from sources, compiled and presented or taken from sources and reproduced. The difference will be indicated by providing a source of the data.

3.7. RESEARCH LIMITATIONS

The major research limitation was the non-static data used in the secondary data collection process. The website used (Infrastructure Journal) is non static and thus is updated on a daily basis. The data had to be extracted instantaneously as a single data dump to avoid future iterations.

Owing to the nature of the research undertaken, participation of survey respondents was also limited as these had to be energy industry professionals with more than 10 years industry experience.

The results stemming from the present research are presented and discussed in chapter 4 and 5 respectively. In chapter 4, the survey results are presented and discussed. Chapter 5 analyses and discusses the data and begins to draw inferences which inform the recommendations.

3.8. ETHICAL CONSIDERATIONS

Ethical behaviour is critical for collaborative work, it encourages an environment of accountability, trust and transparency. Ethical considerations were made for this dissertation given that it involved questionnaires that would be completed by human beings. An ethics clearance form was submitted and approved because there was no human interaction apart from the questionnaire. An electronic consent form was sent to all 50 targeted participants. This form indicated the aim of the research, the institution I am studying at and most importantly gave respondents the opportunity to be anonymous. Given the sensitivity of the research results and the policy implications, it was imperative to give respondents anonymity.

3.9. REFERENCING

Harvard style referencing was used as per University of Johannesburg guidelines.

4. CHAPTER

PRESENTATION AND DISCUSSION OF RESULTS FROM PRIMARY DATA

4.1. INTRODUCTION

This chapter examines the results of the mega-project survey. The survey was aimed at obtaining a deeper understanding of mega-projects from industry professionals. This survey questioned the need for mega-projects as well as their validity and their drivers, given the current economic, financial and political climate that they are being proposed in. In section 4.2, a broad overview of results is presented before the analyses of individual responses is made in different subsections. In section 4.3, the results are discussed in the light of existing literature and industry developments.

4.2. BROAD OVERVIEW OF SURVEYS UNDERTAKEN

This survey was aimed to determine the reasoning or the rationale behind the decision-making processes regarding mega-projects. The survey focused on mega-projects in South Africa and whether or not future investments are likely; bearing in mind that South Africa has committed to a coal base load, gas IPP and nuclear programme.

In order to understand the investment amount involved in the funding of these projects, $1 billion USD, at an exchange rate of R13.46[9] to $1, equates to R13,46 billion for a single project. Throughout the period under review, South Africa did not conclude the financing of a single project to the value of R13,46 billion or above, however, the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) managed to procure investments in excess of R30bn at programme level. This research does not focus on mega-programmes but rather on single mega-projects.

In Table 4.1, a list of projects that were financed between 2013 and 2016 is provided, as well as their combined credit values. Over the review period, South Africa has concluded the financing of 35 projects with a combined value of $4.9bn. Most of these projects were financed as a result of the REIPPPP. The drive for the REIPPPP was a consequence of the 2010 Integrated Resource Plan (2010) and the Paris Accord.

[9] Rand/Dollar Exchange Rate ($1/R13,46) – 9 August 2017

Table4.1: Number of Projects that Reached Financial Close in South Africa between 2013 and 2016 and Combined Credit Value Source: Infrastructure Journal.

Year	Number of Projects	Credit Value (R'million)
2013	14	1256,47
2014	1	18
2015	9	2847,74
2016	1	782,78
Total	25	4904,99

The only single project reaching the scale of a mega-project is the Khathu Concentrating Solar Power (CSP) Plant which drew to a financial close in 2016. This is a 100MW plant based in the Northern Cape; a parabolic trough combined with molten salt concentrating solar power technology. Construction began on the 26th of May 2016 and is expected to reach commercial operation in September 2018 (Khathu Solar Park, 2016). The last mega-projects to close in South Africa were Medupi, Kusile and Ingula which have an updated cost of R100bn, R125bn and R30bn respectively (Mantshantsha, 2017).

4.3. AN ANALYSIS AND PRESENTATION OF SURVEY RESPONSES

This analysis is based on the percentages or proportions of respondents per individual questions that were included in the questionnaire.

When the survey respondents were asked about the future prospects of more mega-projects being built in South Africa, 60% indicated that they envisage mega-projects to be constructed during the next 20 years. Given that the Eskom operating model is pivotal to future investments in mega-projects, it is not alarming that 88% of the respondents claimed that the current operating model was not conducive to an enabling investment environment. This response alludes to a major stumbling block in securing future investments for mega-projects. It is apparent that a new and redefined Eskom will have to emerge within the next two decades.

Eskom aside, there is an electricity supply industry that conforms to market and regulatory requirements. When the respondents were asked whether market and regulatory reforms were required in order to attract investment for mega-projects, 92% said that there was a need for serious market and regulatory reforms. This is important given the complex nature of the electricity supply industry. More reforms would mean transformation in government departments, shareholders, power pools, regional utilities, Eskom, as well as the regulator itself. This may result in the introduction of an independent market operator, or the unbundling of Eskom or the privatisation of generation assets.

The concept of structure was then introduced. A vertical structure is the current Eskom operating model where all business units are vertically aligned and fall under Eskom Holdings. A horizontal structure would comprise of separate business units of generation, transmission and distribution, each being a company on its own. When probed regarding the nature and shape of such a reform, an overwhelming majority of respondents (64%) said that the best model would most likely be a horizontally integrated structure (Figure 4.1) thereby dividing it into separate entities as per business process. This would mean a generation, transmission and distribution company each operating independently of the other. Twenty percent (20%) of the respondents said that the industry should be comprised of a vertically integrated enterprise which combines one firm or perhaps two or more stages of manufacturing, usually operated by separate firms. Sixteen percent (16%) of respondents said that the options presented were not applicable and that other models should be devised. Thus, further research needs to determine what sort of a reform model would be more suitable for South Africa.

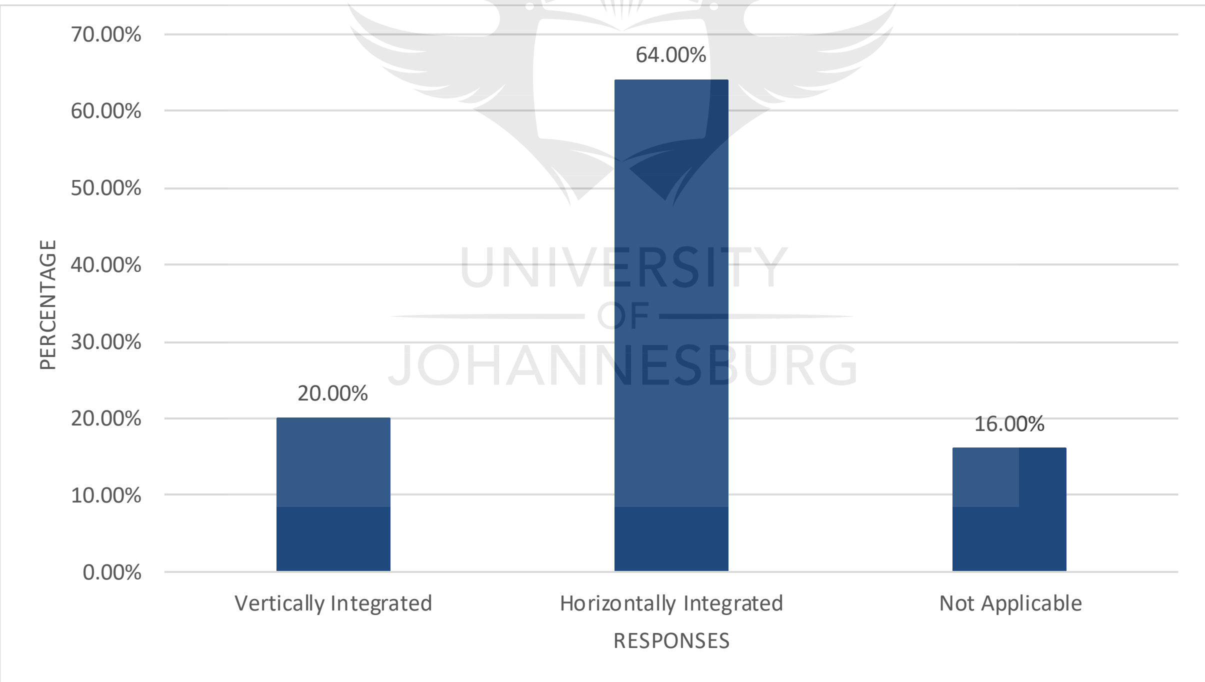

Figure 4.1: Responses on the Shape of reforms.

Delving into the project management aspects of mega-projects, the respondents were asked whether time and cost overruns would be a deterrent to building mega-projects. Eighty eight percent (88%) opined that both time and cost overruns are a deterrent to building mega-projects. This finding is contrary to industry practice as seen in earlier chapters, where despite overruns of 100% not being uncommon, mega-projects still proceed. This is possibly to be expected, as it authenticates the existence of sublimes in mega-project decision making and the materialising of the mega-project paradox.

A question was posed to the respondents as to whether the advent of disruptive technologies e.g. solar PV and embedded generation, would be a deterrent in investing in mega-projects. The results are shown in Figure 4.2. Only 56% of the respondents agreed on the adoption of disruptive technologies. Given the trajectory of Artificial Intelligence (AI) and the Fourth Industrial Revolution, the assumption would be that disruptors would alter the energy landscape and perhaps the future of mega-projects. However, given the demographics of the respondents, this is expected. Most respondents are yet to experience a radical shift in the energy industry as there has not been one. It's possible that their backgrounds and work experiences have not exposed them to the learnings within the information and communication technologies sector over the last decade. There is still a pervasive belief that the energy industry is able to sustain any market and policy reform shocks.

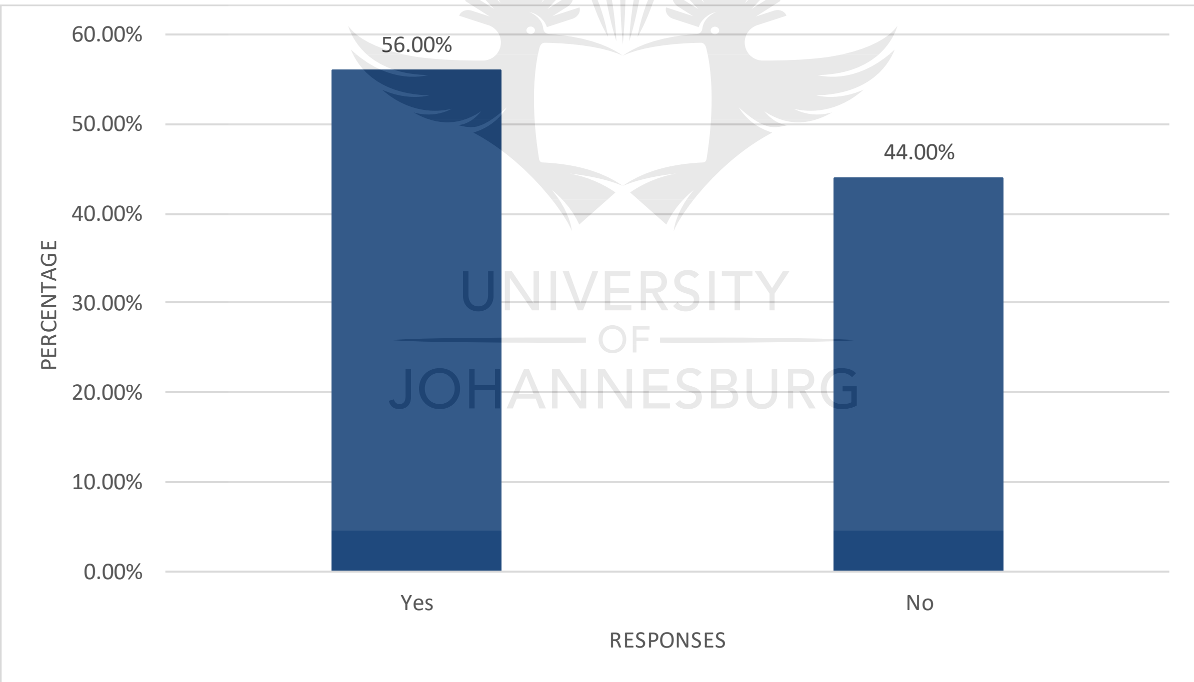

Figure 4.2: Advent of Disruptive Technologies.

One of the most important aspects of mega-projects is the availability and affordability of funding. The survey examined whether funding constraints would be a deterrent to investing in mega-projects, of which 75% of the respondents concurred. The basic tenet of project finance is the sourcing of funds, whether from commercial banks or DFIs.

Without funds, projects do not proceed. In rare instances, such projects are funded by governments, rationalised by one sublime or another, albeit devoid of credit worthiness. It is evident that respondents felt that there was a global capital slowdown and that this would have an impact on the funding of mega-projects.

Another important aspect of finance is the cost of borrowing funds. When asked whether credit downgrades are a deterrent to investing in mega-projects, 80% of the respondents said yes. Based on their opinion, credit ratings would have a negative impact on investing in mega-power projects. Moreover, if a utility (e.g. Eskom) is government linked, a negative sovereign rating will definitely influence the utility. This is also the case for state funders; institutions such as the Industrial Development Corporation (IDC) and the Development Bank of Southern Africa (DBSA).

From questions 10 to 20 on the questionnaires used in this study, responses are depicted in the form of a Likert scale. Respondents were asked how likely South Africa was to build mega-power projects in this century (Figure 4.3) and 55% of the respondents agreed that this was very likely. This is congruent with the findings thus far. The importance of this question (seemingly repeated from question 1) is that the respondents had gone through half of the survey and previous questions may have influenced a different outcome. Previously, 60% of the respondents indicated that South Africa would invest in mega-projects. Using the Likert scale, 71% of the respondents deemed this likely or very likely.

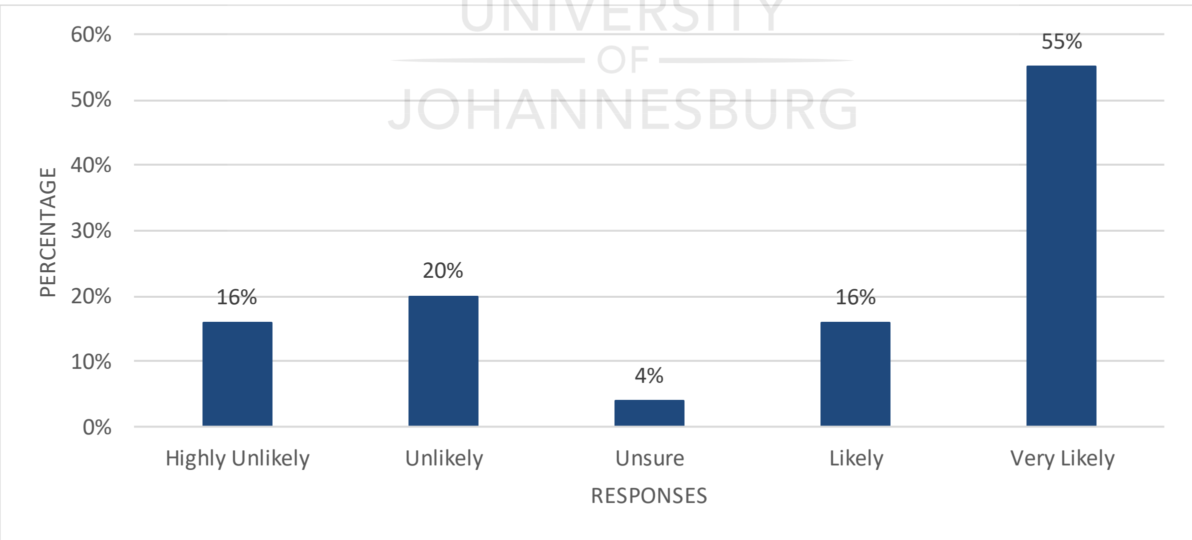

Figure 4.3: How likely South Africa was to build mega-power projects in this century?

Question 11 was based on the likelihood of South Africa investing in mega-power projects given fiscal tightening. It is widely known that fiscal tightening is present both in domestic and global economies; balance sheets are shrinking and may not be able to support mega-projects. Thirty three percent (33%) of the respondents said that it was likely that South Africa would continue to invest in mega-projects, whereas 21% and 25% felt that it was highly unlikely or unlikely, respectively.

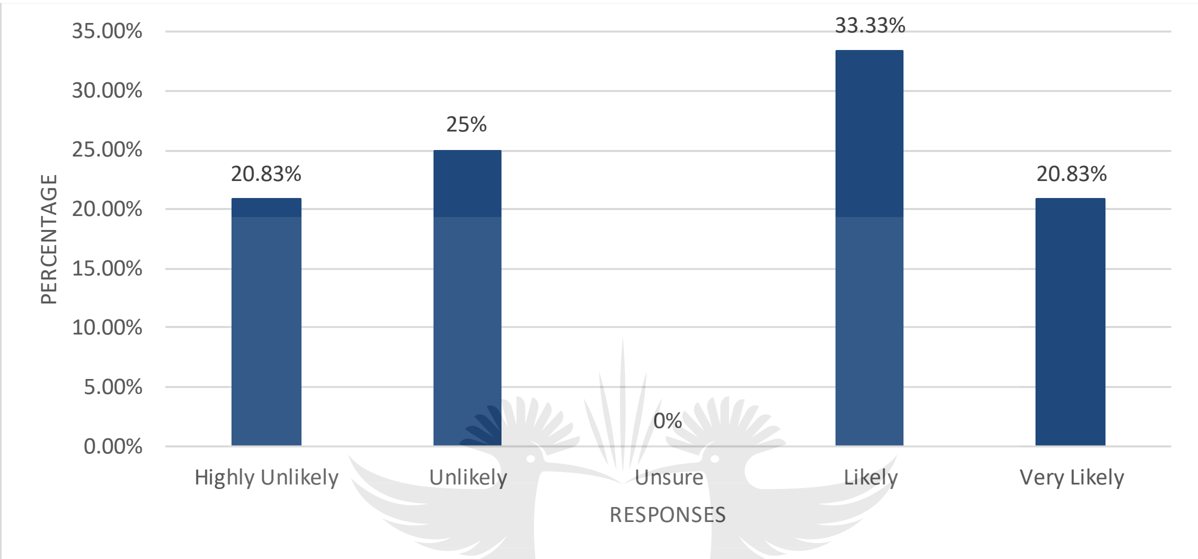

Figure 4.4: How likely is South Africa to invest in mega-power projects given fiscal tightening?

While it may seem unintuitive to spend and invest when fiscal measures are in place, economic principles suggest that spending during recessions and periods of fiscal constraint will lead to an economic upswing. Hence, 54.16% of the respondents deem it likely that the country will continue investing in mega-projects. Mega-projects are often seen as the panacea of resolving economic stagnation and stimulating economic growth.

Appealing to project management and historical contexts, the respondents were asked what the likelihood of South Africa investing in mega-power projects is, given experiences with Medupi and Kusile mega projects. Of the 54.16% (i.e. 33.33% + 20.83%) of respondents who responded in the affirmative (Figure 4.5), despite the current challenges on the new build programme, they said that investment in mega-projects would proceed.

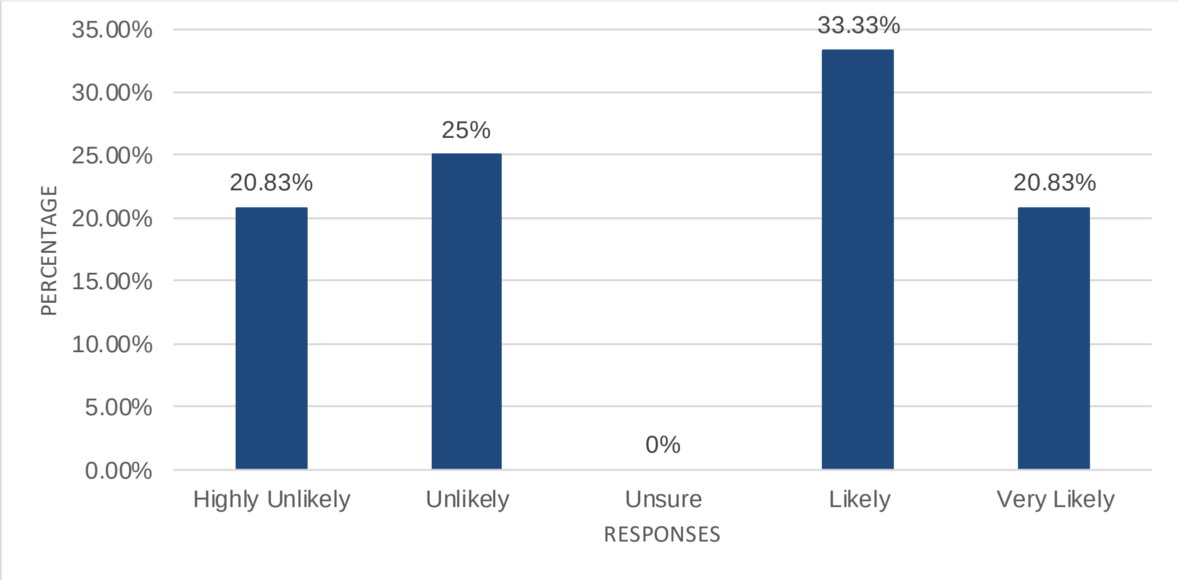

Figure 4.5: How likely is South Africa to invest in mega-power projects given the experiences with Medupi and Kusile?

Given the problems (funding, technical, legal and labour amongst others) experienced on Medupi and Kusile, 33% of the respondents said that South Africa was likely to invest in mega-power projects despite recent history, whereas 21% and 25% felt that it was highly unlikely or unlikely, respectively (Figure 4.5). The challenges experienced by Medupi and Kusile are not a deterrent.

One of the most important aspects in this research is funding constraints of mega projects and this is evident in the responses depicted in Figure 4.6. The level of uncertainty is unprecedented with these survey respondents. The equally opposing responses point to a sceptical industry that almost seeks lenders to guide decision making (Figure 4.6). The importance of funding is critical, therefore this research addresses who the funders of mega-projects are and where are they located, in addition to what they actually fund. This guides governments as to who has funds available for such investments, particularly for fiscally constrained nations who are seeking expansion.

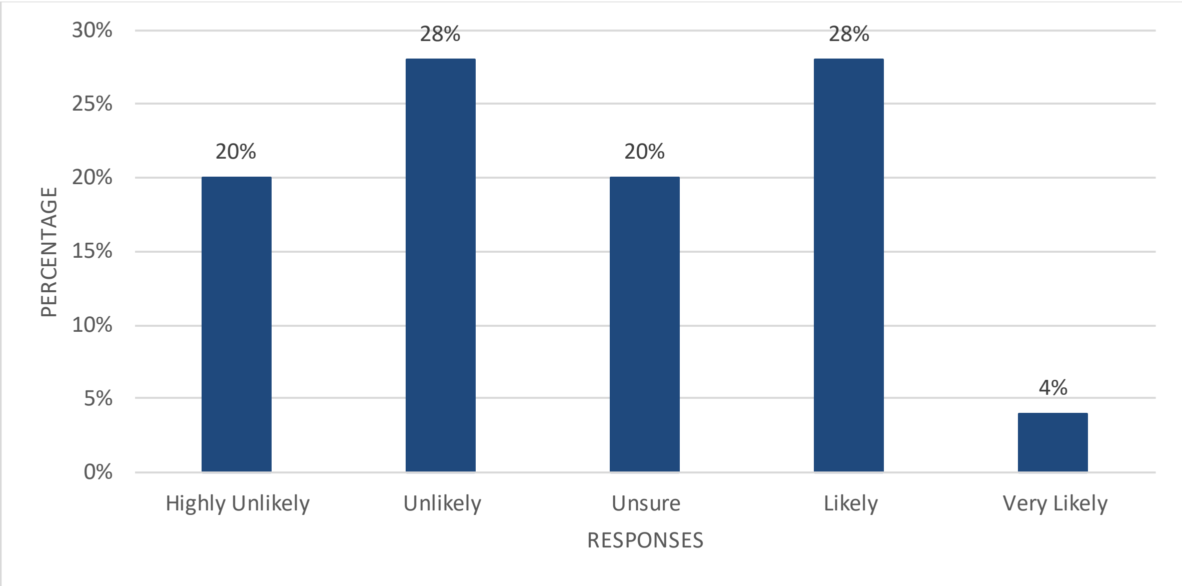

Figure 4.6: How likely is South Africa to invest in mega-power projects given funding constraints?

In comparison to a similar question posed earlier in the survey, whether credit downgrades are a deterrent to investing in mega-projects, 80% of the respondents said yes. The results in Figure 4.7 point to an almost lenient position, as expressed previously. Governments may be forced to spend on infrastructure in order to grow the economy. With this in mind, the question regarding the cost of lending becomes important in terms of what the price elasticity is that will encourage investment in mega-projects. The understanding is that while the cost of lending may be a deterrent, it will not be sufficient to keep investors away if the cost is reasonable.

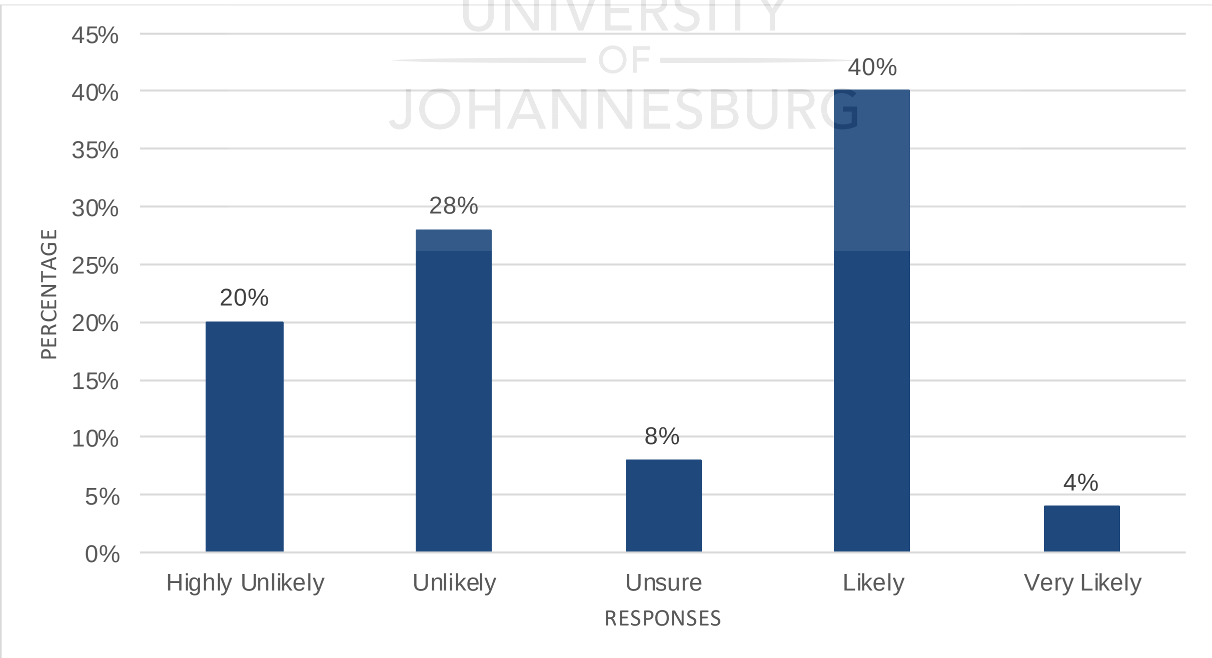

Figure 4.7: How likely is South Africa to invest in mega-power projects given current credit ratings?

In April 2017, S&P Global downgraded South Africa's foreign currency to sub-investment grade with a negative outlook; they were followed soon after by Moody's. A credit downgrade impacts where one can borrow, how much one can borrow and for how long one can borrow. Forty percent (40%) of the survey respondents said that despite current credit ratings, it was likely that South Africa would invest in mega-projects.

The respondents were further asked about the likelihood of South Africa investing in mega-power projects given the current electricity demand forecasts. The results are depicted in Figure 4.8 and occurred in nearly the same proportions for those agree and disagree. As previously explained, mega-projects are seen as the panacea of change and prosperity. An investment in mega-projects is seen as a precursor to economic growth. There is an assumption that despite demand forecasts, by continuing to increase capacity, it will be met by unserved demand and perhaps accelerate economic growth. Whilst these theories may have been accurate twenty years ago, these theories may not necessarily be valid at present.

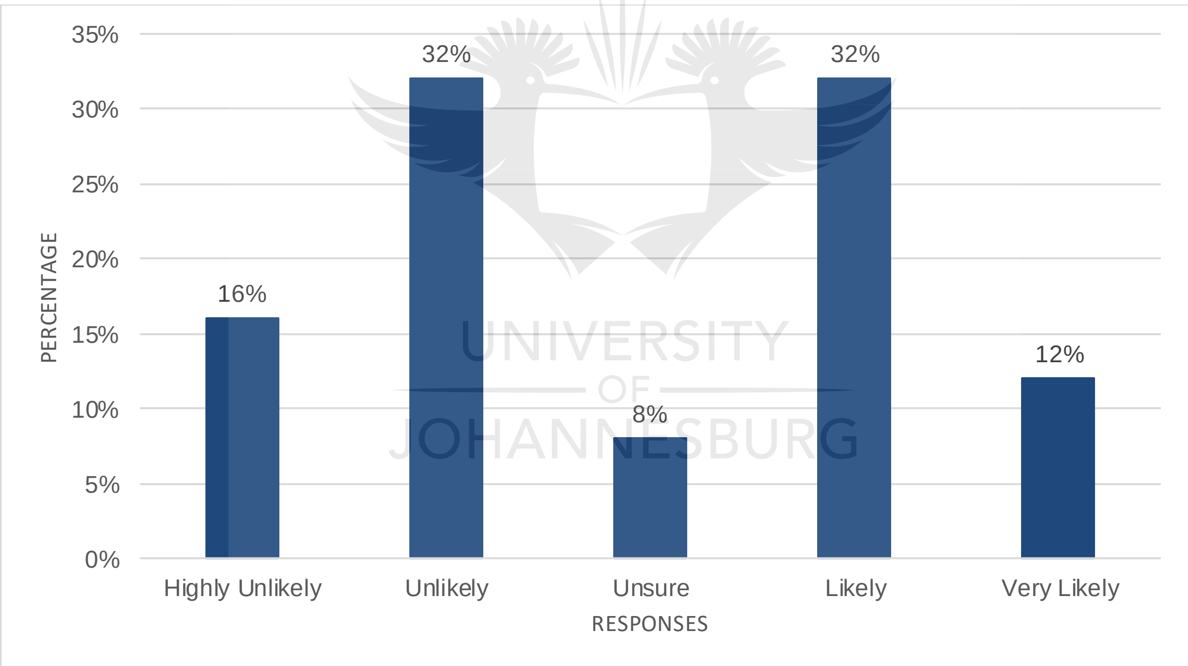

Figure 4.8: How likely is South Africa to invest in mega-power projects given current demand forecasts?

Figure 2.5 in Chapter 2 illustrates the peak demand on the integrated Eskom system. Peak was recorded in 2008/9 at 37 000MW and has since declined by 7% in the 2016/17 year. Demand, despite surplus capacity seems to be in declining due to alternative technologies, energy efficiency and slowed economic growth amongst others. Respondents were divided, 32% said that despite current demand forecasts, South Africa was likely to invest in mega-power projects; whereas another 32% said that it would be an unlikely scenario. No clear majority was established.

When the respondents were asked how likely South Africa is to invest in mega-power projects given perceived or real corruption surrounding nuclear energy, a majority 58.33% of the respondents deemed it unlikely (Figure 4.9). This is to be expected given the prevailing civil society and economic watchdogs.

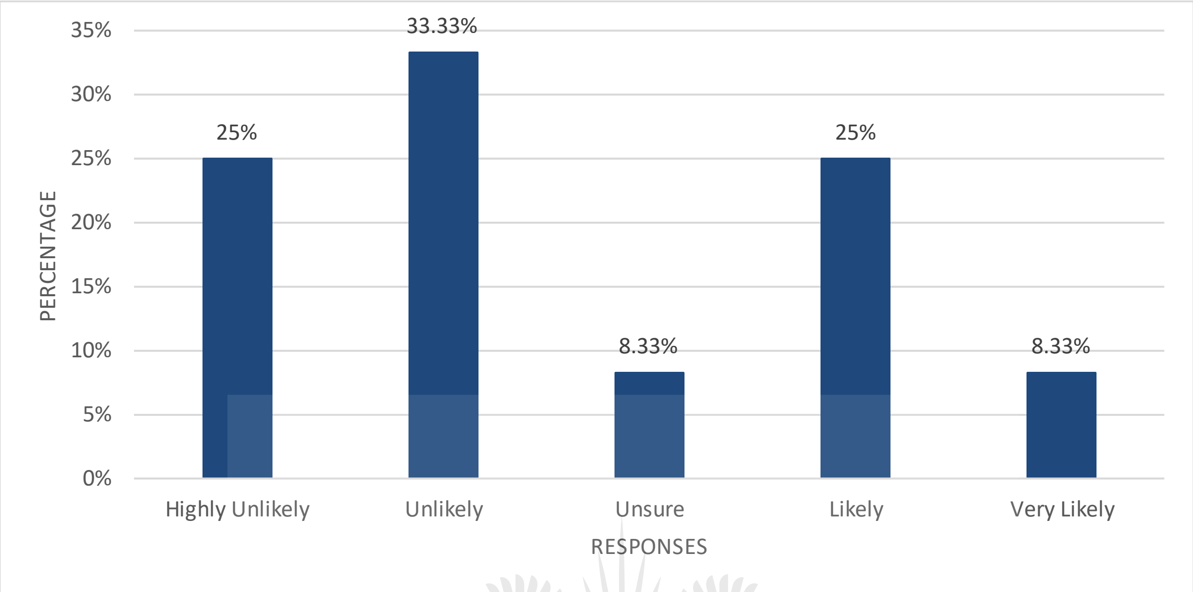

Figure 4.9: How likely is South Africa to invest in mega-power projects given perceived/real corruption surrounding nuclear energy?

When respondents were asked on investments in nuclear technology in particular, 33% said that given the perceived or real corruption rampant in South Africa surrounding nuclear energy, it was unlikely that South Africa would invest in it meanwhile 25% found it to be highly unlikely. On the opposite side of the spectrum, 25% of the respondents thought such investments are despite poor governance. Similarly, 8% thought that this scenario was very likely.

It is noteworthy that these decisions did not relate to cost or affordability of nuclear power but purely to the perceived corruption surrounding its procurement. It is unlikely that the results would have been the same if the question of cost or affordability was raised. The question surrounding nuclear technology then ceases to be about demand, sublimes, cost or affordability. The decision emanates from perceived corruption. By extension, if the process was transparent and free of perceived corruption, nuclear technology may be considered.

The last four survey questions dealt with various sublimes and their influence on decision making. The sublimes are: technical, political, economic and aesthetic. When probed if investment decision making would be influenced by sublimes, the responses were varied. This analysis reveals biases inherent in the human condition, where certain people see their actions as more benevolent than others.

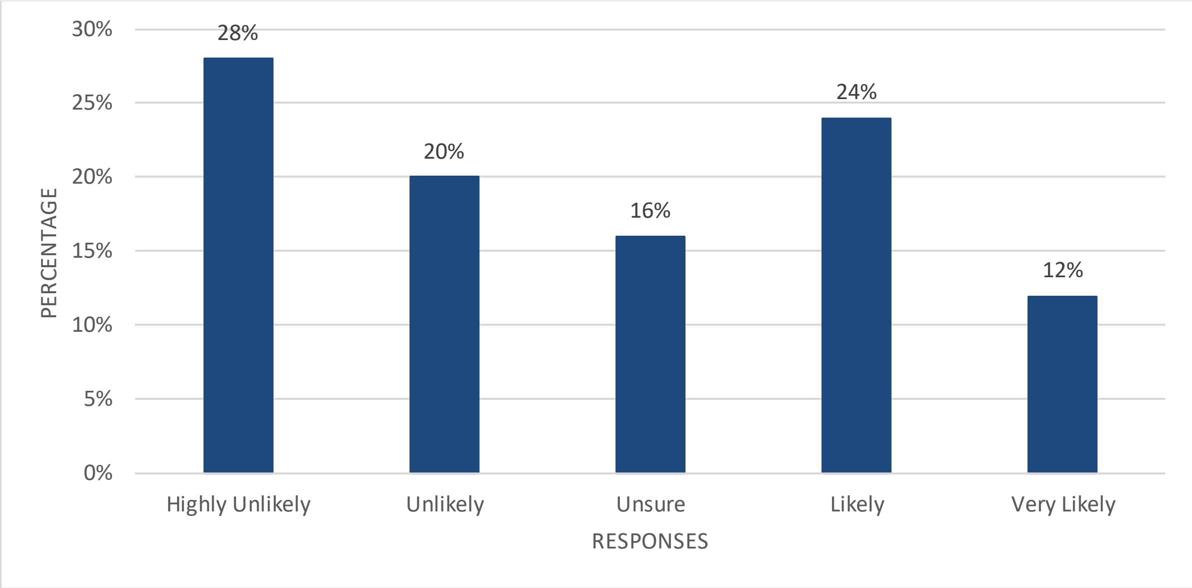

Figure 4.10: Will South Africa's decision to invest in mega-power projects be influenced by a technical sublime?

Twenty eight percent (28%) of the survey respondents said that it was highly unlikely that a technical sublime would influence a decision to invest in mega-power projects, whist 24% said investing on a technical sublime was a likely scenario. Given that most of the survey respondents are technocrats in the private sector, a bias may be prevalent in this answer. There is a view that technocrats do what is good for the country and will not jeopardise their integrity or professional standing for mega-projects that should not be invested in. However, history suggests, that many projects, whether sustainable or not, have been pursued by technocrats as a result of the sublime they possess.

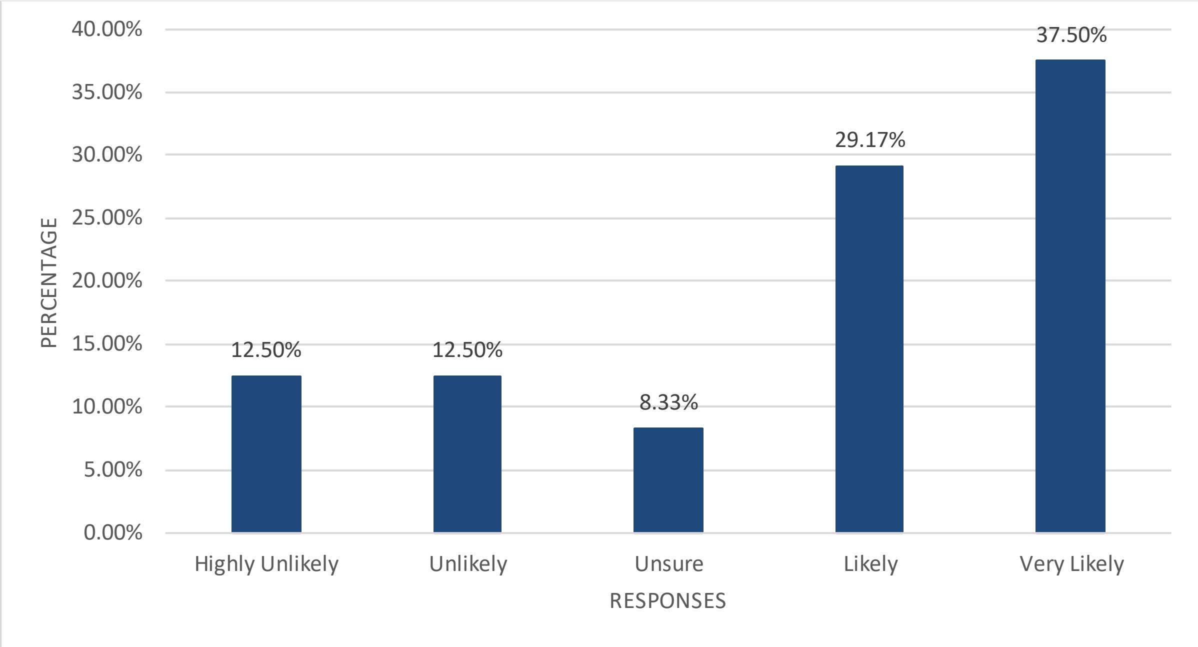

Figure 4.11: Will South Africa's decision to invest in mega-power projects be influenced by a political sublime*?

Again, a bias emerges which assumes that a political sublime is inherently negative (Figure 4.11). The majority (66.67%) of the respondents said that an investment in mega-projects would be influenced by a political sublime. This is anticipated, given that investment decisions often emanate from government policy. Government initiates and drives the mega-project pipeline. There is also a latent belief that government will be a catalyst and spur economic growth through its endorsement of mega-projects.

When asked about the influence on investment by an economic sublime (Figure 4.12), an equal number of respondents (29.17%) were either unsure or said it would be likely that an economic sublime would impact on South Africa's decision to invest in mega-power projects. Given recent developments in the energy funding landscape, contractors, bankers and developers are the ones identifying projects and lobbying governments. Historically, governments would call on interested parties to gauge their interest. Understanding government inefficiencies has prompted private entities to pursue mega-projects. The division between the respondents who are uncertain and those who deem it likely, could be due to the perspectives and places of employment of the respondents.

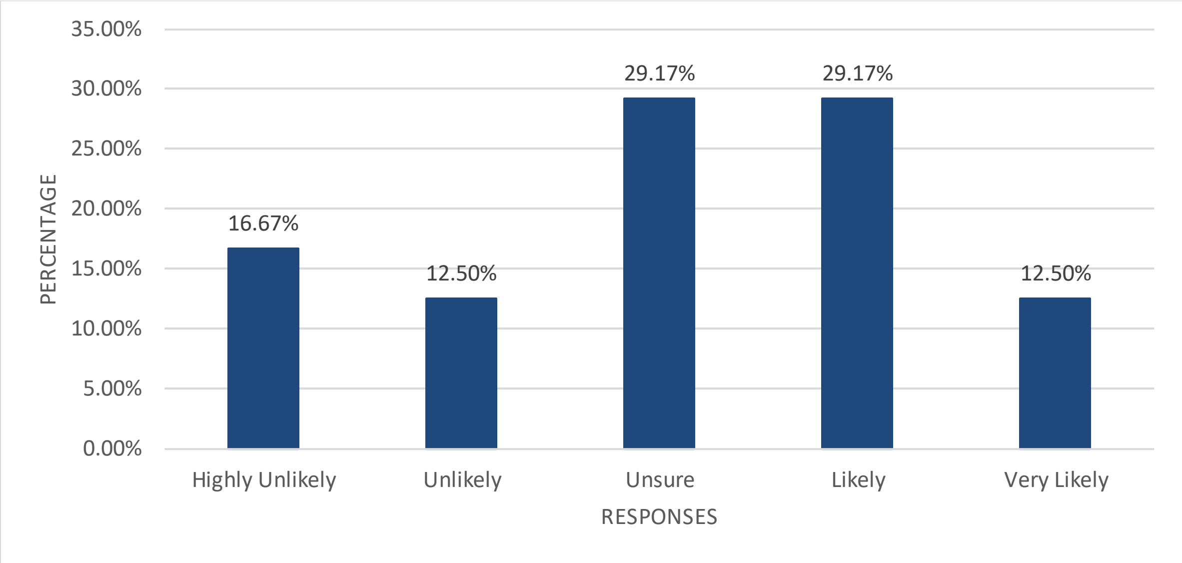

Figure 4.12: Will South Africa's decision to invest in mega-power projects be influenced by an economic sublime*?

The final question posed to respondents was the likelihood of South Africa basing their decision to invest in mega-power projects on the influence of an aesthetic sublime (Figure 4.13).

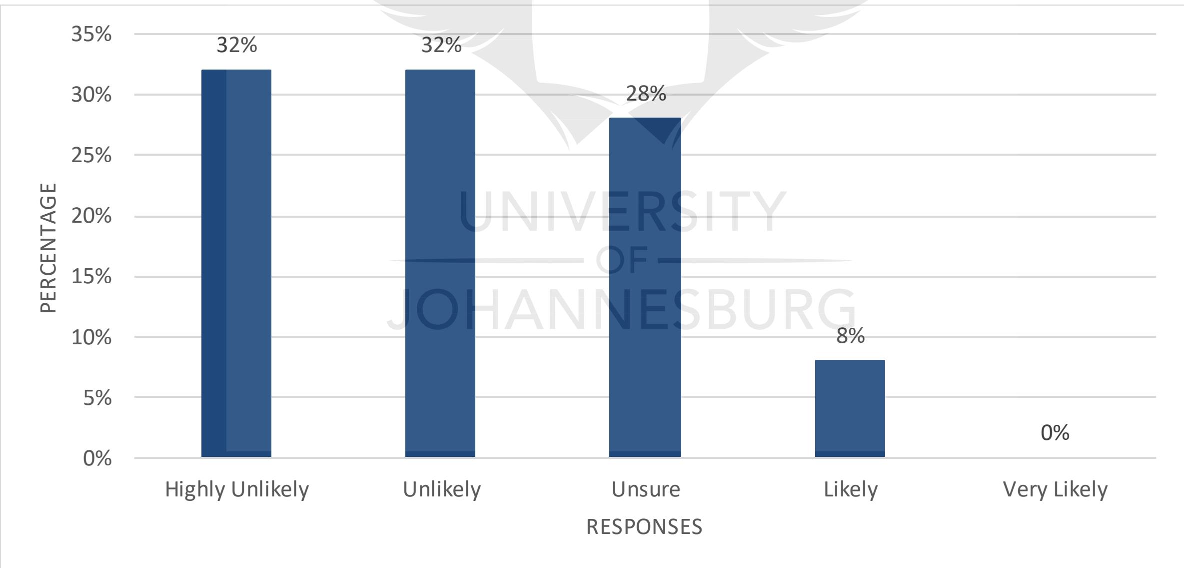

Figure 4.13: Will South Africa's decision to invest in mega-power projects be influenced by an aesthetic sublime*?

An equal number of respondents (32%) said that South Africa's decision to invest in mega-power projects as a result of an aesthetic sublime was both highly unlikely and unlikely. This is noteworthy because when Medupi and Kusile are described, they were said to be "colossal", "monumental" and "visible from space". Perhaps the initial decision is not one of an aesthetic sublime, but eventually as the project goes through its various design stages, an aesthetic sublime is discussed.

4.4. DISCUSSION OF SURVEY RESULTS

Sixty (60) percent of survey respondents said that mega-projects would be constructed within the next 20 years. Deloitte (2017) states that there has been an unprecedented magnitude of African infrastructure development plans as well as the growth initiatives within the private sector. PwC (2014) further states that there is a funding gap for crucial infrastructure projects and innovative methods of funding need to be implemented. This is significant given that the number of projects is increasing and there are funding shortfalls which only serve to compound mega-project financing.

This finding is congruent with that of Frey (2016) who believes that mega-projects will see an exponential growth to about 24% of the global GDP within a decade. According to Frey (2016), this rise in mega-projects can be attributed the the following factors:

- A shift towards mega-cities,
- The wages paid for builders of mega-projects will improve the local economy to the point of spurring on new mega-projects,
- Global awareness will drive an aesthetic sublime,
- In an age of technological unemployment, mega-projects will provide jobs, &
- The sheer size and impact of these projects have the potential for positive economic spin-offs.

As mega-projects continue to grow, the world will likely spend more on infrastructure in the next 40 years than it has in the last 4000 years (Frey, 2016). Mega-projects currently constitute 8% of global GDP (Flyvberg, 2017) and this is expected to increase to 24% within a decade (Frey, 2016). The mega-project paradox has baffled numerous observers but what perhaps is more interesting is how these mega-projects are becoming increasingly ambitious (Flyvberg, 2017). In a paper titled "White Elephants" the authors express that despite the increase in mega-projects the investment growth has not led to output growth which is a concern (Robinson & Torvikz, 2004).

Given the increasing economical unsustainability of most mega-projects, their number is spiralling upwards. Whilst survey respondents indicated that overruns of time and cost are a deterrent in investing in mega-projects, the increase in mega-projects however is contrary to that notion. In a survey conducted by (PwC, 2014), nearly 40% of respondents said they had budget overruns of between 10% and 50% while a third mentioned costs variances of less than 10%. Only 22% were either below or on budget. Respondents cited issues relating to project management, economic factors, bureaucracy, client indecision and commercial agreements as being the most common causes of cost variances.

Time overruns were also very common with 86% experiencing time overruns. These were related to inadequate front end engineering and design, internal procurement issues, weak project management, insufficient resources as well as financing issues. This disparity is directly related to the mega-project paradox, as it authenticates the existence of a number of sublimes (different reasons) in mega-project decision making processes.

If South Africa has ambitions of another energy mega-project in the next two decades then operating model reform at Eskom is necessary according to 88% of survey respondents. According to (PwC, 2014) infrastructure regulation in Africa is still in its infancy. Most African countries have taken initial institutional reforms in the form of policy. However, what have lagged are regulatory and governance reforms especially those that will facilitate enhanced cross border activity.

Electricity industry reform has been successful but has certainly had failures in some markets. The initial reforms have inadvertently been replaced by other reforms and have led to the introduction of "hybrid Markets" which have been the bane of many policy makers (Sioshansi, 2006). Given increasing calls for the reform of Eskom, the function and intent of regulation of the market needs to be thoroughly investigated prior to implementation. According to (Sioshansi, 2006) a call for regulation has to consider the generation business, energy markets, resource adequacy and investment.

According to (Eberhard, 2001 p.14), electricity market reforms generally have the following elements:

- Public utilities are commercialised and corporatized,
- Restructuring of the industry to increase competition,
- The creation of electricity market trading mechanisms,
- Increased private sector participation, &
- Changes in regulatory oversight.

While this may be a desired end state for Eskom even according to their own management, however how does the reform of a loss making indebted entity commence? And therein lies the problem in reforming Eskom and considering an alternative operating model.

In what is hailed as an ideal scenario, there would be many generators all bidding to supply the grid through a single buyer office and a reliable grid (Eberhard, 2001). This will bring in competition and different tariffs for different qualities of electricity e.g. peaking, baseload (Eberhard, 2001). This is assumed to have a high degree of transparency and is thought to bring prices down, however the reality has been vastly different.

In the case of the United Kingdom, debate is raging whether the deregulated model is the best approach given skyrocketing electricity prices, price fixing and corruption (Engineering News, 2014). In the case of the United States, utilities are privately owned however the sector is highly regulated. The US seems to be a good case study in deregulated markets notwithstanding the California energy crisis of 2000/1 (Engineering News, 2014).

Reform also has to consider the emergence of disruptive technologies which 56% of survey respondents said would be a deterrent to investment. Whilst this concern may be valid, it seems it only applies to traditional methods of electricity generation. Investors are keen on investing in disruptors. Disruptive innovators are seen to have three main attributes (Green & Newman, 2016):

- They occupy a niche that eventually becomes a major technological disruption
- Their presence and impact grows exponentially
- They create stranded assets

It is the last bulleted point which is critical for investors. Given a capital outlay over a 20 year power purchase agreement, a stranded asset would be a financial disaster (Robinson & Torvikz, 2004). This can lead to the protection of industries and the flouting of good practice in an effort to ensure the financial viability of a company. This is evidenced in the case of Eskom and municipalities who when the proliferation of captive power plants began were protected by the NERSA decision to curtail captive power plants above 1MW through a generation licence (NERSA, 2018). Given Eskom's indebtedness and the tenor of the debt, these interim measures do provide little comfort for investors however for how long?

In another example of disruption, is the emergence of the Southern African Power Pool (SAPP) energy trading pool which has opened the electricity market to subscribed countries. This platform allows energy trading between countries based on their anticipated day ahead capacity. This is traded on the "Day Ahead Market" (DAM). What is usually a competitive trading platform, can with the prevalence of a monopolistic entity become a hostile and uncompetitive market. Table 4.2 shows net export position of Electricidade de Mozambique (EDM) when trading was competitive (2010) and when Eskom had excess capacity (2015) and started 'dumping' cheap power on the DAM. This led to a loss of 1949GWh in export sales when compared to 2010, *ceteris paribus (*i.e. all things being equal*)* for EDM and significantly impacted their finances, lending position and thus their electricity sales strategy.

Table 4.2: Net Imports (+) and Exports (-) Source: SAPP.

Country	2010	2015
Angola	0	0
Botswana	2985	3534
DRC	-755	0
Lesotho	121	223
Malawi	0	0
Mozambique	**-3542**	**-1593**
Namibia	2255	2383
South Africa	**-2475**	**-5313**
Swaziland	909	479
Tanzania	57	60
Zambia	-545	-563
Zimbabwe	63	46

The availability and affordability of funding has been raised as a critical matter, 75% of survey respondents said this can be a deterrent to investment. This is similar to what was found by (PwC, 2014) in their report titled: "Trends, challenges and future outlook – Capital projects and infrastructure in East Africa, Southern Africa and West Africa."

- Thirty six percent (36%) of reasons for delays in completion of power projects in Africa is finance/ funding related,
- Forty three (43%) of respondents stated that the greatest challenges to capital projects in the energy sector is availability of funding,
- Governments have limited funding and therefore capital markets are a viable option &
- A shortage of funding has seen an increase in Public Private Partnership (PPP) funding structures.

Funding and the affordability thereof is a critical element of ensuring project success. Linked to the cost of borrowing is the credit ratings related to a country or a utility which affects their ability and cost of borrowing. According to (PwC, 2014), the debt burden of African countries as compared to their GDP is low however African countries still have difficulty borrowing. This is due in part to a low tax base and poor credit ratings – the perceptions of sustainable debt markets in Africa are lower. Eighty percent (80%) of survey respondents said that credit ratings would be a deterrent in investing in mega-projects, this seems to be congruent with market sentiments. The ability to fund alone is not enough, the cost of borrowing plays a significant role.

Given this conundrum, many borrowers and funders are looking at alternative funding methods that are not heavily reliant of credit ratings. These tend to be PPP configurations or even infrastructure in exchange for minerals funding as is the case between Angola and China and their “infrastructure for oil” agreement (PwC, 2014).

The overall findings of the survey and market sentiments are correlated. There is an inherent understanding that a mega-project paradox exists and that investment in mega-projects will continue despite all challenges. There is however a common understanding that funding and the cost thereof may inhibit future mega-project investment.

5. CHAPTER

DISCUSSION OF RESULTS

SECTION B: PRESENTATION AND DISCUSSION OF RESULTS FROM SECONDARY DATA

5.1. INTRODUCTION

Chapter 5 analyses the empirical data gathered from the Infrastructure Journal for the purpose of analysing mega-projects. The data presented will provide insight into who is funding the projects and their locations. The fundamental aspect of this chapter is an analysis of project finance deals in the energy sector. It examines whether or not mega-projects are being funded and what the trend is; which countries are building them; the rationale for building mega-projects as well as what technologies are being used. This is critical as it starts to triangulate some of the qualitative data and draws correlations through the data.

5.1.1. Top 10 Global Infrastructure Deals

Table 5.1 lists the top 10 infrastructure deals in the world in all sectors. It is worth mentioning that these deals are predominantly acquisition costs in the power sector or projects in the oil and gas sector.

Table 5.1: Infrastructure Deals Source: Infrastructure Journal.

Sector	Transaction Name	Transaction Value ($m)	Location	Financial Close Date
Oil & Gas	Yamal LNG	30 249	Russia	2016-06-25
Power	Barakah Nuclear Power Plant (5600MW)	23 714	United Arab Emirates	2016-10-20
Oil & Gas	Tengizchevroil Expansion	16 000	Kazakhstan	2016-07-27
Power	Ausgrid Privatization	12 623,78	Australia	2016-12-01
Power	Acquisition of ITC Holdings Corporation	11 300	United States	2016-10-14
Oil & Gas	Acquisition of Columbia Pipeline Group	10 200	United States	2016-06-30
Power	Acquisition of Meenakshi Coal-Fired Power Plant (1000MW)	9 720,26	India	2016-11-17
Power	Acquisition of AGL Resources	8 000	United States	2016-07-01
Transport	Port of Melbourne Privatization	7 379,96	Australia	2016-10-31
Power	Acquisition of Fortum Distribution Sweden	7 050,58	Sweden	2016-07-22

The total number of energy (power, renewables, oil and gas) deals that reached financial close in 2016 amounted to 208 projects across the world. This was approximately 0.6 deals reaching financial close on a daily basis. Table 5.1 depicts the top ten infrastructure deals that took place in 2016. It is important to note that 60% of the deals are in the power generation sector. This sector encompasses thermal generation, transmission and distribution. Furthermore, the power projects listed are acquisition costs which refer to the acquiring of an existing asset. It was found that only one of these power projects was linked to the construction of a power plant. This could indicate the selling down of assets due to privatisation as a result of changing regulatory models. In addition, it may signify that the impact of the global economic meltdown has led to increased seller financing, asset based lending and alternative sources of borrowers (Brown, 2011).

The total number of infrastructure deals that reached financial close in 2016 stands at 1273, with 53% of these being in power and renewables (Infrastructure Journal, 2017). If oil and gas figures are included, this amount rises to 69% (Infrastructure Journal, 2017). Figure 5.1 presents the various sectors and how many transactions reached financial close. This may seem to contradict the top ten deals stated earlier (Table 5.1), predominantly power as well as oil and gas. However, it is imperative to remember that whilst renewables have the greatest number of projects by volume, power projects have the greatest amount by value. This can be attributed to the construction costs (overnight costs[10]) of conventional technologies. Typical overnight costs for conventional technologies range between $935 and $6192/kW and renewables between $1548 and $4694/kW (EIA, 2018).

5.1.2. Infrastructure Deals that reached Financial Close in 2016

The sector breakdown by volume in Figure 5.1 indicates that the oil & gas, renewables and power sectors have taken up a large portion of project share when compared to other sectors. This indicates the importance of the in unlocking key economic challenges and infrastructure requirements.

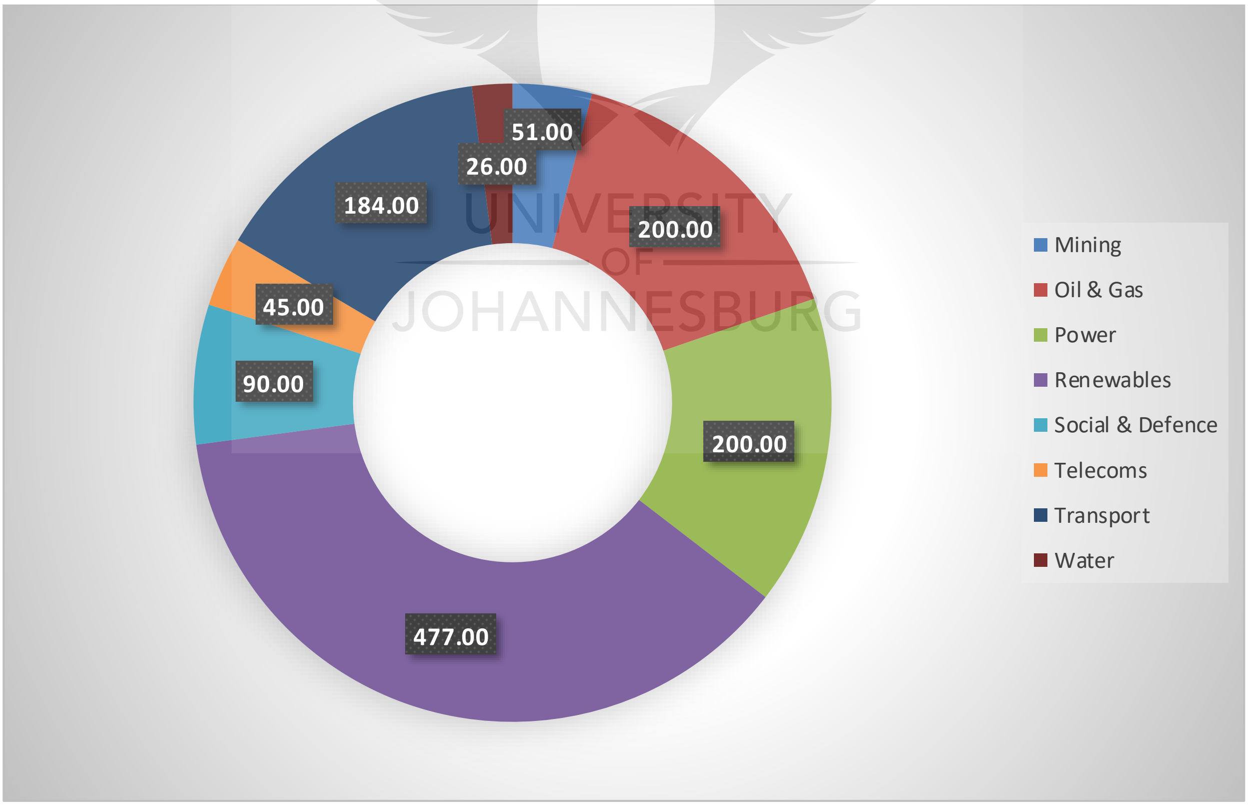

Figure 5.1: Sector Breakdown by Volume Source: Infrastructure Journal.

[10] The capital costs of a project assuming a project is built overnight. Overnight costs exclude interest during plant construction and development.

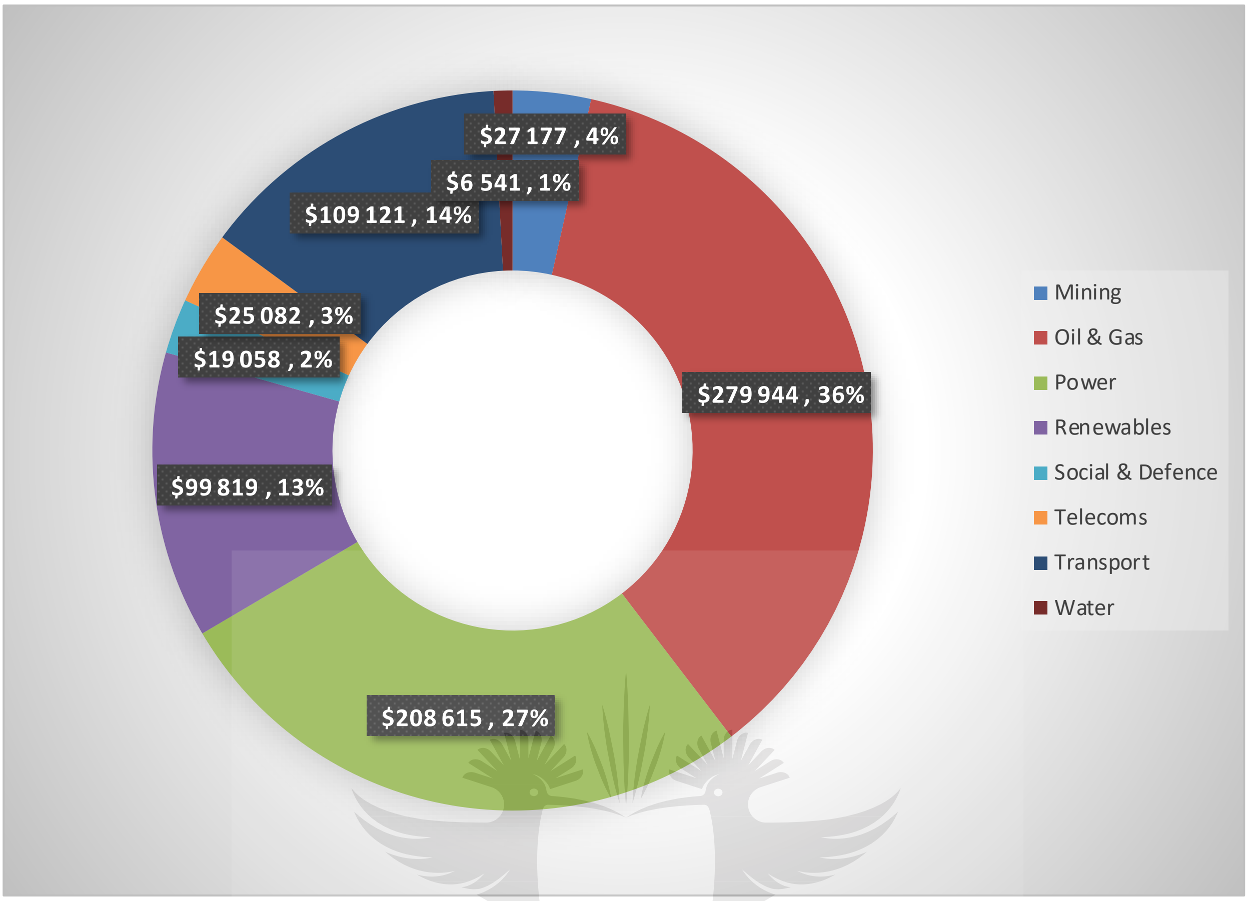

Figure 5.2: Sector Breakdown by Value Source: Infrastructure Journal.

Moreover, Figure 5.2 shows that of the $793 632 million transaction value from all sectors, the energy sector alone contributed $588 378 million, which accounts for 74% of total infrastructure funding. On the other hand, renewables as a standalone, account for only 13% of the transaction value. The reason for this trend is not necessarily because renewables are cheaper but because power projects are typically larger in megawatt output and are capital intensive. They also tend to take the form of mega-projects, which by definition, are in excess of $1 billion (Priemus et al, 2008). Figure 5.2 provides the sector breakdown by value and clearly indicates that power, as well as oil and gas comprise 63% of total project financing. It is evident from Figure 5.2 that energy (power, renewables, oil and gas) deals dominate the funding landscape. The credit value of these deals is $86 631 000 000.37 which is approximately $87 billion US Dollars (Infrastructure Journal, 2017).

5.1.3. Number of Projects by Technology Type

The number and type of projects reaching financial close is critical in determining what gets funded. Funders through policy makers determine global trends and drive the market. This was witnessed during Germany's renewable energy drive which saw mass installations of PV panels and price decreases.

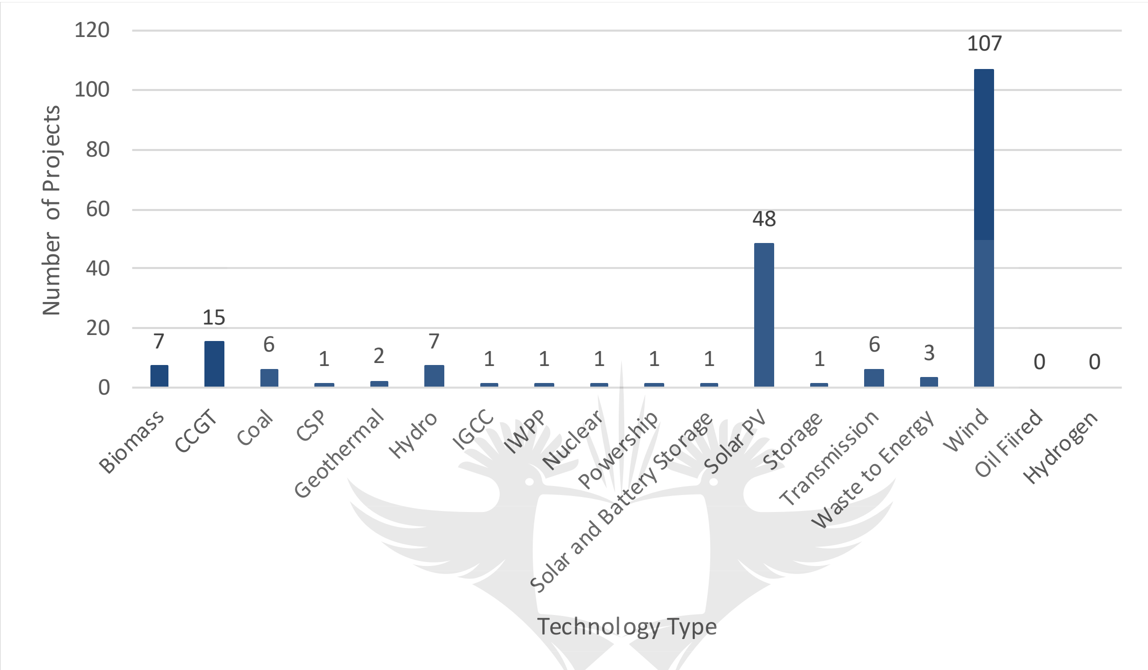

Figure 5.3: Number of Projects by Technology Type Source: Infrastructure Journal.

When analysing per technology type in 2016 by volume (Figure 5.3), of the 208 projects that reached financial close, 107 of those were wind technology and a further 48 were solar PV. The renewables component alone represented 85% of the total projects that reached financial close. The prevalence of renewable projects is driven largely by country commitments to the Paris Accord and a diversification of a previously energy intensive generation mix.

5.1.4. Number of Projects by Country

The number of projects being built in a country can have several meanings. Such as a policy drive similar to "Energiewiende[11]" in Germany. A move away from a certain technology such as the discontinuation of nuclear in Japan and Germany and the need to substitute that energy. Economic growth, energy independence and expansion drive projects as is the case

[11] Germany's Renewable Energy Revolution

in most of Africa, Asia and the Middle East. There are also resource discoveries such as those in the United States.

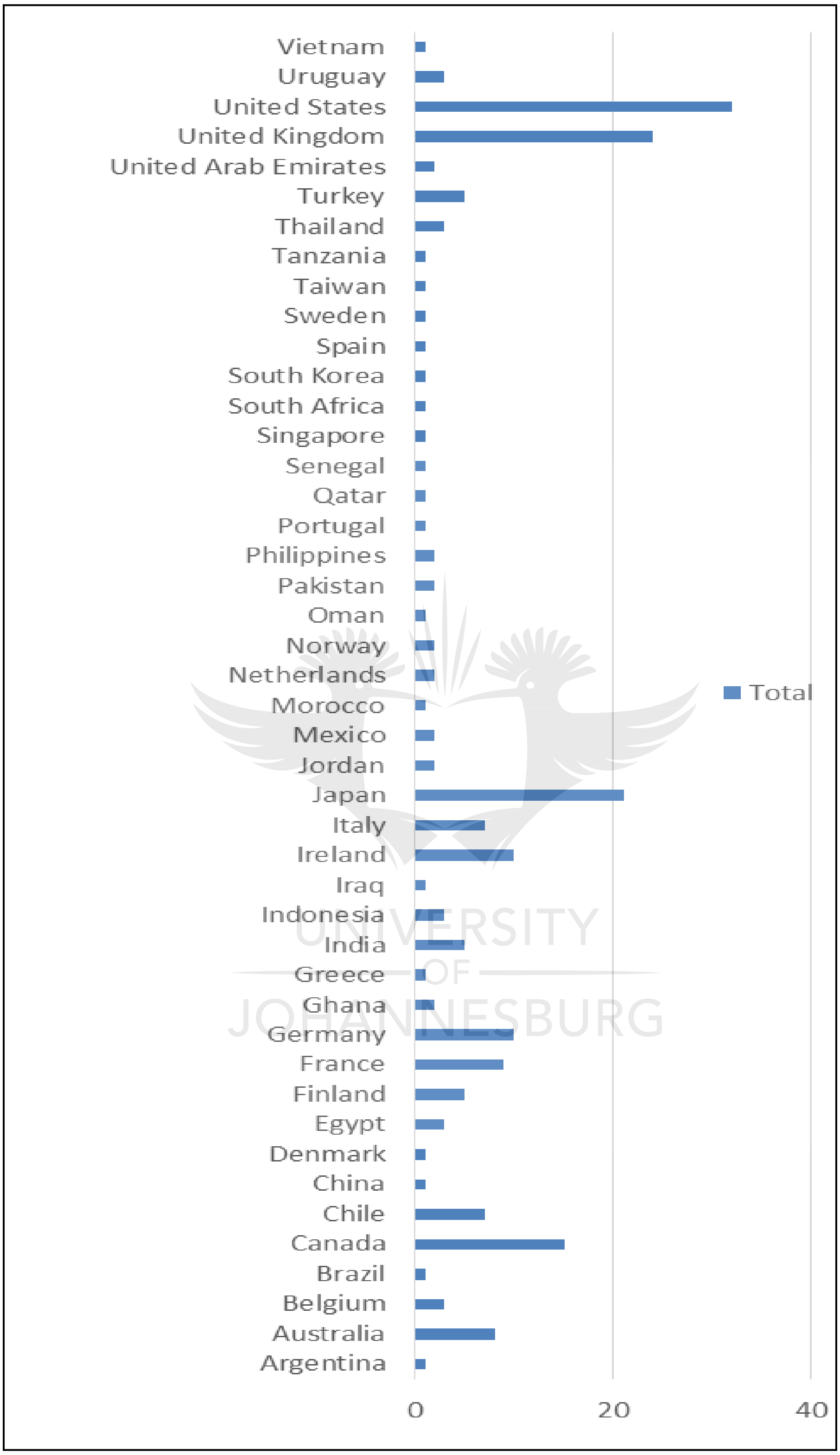

Figure 5.4: Number of Projects by Country Source: Infrastructure Journal.

Figure 5.4 illustrates the total number of projects per country. It shows the USA, the UK and Japan as having the highest number of projects, comprising 37% of total projects.

These three countries are currently pursuing build programmes for the following reasons:

Japan: Following the Fukushima nuclear incident, there has been a concerted effort to move away from nuclear energy generation technologies (Kim & Chung, 2017) . As a result, Japan has experienced power constraints which have resulted in power outages (Liu et al., 2016). In order to enable the security of supply, the projects selected for funding are aimed to be completed in the shortest period of time. In addition to time constraints and the fact that the country is an island, they have selected flexible gas technology along with intermittent renewables.

United Kingdom: The UK is facing an impending power deficit (Harvey, 2016); hence they took the decision to approve the Hinkley Point nuclear power project. In addition to the nuclear base load, the UK is exploring projects that will be connected to the grid in the shortest period of time, to supplement demand. Consequently, the UK has opted to make use of renewable technologies such as wind and solar.

United States: Following the Paris Accord and the exploitation of their shale resources, the USA has shut down a number of coal fired plants and has transitioned to gas and renewables. This technology mix provides grid stability (Russell et al., 2016).

5.1.5. Technology Type per Country

Certain countries have a technology preference due to their Paris Agreements, country policy, resource discoveries and access to capital. These are all drivers for what each country prioritises for their energy mix. Table 5.2 gives a visual representation of all technologies and which countries are invested in them. There is a preference for renewables coupled with gas for most countries. Coal hydro and nuclear are still present however seem to be on the decline.

Table 5.2 Technology Type and Number per Country Source: Infrastructure Journal.

Country	Biomass	CCGT	Coal	CSP	Geothermal	Hydro	IGCC	IWPP	Nuclear	Powership	Solar Battery	Solar PV	Storage	Transmission	Waste 2 Energy	Wind
UK	3												1		1	17
Other	4	7	4			5						12				41
Egypt		2														
US		6										12				14
Philippines			2													
South Africa				1												
Netherlands					1											
Spain					1											
Canada						1						5				8
China						1										
Japan							1					16				
Qatar								1								
UAE									1							
Ghana										1						
Tanzania											1					
Australia												3				
Chile														2		
India														2		
Mexico														1		
Pakistan														1		
Finland															1	
Singapore															1	
France																8
Germany																9
Ireland																10

Many countries are diversifying their energy mix in order to have a flexible base load as renewable technologies are being widely adopted. The adoption of such an energy mix leads to what can be regarded as a disruption in the technology sector. This table is pivotal in understanding which countries have opted for which technologies and their rationale. It begins to show trends for certain countries which opt for multiple technologies in order to diversify their energy mix.

Combined cycle gas turbine (CCGT), solar PV and wind technologies by far make up the largest proportion of technologies. The countries who opted for solar and wind technologies have also opted to supplement this with gas technology.

This pattern is clearly the case for countries such as the UK, the USA, Japan, Germany, France and Egypt. This is not by coincidence but rather due to the flexibility of gas for tracking the intermittency of renewables. As a result of the Fukushima incident and the resultant shutdown of nuclear reactors in the country, Japan is cautiously pursuing renewables supplemented by gas technology.

The United Arab Emirates opted for nuclear technology which will provide them with 5600MW of base load power. In addition to nuclear technology, they also opted for coal technology. According to Dietmar Siersdorfer (CEO of Siemens ME, UAE), the Middle Easts' growing population requires reliable and efficient power supply at an exponential rate (John, 2017).

Canada being the only non-Asian country investing in coal, has deviated from the global trend; Canada has opted for coal base load supplemented by renewables (Figures 5.7, 5.10, 5.16 and 5.20). With 15 projects, gas technology has the highest number of projects for a base load technology. The United States has six gas projects (Figure 5.6) which reached financial close. The USA has pursued this technology because their shale resources have proven to be cheap and deployable in both domestic and export markets (Shearer, et al., 2014).

Following Ghana's "Dumsor"[12] which lasted for 24 hours in some cases, the country needed dispatchable technology that could be constructed and deployed online quickly (Kumi, 2017). The country contracted with a Turkish based company, Karadeniz, for the manufacturing of a floating power plant known as a Powership. The Powership is a relatively new (to project finance) technology that relies on a fuel source such as gas or heavy fuel oil for its operations. It is in fact a floating power plant.

Wind technology has been adopted by 25 countries globally, all of them being coastal countries due to their high and patterned wind factors. Wind technology has become a popular choice, most likely because it enjoys higher capacity factors[13] and efficiencies[14] in comparison to other renewable technologies (International Renewable Energy Agency, 2017).

[12] Rotational outages

[13] "The net capacity factor of a power plant is the ratio of its actual output over a period of time, to its potential output if it were possible for it to operate at full nameplate capacity indefinitely" (United States Nuclear Regulatory Commission, 2018)

[14] "The percentage of the total energy content of a power plant's fuel that is converted into electricity. The remaining energy is lost to the environment as heat" (United States Nuclear Regulatory Commission, 2018)

Technologies based on electricity storage have only been adopted by Tanzania and the United Kingdom. Such an adoption seeks to overcome the intermittency of power supplies and the need to establish a flexible base load.

5.1.6. Megawatts to be Installed

This scatter diagram provides a visual representation of the megawatts that are being installed. The scatter diagram provides a distribution that is scattered in the lower range which is below 500MW with very few projects being larger than 500MW.

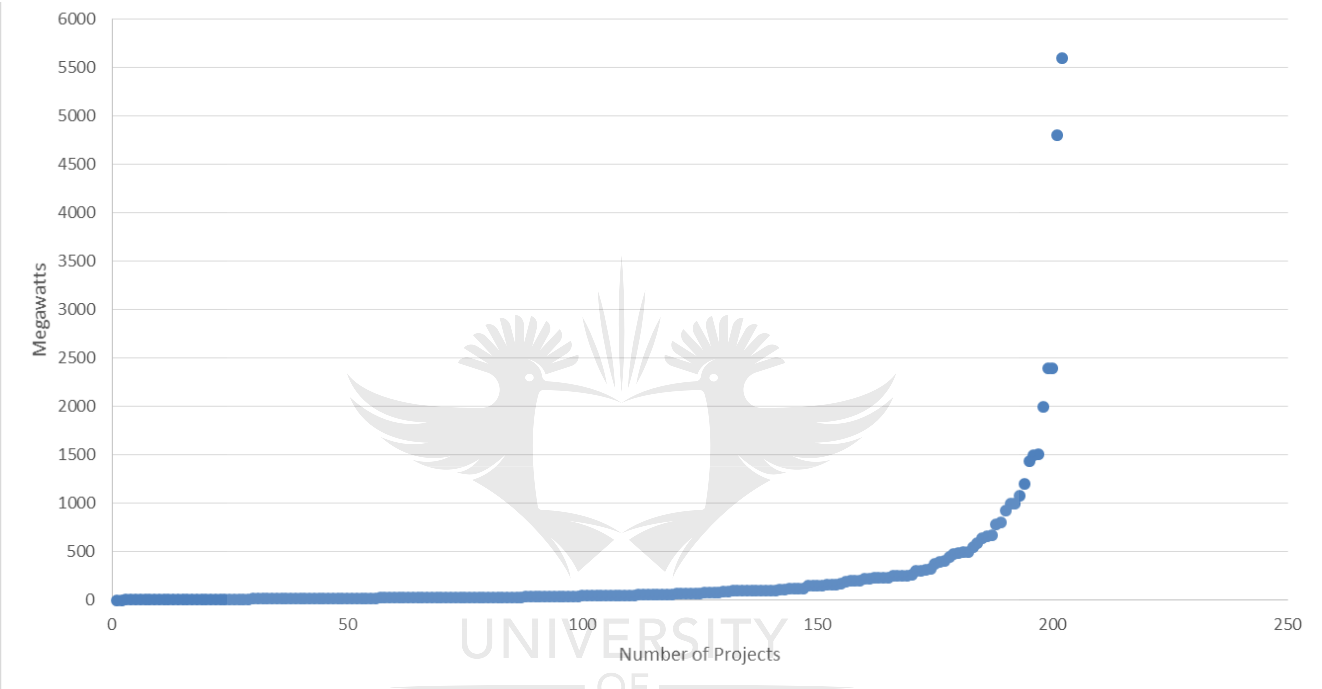

Figure 5.5: Megawatt Scatter Diagram Source: Infrastructure Journal.

The mean for this dataset (Figure 5.5) is 231,35MW, the mode is 100MW and the median is 47MW. A scatter diagram shows the total capacity in megawatts of all 202 projects; these projects represent a total of 46 734,24MW which have been contracted for. The capacity range is between 1MW to 5600MW; with the smallest being for wind technology and the largest for nuclear technology. One hundred and fifty (150) projects have a capacity of 149MW and less; this comprises 73% of all projects and indicates a dominance of smaller capacity projects as a result of more renewable technologies. There are 32 projects in the range between 149 to 500 megawatts; and only 10 projects which are 1000MW and above.

5.1.7. Megawatt per Country

The planned installed megawatt capacity for each country is important in understanding the funding requirements as well as drivers. Countries with a high energy requirement are often displacing a technology, have made new resource discoveries or are in a positive growth cycle – this is witnessed in the top 5 countries listed in Table 5.3.

The United States and United Arab Emirates have contracted the largest amount of megawatts at approximately 8000MW each. The UAE is increasing capacity in order to meet growth requirements as well as increased demand (John, 2017). The USA is experiencing an increase in energy demand as a result of the growth in the industrial and transport sectors (US Energy Information Administration, 2017).

This is closely followed by Egypt at 6350MW. During 2014, Egypt suffered frequent power cuts which necessitated the need for increased power generation in a short space of time (Oxford Business Group, 2016); hence the option for two gas fired plants and a solar PV plant with a high installed capacity.

A total of 46 734 megawatts have been contracted. It is estimated that about 80% of this power will be online by 2020; the balance appearing online by 2022 (Infrastructure Journal, 2017).

In excess of 16 000 megawatts are reserved for gas technologies, followed by wind technology at 10 055MW. Although there is no country correlation between these two variables in 2016, it would be interesting to monitor the long term correlated trend.

Coal and nuclear technologies also feature, undoubtedly to provide base load power. There appears to be no positive correlation either between these two base load technologies and the selection of renewables, apart from Canada. Of the 15 gas projects, six are in the USA, due to the booming gas industry in the USA led by inexpensive fuel (US Energy Information Administration, 2017).

It is noteworthy that CCGT has the highest megawatt capacity, at 16 737MW (36% of total capacity). However, the capital costs as shown in Figure 5.8 are less than those of nuclear and wind technologies combined, albeit for more power that is generated. Wind technology has 107 projects that will produce 10 055MW, whereas gas technology has 15 projects with a capacity of 16 737MW; it is therefore evident that in terms of overnight costs, gas technology is still cheaper.

Table 5.3: Megawatt per Country Source: Infrastructure Journal.

Country	Capacity (MW)
United States	8102
United Arab Emirates	8000
Egypt	6350
Japan	2890
Qatar	2400
Indonesia	2114
United Kingdom	1772
Oman	1509
Iraq	1500
Philippines	1218
Norway	1160
Chile	986
Australia	918
Belgium	737
Canada	712
Turkey	691
Pakistan	660
Jordan	574
Germany	562
Finland	554
Ghana	425
Thailand	336
Ireland	293
Brazil	255
Italy	252
Uruguay	240
Morocco	202
Mexico	200
Sweden	148
France	140
Singapore	120
Vietnam	102
Argentina	100
South Africa	100
India	97

Greece	73
Denmark	50
China	48
Netherlands	47
South Korea	43
Spain	25
Senegal	20
Portugal	10
Taiwan	1
Tanzania	0
Total	46 734

Megawatts to be installed per technology indicates technology preference as well as the possible policy support the technology receives. A technology with a high planned megawatt capacity is usually supported by government, enjoys subsidies, is a recent resource find or is considered stable enough to provide large amounts of power.

Table 5.4: Megawatts per Technology Source: Infrastructure Journal.

Technology	Capacity (MW)
Biomass	669
CCGT	16737
Coal	6278
CSP	100
Geothermal	41
Hydro	730
IGCC	1080
IWPP	2400
Nuclear	5600
Powership	225
Solar and Battery Storage	0
Solar PV	2200
Storage	6
Transmission	0
Waste to Energy	613
Wind	10055
Total	46734

5.1.8. A Focus on Mega-projects

The core of this dissertation is a discussion on mega-projects which are tabled below. Mega-projects are considered the largest infrastructure projects that attract the best engineers and a suite of funders. The are several needs for mega-projects and each dependent on a country and their ambitions. Table 5.5 lists the mega-projects that reached financial close in 2016 and will form part of the national grid from 2019. It details the technologies that were selected, the capacities as well as the countries these mega-projects will be built. Table 5.6 also lists these projects by project value to give an indication of the mega-project financing that is required.

Table 5.5: Mega-Projects by Country, Capacity and Technology Source: Infrastructure Journal.

Country	Number of Projects	Project Name	Technology	Capacity (MW)
Belgium	2	Norther	Offshore Wind	370
		Rentel	Offshore Wind	309
Chile	1	Cardones-Polpaico	Transmission	N/A
Germany	1	Merkur	Offshore Wind	396
Indonesia	1	Central Java	Coal	2000
Japan	1	Fukushima	IGCC	1080
Norway	1	Project Skywalker	Onshore Wind	1000
Oman	1	Sohar 3 & Ibri	CCGT	3219
Pakistan	1	Thar	Coal	660
Philippines	1	Kauswagan	Coal	550
Qatar	1	Facility D Desalination Plant	IWPP	2400
UAE	2	Barakah	Nuclear	5600
		Hassyan	Coal	2400
UK	3	Beatrice	Offshore Wind	588
		Dudgeon	Offshore Wind	402
		Tees CHP	Biomass	299
US	3	Westmoreland	CCGT	925
		Towantic Energy	CCGT	785
		Lackawanna	CCGT	1438

Thirteen countries are embarking on mega-programmes; these are not necessarily single projects but multiple projects comprising of an energy programme. Table 5.5 lists the mega-projects by country, capacity and technology. Of the 208 projects that reached financial close in 2016, only 19 were mega-projects (Infrastructure Journal, 2017).

These projects are being planned for construction in the 13 countries listed in Table 5.5. The projects utilise gas, coal, nuclear, wind and biomass technologies. Biomass has the lowest planned capacity at 299MW, while nuclear technology has 5 600MW planned capacity and a capital cost in excess of $23bn (Table 5.2).

The United States has invested in gas mega-projects due to the cost of gas, the diversification of the energy mix and the reduction in coal fired plants (Russell, et al., 2016). Whereas the UAE has growth and demand considerations. For these countries, the driver is energy demand and the diversification of the energy mix. There are no obvious sublimes in their energy mix decisions.

Wind technology is dominant in Germany and Belgium, where the main reasons are ensuring security of supply and making sure that energy is affordable while decarbonising (International Energy Agency, 2009). In both countries there is a pervious political agenda which steers the political sublime towards renewables. Japan, which shut down its nuclear reactors, is making a desperate attempt to increase capacity, thus gas technology is the natural solution. There is no mistaking that sublimes may be at play, particularly amongst developed countries, however, most countries are looking at a low cost diversified mix that is less carbon intensive.

5.1.9. Transaction Value of Mega-projects

Transaction value can be an inhibitor for developing nations to access funding. High transaction values such as those in Table 5.6 are usually for developed countries who possess an adequate balance sheet and a good credit rating and can attract funds from all over the world.

Table 5.6: Mega-Projects by Transaction Value Source: Infrastructure Journal.

Country	Number of Projects	Project Name	Transaction Value ($Million)
Belgium	2	Norther	1276.95
		Rentel	1235.82
Chile	1	Cardones-Polpaico	1200.6
Germany	1	Merkur	1942.87
Indonesia	1	Central Java	4300
Japan	1	Fukushima	2755.05
Norway	1	Project Skywalker	1428.45
Oman	1	Sohar 3 & Ibri	1726.21
Pakistan	1	Thar	1108
Philippines	1	Kauswagan	1045
Qatar	1	Facility D Desalination Plant	2969
UAE	2	Barakah	23714
		Hassyan	2890.4
UK	3	Beatrice	3793.74
		Dudgeon	2166
		Tees CHP	1188.08
US	3	Westmoreland	1274.2
		Towantic Energy	1144.93
		Lackawanna	1004.71

In order to draw fair comparisons and to better understand the data, the dataset was expanded beyond to 2016, to incorporate prior years. A view of the years prior, 2013 to 2016 show a trend and if modelled would have perhaps given a forecast.

Table 5.7: Number of Projects 2013 – 2016 Source: Infrastructure Journal.

Year	Number of Projects Closed
2013	275
2014	319
2015	332
2016	208

Table 5.7 lists the number of projects from the preceding three years which display a steady increase that comes to an abrupt decline in 2016.

Between 2015 and 2016 the number of projects declined by 37%; this speaks to tightening global capital markets exhibited by currency unavailability or shortages, convertibility of local currency and the global economic downturn which has impacted the availability of liquidity (International Financial Law Review, 2017). In relation to South Africa, prior year increases were related to surplus demand and the need to expand capacity (Pieters, et al., 2014). In 2016, only one project reached financial close due to decreased demand and affordability issues related to Eskom.

A notable phenomenon is the change in technologies over the years and in particular, the number of technologies reaching financial close. Table 5.7 and Figure 5.7 furnish a tabular and a diagrammatic illustration of the number of technologies between 2013 and 2016.

Figure 5.6 compares power technologies throughout a four year period, from 2013 to 2016. The trend shows a concentration in renewable technologies, particularly onshore wind and solar PV. During the 2013 – 2015 period, these two technologies showed tremendous growth, however, in 2016 this trend was halted. Offshore wind technology has been eliminated and no projects reached financial close in 2016. The (International Energy Agency, 2018) believes that offshore wind technology has great potential, despite its mere 0.2% contribution to global electricity generation. The IEA believes that offshore wind has been destabilised by the shale gas revolution in the United States, as well as lower prices and uncertainty in demand.

Solar PV has seen a sharp decline from a 2014 high of 102 projects, to a paltry 50 projects in 2016 - a significant decline of 51%. Conversely, this decline is not negative as there is an over-saturation of PV projects in the market and even though this brings down prices, it could be fuelling the decline in projects funded (Carus, 2013). The decrease in costs could also be the reason why solar PV projects are not prominently featured in mega-projects any longer.

Wind technology projects increased considerably from 106 projects in 2013 to 145 projects in 2015; the upward trend was challenged in 2016 when only 107 projects reached financial close – one up from 2013 (Figure 5.6). The upward trend can be attributed to wind technologies attaining grid price parity, increased reliability due to faster learning rates, greater efficiencies, favourable wind policy and improved capacity factors (U.S. Department of Energy, 2008; Deloitte, 2015).

The number of hydro projects reaching financial close have been consistent between the four periods under review. The decision to invest in hydro is not driven by market movements or disruptors but predominantly by the availability of water in a particular country.

Coal technology is experiencing one of the most prevalent declines, by as much as 50% during the years under comparison. This is in line with global patterns moving away from carbon emitting technologies (Russell, et al., 2016; U.S. Energy Information Administration, 2017).

Gas technology in the form of CCGT has experienced persistent growth fuelled largely by the boom in the natural gas market. This growth has been sustained by gas from the USA and the Middle East to satisfy both internal as well as Asian demand. The actual Liquefied Natural Gas (LNG) facilities are not factored into the data, as they do not represent gas to power projects. In this study, only power projects are considered.

Despite the technology changes, the dominant technologies consistent for all reporting periods are CCGT, coal fired, solar PV and wind. Concentrating solar power at a 2015 high of seven projects, has declined to just one project and the future seems even bleaker. CSP relied heavily on subsidies and required immense research and development; this is what removed CSP developers from the market because players such as Abengoa had unsustainable research and development costs, coupled with the decline in the Spanish economy. Furthermore, the 2016 EIA levelised cost of energy analysis (U.S. Energy Information Administration, 2017) shows no further coal, offshore wind or CSP for the USA. Coal technology may be overturned owing to the Trump administration; however, the future of CSP and offshore wind technology is bleak.

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Table 5.8: Comparison of Number of Projects by Technology 2013 – 2016 Source: Infrastructure Journal.

Technology	2013	2014	2015	2016
Biofuels	0	5	2	0
Biomass	14	6	10	7
Carbon Capture & Storage	0	1	1	0
Co-Generation	2	7	3	0
Coal-fired	8	10	13	6
Gas-Fired	17	16	19	16
Geothermal	1	4	4	2
Hydro	9	10	11	7
IWPP	1	1	1	1
Marine	0	2	0	0
Nuclear	0	1	0	1
Offshore Wind	3	1	8	0
Oil-fired	3	2	2	0
Onshore Wind	106	124	145	107
Photovoltaic Solar	90	102	86	50
Powership	0	0	0	1
Small Hydro	5	11	7	0
Thermal Solar	2	3	7	1
Transmission & Distribution	4	8	9	6
Waste-to-Energy	10	5	4	3
Total	275	319	332	208

Figure 5.6 shows the technology trends and their growth or demise over the four year period. Worth noting is the growth of onshore wind and solar which was largely driven by disruption, climate policy and financiers.

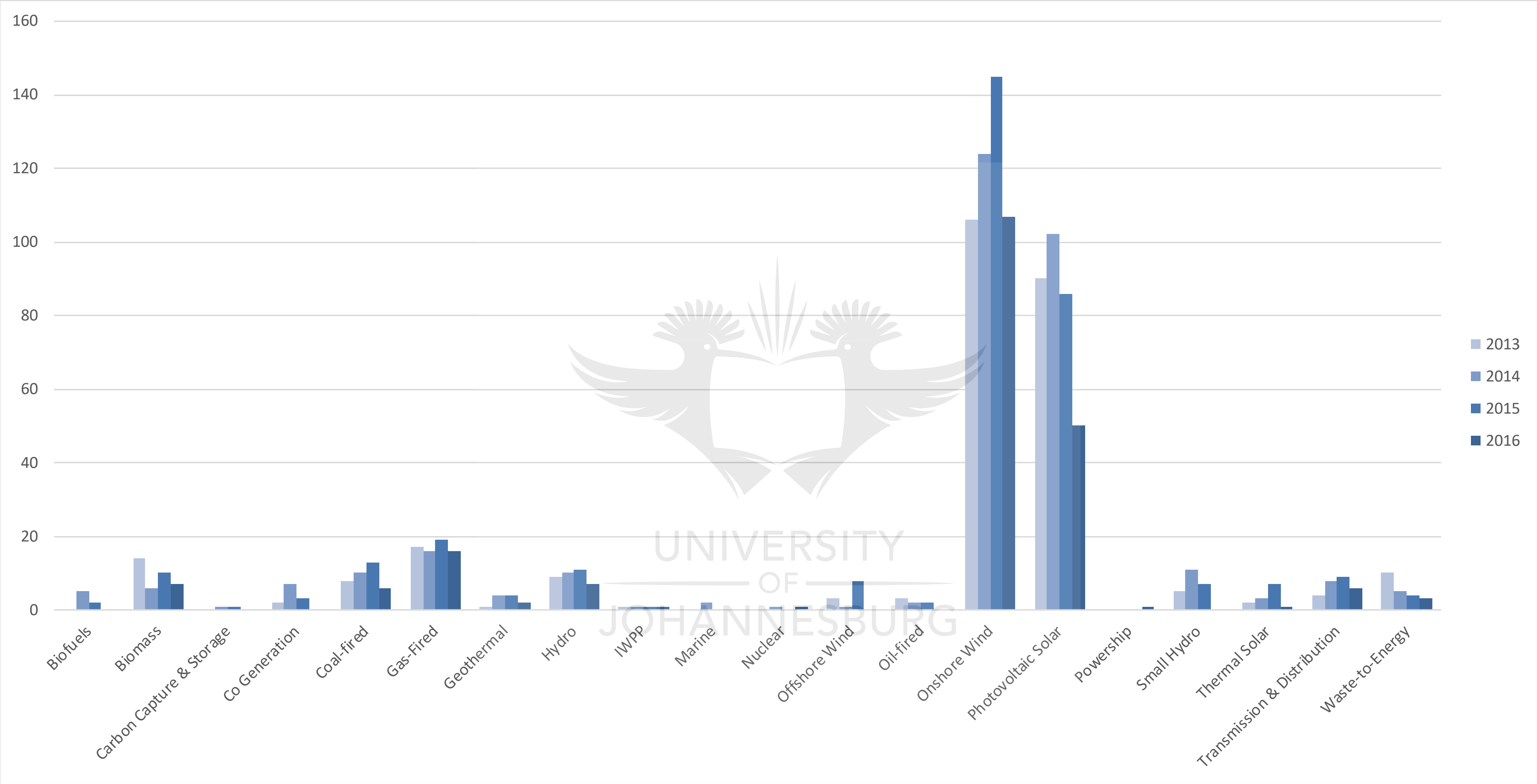

Figure 5.6: Comparison of Number of Projects by Technology 2013 – 2016 Source: Infrastructure Journal.

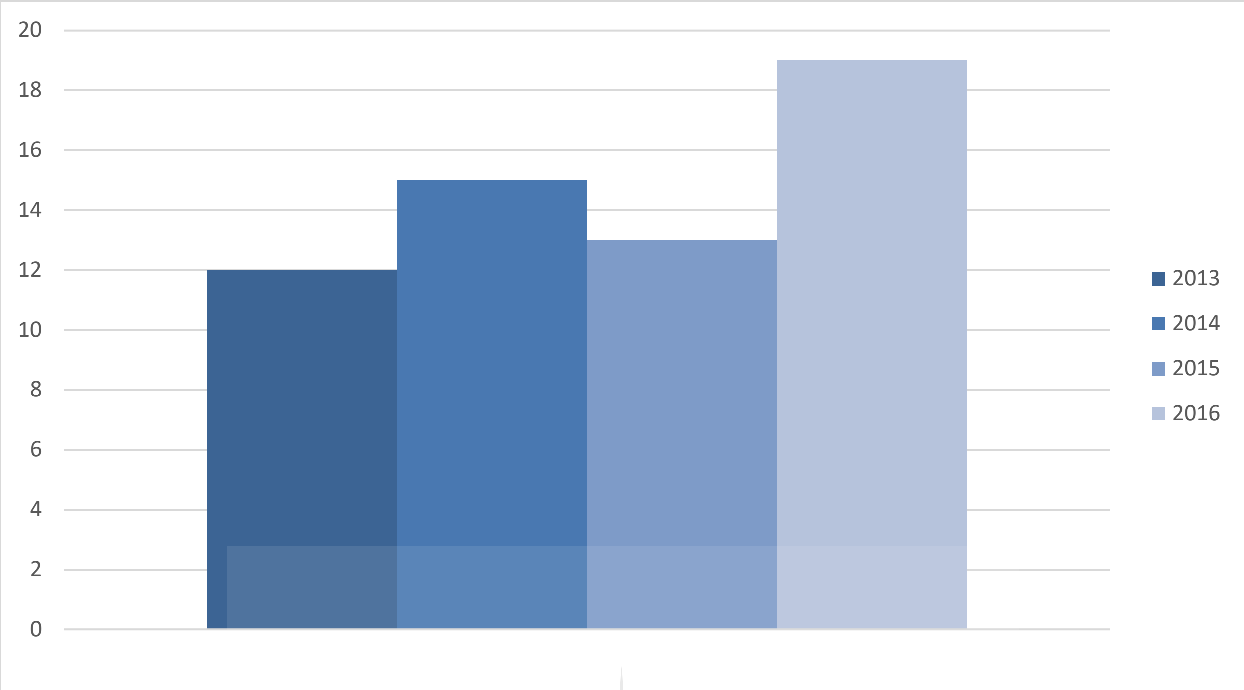

Figure 5.7: Mega-project Comparison Source: Infrastructure Journal.

Figure 5.7 delves into the mega-project comparison where in 2013, only 12 mega-projects reached financial close. This was followed by an increase in the number of successful deals, a subsequent dip and then a vast increase to 19 projects in 2016, which indicates an increase of 58% between 2013 and 2016

5.1.10. Mandated Lead Arrangers (MLAs)

MLAs are the lead debt arrangers and coordinate other funders; thus being recognised as a Top 10 MLA indicates market leadership, experienced deal teams, preferential pricing and a good market reputation.

Infrastructure projects in different economic sectors are funded across the world. These projects comprise of a wide range of sectors, namely, information and communications technologies (ICTs), water, transport, as well as a suite of widely ranged technologies. The results depicted in Table 5.9 displays the Top 10 Mandated Lead Arrangers (MLAs) in the power sector.

Table 5.9: Top 10 Mandated Lead Arrangers (MLAs) Source: Infrastructure Journal.

Rank 2016	Rank 2015	Company	Deal count 2016	Deal count 2015
1	1	Mitsubishi UFJ Financial Group	164	153
2	4	Sumitomo Mitsui Financial Group	127	138
3	2	ING Group	92	150
4	5	Credit Agricole Group	79	119
5	7	Societe Generale	72	99
6	6	BNP Paribas	72	112
7	8	Mizuho Financial Group	69	91
8	11	Natixis	64	62
9	3	Santander	64	139
10	15	NordLB	61	54

Eight (8) of the 2015 ranked MLAs featured in the 2016 Infrastructure Journal - Global Top 10 list - indicating a market dominance and a preference among project sponsors. An analysis of the 2015 and 2016 deal counts, indicates a total of 1117 and 864 deals, respectively. This depicts a decrease of 29% within the two years, which possibly indicates a shrinking global economy, a decrease in projects funded and a limited deal flow. According to the International Financial Law Review (2017), fewer and less valuable projects had reached financial close in 2016 in comparison to previous years. It appears that the year 2016 was a record period for most country downgrades.

The downward trend in investments also holds true for DFIs (Table 5.10) between 2015 and 2016. During this period (2015 - 2016), there was a 5% decline in deal count from 168 to 160 projects respectively. This decline in DFIs is not as significant as that of commercial lenders. This may be due to DFIs being viewed as infrastructure lenders whose objectives are to address market failures, as well as addressing broader development policy objectives (Gumede et al., 2011).

While most of the MLAs usually emanate from Japan and France, it gives the impression that the DFIs are far more global in their exposure, however, they seem to be moderated by a predominantly European funding influence. The knowledge of who finances projects is fundamental, especially in the case of DFIs; for the reason that in infrastructure finance, lenders such as DFIs and export credit agencies have an influence on the technology choice. This is invariably a result of infrastructure and development mandates that govern most state owned lenders (George & Prabhu, 2003). Most European banks invest heavily in energy renewables and have a vested interest in maintaining the status quo due to the spread of their technologies and expansion of their markets (George & Prabhu, 2003; Pouris, 2012).

5.1.11. Development Finance Institutions

Development Finance Institutions (DFIs) are often regional finance institutions whose mandate is to finance development infrastructure such as transmission, roads, airports and power plants. Given that most energy projects are government supported or owned, an analysis of this funder gives insight into the growth of their finance book.

Table 5.10: Top 10 Development Finance Institutions (DFIs) Source: Infrastructure Journal.

Rank 2016	Rank 2015	Company	Deal count 2016	Deal count 2015
1	6	Export Development Canada	23	15
2	1	KfW	22	35
3	2	International Finance Corporation	20	32
4	3	European Investment Bank	19	30
5	11	Korea Development Bank	16	7
6	7	European Bank for Reconstruction and Development	15	14
7	11	Inter-American Development Bank	14	7
8	14	Overseas Private Investment Corporation	13	6
9	7	Japan Bank for International Cooperation	12	14
10	10	Proparco	6	8

5.1.12. Transaction Value by Technology

The importance of this graph is illustrated in the comparison between combined cycle gas turbines (CCGT), nuclear and wind technologies. Whilst both nuclear and wind are for a similar amount, wind accounts for 107 projects whilst nuclear only accounts for one project.

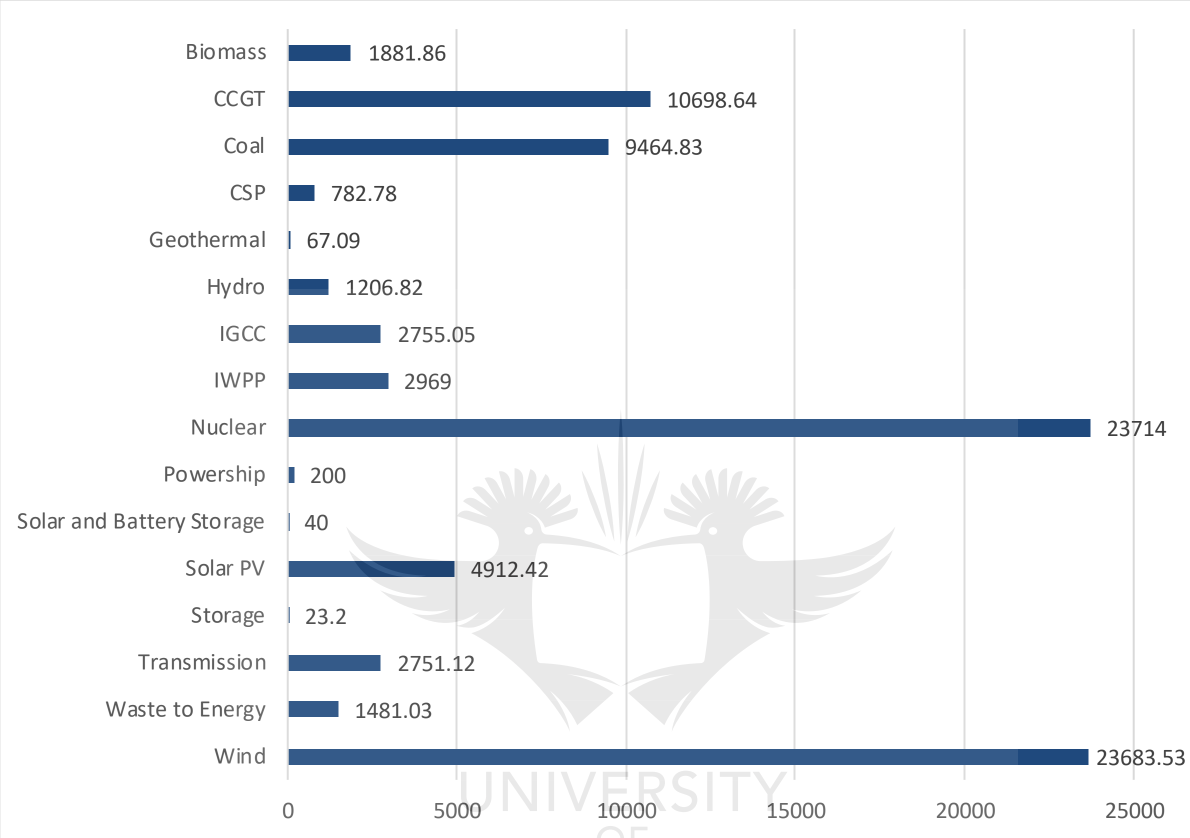

Figure 5.8: Transaction Value per Technology Source: Infrastructure Journal.

In Figure 5.8 the transaction value (USD millions) per technology type is displayed. Nuclear technology investments ($23bn) exceeded all other technology types by a substantial margin. In descending order, nuclear technology is followed by both CCGT ($10.98bn) and coal technology ($9.46bn). Figure 5.24 also shows that the top four technologies by credit value are nuclear, wind, gas and coal with a total credit value of $67bn, (78% of the total credit value) which reached financial close in 2016 and comprises of 62% of total projects. Low levels of investment in storage as well as PV combined with storage may indicate that storage is still a novel but expensive technology. Contrary to this notion, according to the (International Renewable Energy Agency, 2017), while the price of battery storage has not increased significantly enough to enjoy wide scale deployment, the use of pumped hydro for storage has supplemented this need. The credit value is skewed towards wind and nuclear technologies, both in excess of $23bn each.

It is worth paying attention to the fact that the capital outlay required for a single nuclear plant with the capacity of 5 600MW is similar to that of 10 055MW of wind technology from 107 projects; obviously this comparison does not analyse levelised costs of either technology, but focuses purely on the credit value. Apart from wind technology, which has 107 projects; 5.24 shows that thermal technologies such as coal, gas and nuclear still have a substantial capital requirement.

The transaction value of the 19 identified mega-projects is listed in Table 5.5. These projects account for only 10% of the total power sector contribution of $588bn. The UAE, the UK, Belgium and the USA have the largest number of mega-projects with a minimum of two mega-projects. An analysis of the funders is not possible, as one project could have up to 30 lenders (a mix of equity players, DFIs and commercial lenders).

5.2. CONCLUSION ON DISCUSSION OF RESULTS

It is certain that the mega-project paradox does exist. The number of mega-projects has been steadily increasing over the last few years, following an upward trend (Flyvbjerg, 2014). Sixty percent (60%) of the survey respondents indicated that mega-projects will continue being built and that South Africa will build additional mega-projects within this century. In 2013, 12 projects were deemed mega-projects and this increased to 19 in 2016 (Infrastructure Journal, 2017). The increase in mega-projects is negatively correlated to the number of projects reaching financial close, which has decreased substantially during the period under review. This correlation phenomenon falls outside the scope of this dissertation. However, several reasons that may be attributed to this trend are increasing costs, rapid economic growth, technology shifts as well as utility scale renewable installations such as solar parks.

The mega-project technologies are gas, nuclear, coal, wind and biomass. Gas technology is prominent as a result of the global gas boom which has seen market players emerging– the gas market is being driven by supply from the United States, Qatar, Saudi Arabia and Australia; and is thus buoyed by demand from Asia, the Americas and the Middle East (Infrastructure Journal, 2017).

Coal and nuclear technology are being invested in by countries who have experienced rapid economic growth and are looking to fulfil their base load requirements as well as diversify their energy mix. The wind technology projects, which form the mega-projects, are all offshore wind plants. This is an important exception, especially when one compares the levelised costs of onshore and offshore wind technology installations (Infrastructure Journal, 2017).

It is worthy of noting that when infrastructure projects are analysed, the largest top nine projects are not in the energy sector. According to (Business Insider, 2017), the top nine projects under construction in 2017 were the space station, airports, water, real estate, bridges and rail. Two of these nine mega-projects were in real estate, which shifts away from traditional infrastructure programmes that consider economic growth and advancing the developmental goals of societies. Transport modalities also have a massive share of projects, mainly in China and Dubai. China does not feature on the project finance lists, but interestingly has three projects in the top nine. As discussed earlier, China does not source its funds from the capital markets, their sheer size and market capitalisation allows the government to fund these projects from its balance sheet (International Financial Law Review, 2016).

Flyvbjerg (2014) mentions the “iron law” of mega-projects - he wrote that they are “over budget and over time, over and over again”. Flyvbjerg (2014) has termed this the “survival of the unfittest”, with undeserving projects being selected in preference to those with reasonable cost benefit estimates. This dissertation has also alluded to the existence of additional sublimes which may be part of the reasoning behind some of the mega-project decisions taken.

An analysis of mega-projects in developing countries by (Othman, 2013) reveals that mega-projects are not being built in developing countries due to the level of high design knowledge that is required and the absence of technical skills; a lack of competent human resources and managerial capabilities also exists, along with exorbitant investment costs. This is contrary to the global findings on mega-project trends. This finding is of paramount importance, given the experience with the New Build Programme and any future plans to build mega-projects in South Africa.

The increase in mega-projects in the energy sector raises questions as to whether this rings true for other sectors too, in particular, transport and residential infrastructure. Regardless of the answer, what is evident is that mega-projects are on the increase and are becoming exponentially larger. They are also not found in typical industries but are geared towards services, lifestyles, tourism and mobility.

Alexander (2015) cautions against the sustainability of the mega-project boom, implying that perhaps mega-projects are a victim of the “iron law” of mega-projects as postulated by (Flyvbjerg, 2014) and that mega-projects are being driven by geopolitics and not careful economics (Alexander, 2015).

Apart from the United States, which has mega-projects every year, there is no dominant trend in the countries where these mega-projects are constructed. The selection seems sporadic and dependent on the needs of the country. Table 5.11 lists the countries who have invested in mega-projects between 2013 and 2016.

Table 5.11: Countries with mega-projects Source: Infrastructure Journal.

Year	2013	2014	2015	2016
Country	Canada	Argentina	China	Belgium
	Chile	Canada	Germany	Chile
	Germany	Costa Rica	Israel	Germany
	Kuwait	Indonesia	Malaysia	Indonesia
	Morocco	Laos	Morocco	Japan
	Peru	Malaysia	Philippines	Norway
	Saudi Arabia	Morocco	United Kingdom	Oman
	Turkey	Netherlands	United States	Pakistan
	United States	Philippines	Vietnam	Philippines
		Turkey		Qatar
		United Arab Emirates		United Arab Emirates
		United States		United Kingdom
		Vietnam		United States

These findings corroborate the findings by (Othman, 2013) on the construction of mega-projects. Whilst there are developing countries on these lists, they are by far in the minority. Issues related to excessive costs and capability certainly play a role in mega-projects succeeding and is possibly why we see less mega-projects in developed countries.

These countries may individually be applying the sublime principals in determining what projects need investment, however, this analysis falls outside of the scope of this research. Apart from Morocco, no African country is investing in mega-projects. South Africa last had mega-projects during the New Build Programme. Since then, numerous power projects have been constructed but not on the scale of mega-projects. It is anticipated that the coal IPP as well as the gas IPP programme will launch South Africa into the mega-project sphere once again, yet the road to investment and eventual financial close is perilous.

Research by (Alexander, 2015) shows that most mega-projects are being built in the Group of 20 (G20) countries as listed in Table 5.12. Comparing the two tables is very insightful as 50% of the G20 countries are investing in mega-projects.

Table 5.12: List of G-20 Countries.

List of G-20 Countries	
Argentina	Japan
Australia	Republic of Korea
Brazil	Mexico
Canada	Russia
China	Saudi Arabia
France	South Africa
Germany	Turkey
India	United Kingdom
Indonesia	United States
Italy	European Union

Globally, considering non-sector specific projects, most mega-projects are being built in China and Dubai. According to the (Business Insider, 2017) article, of the top nine mega-projects being constructed in 2017, six of them are in Dubai and China, in the real estate sector. These countries typically make use of their own balance sheet funding and do not feature on project finance league tables (International Financial Law Review, 2017). This contrasts with the information above and may indicate that for more risky projects such as real estate, project finance is more difficult to obtain.

Mega-projects by their sheer scale, invite multiple global funders. Providing an analysis on an individual project basis will not yield any results or provide deeper insights. As a result, data from the top 10 mandated lead arrangers has been used to indicate who the funders are. An analysis of the MLAs reveals that 40% of the MLAs are from French banks, while 30% are from Japanese banks. There are no African MLAs or even MLAs from the BRICS[15] or developing countries.

It is important to understand who funds the projects as this has a direct impact on what kind of technologies are funded; who gets the funding and what the funding entails. For instance, numerous funding agencies place a requirement on their borrowers to use the technology or manufacturers of the MLA country of origin (KFW, n.d.) . Whilst certain lenders have a mandate from their governments not to fund certain technologies (The Guardian, 2017), others do not specify terms and conditions.

[15] Brazil, Russia, India, China, South Africa

During Eskom's New Build funding application to the World Bank, the funding requirements for investing in a coal fired plant stipulated that Eskom would have to build a renewable plant to offset their carbon emissions (World Bank, 2011).

Following the 2008 global economic crisis, it was stated in an article (World Finance,2009) that the global financial crisis was forcing governments to spend billions of dollars on infrastructure projects as a way of regenerating growth. These funds would not necessarily yield high returns but would help stimulate the economy. This was at the risk of increased unemployment and a decrease in output from recession hit industries such as manufacturing and construction. This analysis gives credence to why the energy sector was so inundated with projects following this period because the manufacturing of components is crucial in creating industries and economic growth. This coupled with global expansion by European and Asian countries, particularly into Africa, meant that these governments could stave off their economic decline.

The consensus almost seems irrational that despite demand data, growth projections and fiscal tightening, the number of mega-projects is growing. Survey respondents said that despite credit downgrades, as well as cost and time overruns, mega-projects will continue being built. Regardless of sublimes and disruptive technologies which may or may not influence projects, the investment in and construction of mega-projects will continue. Funding constraints were seen as the only trigger to halting mega-projects, with 75% of the respondents saying that this would deter investment.

In a construction related article (Rodrguez, 2017), Rodriguez feels that mega-projects have become necessary evils. He says that although these projects are held in awe for their scale, they are equally viewed as being suspicious. He uses the Three Gorges Dam as an example by stating that if a project delivers power to an expanding China, but displaces more than a million and a half Chinese people and destroys farmland, can it still be lauded as a success?

In the McKinsey report titled "Megaprojects: The good, the bad, and the better" – they estimate that the world needs an infrastructure capital outlay of $57 trillion by 2030 to permit the projected levels of GDP growth globally. Of the stated amount, approximately two-thirds will need to be spent on developing markets where there is a growth in middle classes, an increase in population, urbanisation and increased economic growth (McKinsey, 2015). The report further maintains that years will pass and these countries would still not have their required infrastructure as the risks associated with these projects is well documented. They cite the following reasons:

- Over optimism and over complexity
- Poor execution
- Weakness in organisational design and capabilities

Despite these reasons, the report affirms that a compromise is needed between the short term financial obligations and the long term societal benefits. This is a critical element when supporting and investing in mega-projects as their social value may defy all economic logic and necessitate investment.

Alexander (2015) cautions developers, governments and lenders. She states that mega-projects are not sustainable in the long term as they are not based on sound economic principles; they are driven largely by geopolitics and sublimes. In addition, there is the risk of corruption, waste and unsustainable public debt. She also raised concerns about the environmental risks that these mega-projects carry. She postulates that mega-projects should alleviate these risks and not exacerbate them. Finally, given that mega-projects are often Private Public Partnerships (PPP), private seekers will always seek to increase their return on investment at the expense of social and environmental necessities. There is a risk of profiteering undermining the public good.

According to (Söderlund, et al., 2018 p.9), there are at the minimum four critical issues in mega-project research:

- Their existence and prevalence
- Their management and organisation
- Their success and performance, or underperformance
- The future of mega-projects and how they address major societal challenges

This dissertation has provided an understanding of the nature of mega-projects and why they are pursued. Furthermore, this dissertation has delved into their organisation, management and funding. It concludes by giving a glimpse into the future of mega-projects and whether or not South Africa will have a mega-project in the next twenty years.

The funding of mega-projects continues and on an even larger scale. There are clear patterns that this decision is not driven by economic fundamentals such as demand and supply and cost but rather by sublimes as well as socio-economic and political factors.

6. CHAPTER

CONCLUSIONS AND RECOMMENDATIONS

6.1. INTRODUCTION

This dissertation was premised on the changing global utility landscape and on whether given the "mega-project paradox" is the New Build the last mega-project South Africa will see this century. The following key questions guided the research enquiry: what are the current opinions and views on the investment uncertainty of these mega-projects given the risks and challenges associated with them?

6.2. CONCLUSIONS

Based on reviewed literature in this dissertation and the research question and objectives that were formulated, the following conclusions can be made. In the literature review of this dissertation, the challenges of funding mega-projects and exploring the mega-project paradox and their implications on South Africa and the world were examined. Then attention focussed on the various technology disruptors in the electricity power sector and how they are affecting global utilities. These disruptors are varied and have far reaching sustainability implications from a technical, regulatory, and economic context.

Given the results that were presented and discussed in Chapter 4, despite a decline in the global energy project financing, more mega project constructions are being expected based on the views and opinions of at least 60% of respondents in this survey. This trend is driven by several factors including the development of mega cities, need for jobs, and anticipated economic spinoffs. Hence, it is not surprising when views and opinions on government policy (political sublime) as well as the economic drivers (economic sublime) are in favour of more mega projects.

However, in terms of the investment uncertainty of these mega projects, the paradox for continuing these projects has come to fore in this survey because of numerous factors such as frequent cost and time overruns. Time overruns were reported by respondents as a major constraint militating against the sustainability of most mega projects. Time overruns were caused by inadequate front end engineering and design, poor internal procurement processes and project management, inadequate resources as well as financing bottlenecks. Given the investment uncertainty as well as the risks and challenges on mega-projects which were stated in objective 1, it seems that these risks and challenges are not an investment hindrance. Furthermore, 28% - 40% of survey respondents expected future constructions of more mega projects despite unfavourable credit ratings, funding constraints, and the negative experiences associated with big projects such as Medupi and Kusile in South Africa. In fact, the dismal failures experienced in the management and financing of Medupi and Kusile mega projects seems to be no deterrents, thus necessitating the need for more rigorous economic impact assessments in the planning and feasibility of mega projects that can accurately weigh or compare infrastructural development costs against anticipated economic and socio-political benefits.

In a bid to establish whether mega-projects are being funded and by whom through objective 2 it is evident that mega-projects continue to be funded, even on a larger scale. This is despite the high propensity of time and cost overruns and macro-economic indicators that send a different message. Constraints exist and are accepted by the markets, however, there is a belief that mega-projects will continue to be funded. This dissertation has through objective 3 shown that funding is global and varied and if economic fundamentals are to be believed, we are led to believe that the era of mega-projects should be declining, yet this is not the case. Therefore, an assumption is made that mega-projects in particular, stem from a different set of principles. Mega-projects speak more about anticipated social and economic growth, job creation, localisation, skills development and sublimes than they do about economic fundamentals. Mega-projects appeal to opportunity, innovation, political will and economic contribution.

6.3. RECOMMENDATIONS

It is recommended that additional research be undertaken in the following areas:

- Establishing the optimal EPC contracting strategy for South Africa in the energy sector given the mega-project paradox
- Optimising the IPP procurement programme to leverage stakeholder buy-in: Assessing Eskom and NERSA participation, transformation of the IPP office and the industry
- A Project Management Nightmare: Interrogating the reasons why Medupi and Kusile are still not fully commissioned 11 years later

The following recommendations are made in order to create efficiencies and salvage what is fast becoming Eskom's death spiral in South Africa.

– Existing commitments to the expedited REIPPPP[16] round which was scheduled to reach financial close end October 2017 should be honoured as well as the coal base

[16] Renewable Energy Independent Power Producer Procurement Programme

load programme. Any future rounds which have not been auctioned such as the gas and nuclear programme need to be halted,

- Following unbundling, Eskom must split its electricity power generation business model into renewables and a thermal production infrastructure,
- Eskom (as a newly formed renewables company) should go into partnerships with IPPs, thus diversifying away from mega-projects to off-grid solutions, micro grids, grid based renewables, and rooftop solar installations which do not need massive infrastructure investments and capital expenditure.

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8. Appendix A:

Question 1

In your experience do you foresee any mega-power* projects being constructed in South Africa in the next 20 years?

**Projects with a cost exceeding $1 Billion or a single project with an installed capacity exceeding 1000MW*

Question 2

Is the current Eskom operating model conducive to the investment in mega-power projects?

Question 3

Do you think market and regulatory reform of the electricity supply industry are necessary for further building of mega-power projects?

Question 4

If you do think market and regulatory reform is necessary, how do you see the Eskom operating model looking like?

Question 5

Do you think cost overruns are a deterrent to building megaprojects?

Question 6

Do you think time overruns are a deterrent to building megaprojects?

Question 7

Do you think the advent of disruptive technologies e.g. solar PV, embedded generation will be a deterrent to investing in mega-projects?

Question 8

Do you think funding constraints are a deterrent to investing in mega-power projects?

Question 9

Do you think credit downgrades are a deterrent to investing in mega-power projects?

Question 10

On a scale of 1 – 5 (1 = highly unlikely; 2 = unlikely; 3 = unsure; 4 = likely; 5 = very likely) How likely is South Africa to build mega-power projects in this century?

Question 11

On a scale of 1 – 5 (1 = highly unlikely; 2 = unlikely; 3 = unsure; 4 = likely; 5 = very likely) How likely is South Africa to invest in mega-power projects given fiscal tightening?

Question 12

On a scale of 1 – 5 (1 = highly unlikely; 2 = unlikely; 3 = unsure; 4 = likely; 5 = very likely) How likely is South Africa to invest in mega-power projects given the experience with Medupi and Kusile

Question 13

On a scale of 1 – 5 (1 = highly unlikely; 2 = unlikely; 3 = unsure; 4 = likely; 5 = very likely) How likely is South Africa to invest in mega-power projects given funding constraints?

Question 14

On a scale of 1 – 5 (1 = highly unlikely; 2 = unlikely; 3 = unsure; 4 = likely; 5 = very likely) How likely is South Africa to invest in mega-power projects given current credit ratings?

Question 15

On a scale of 1 – 5 (1 = highly unlikely; 2 = unlikely; 3 = unsure; 4 = likely; 5 = very likely) How likely is South Africa to invest in mega-power projects given current demand forecasts?

Question 16

On a scale of 1 – 5 (1 = highly unlikely; 2 = unlikely; 3 = unsure; 4 = likely; 5 = very likely) How likely is South Africa to invest in mega-power projects given perceived/real corruption surrounding nuclear?

Question 17

On a scale of 1 – 5 (1 = highly unlikely; 2 = unlikely; 3 = unsure; 4 = likely; 5 = very likely) Will South Africa's decision to invest in mega-power projects be influenced by a technical sublime*?

**"the rapture engineers and technologists get from building large and innovative projects with their rich opportunities for pushing the boundaries for what technology can do, like building the tallest building, the longest bridge, the fastest aircraft, the largest wind turbine, or the first of anything."*

Question 18

On a scale of 1 – 5 (1 = highly unlikely; 2 = unlikely; 3 = unsure; 4 = likely; 5 = very likely) Will South Africa's decision to invest in mega-power projects be influenced by a political sublime*?

**"the rapture politicians get from building monuments to themselves and their causes. Megaprojects are manifest, garner attention, and lend an air of pro-activeness to their promoters."*

Question 19

On a scale of 1 – 5 (1 = highly unlikely; 2 = unlikely; 3 = unsure; 4 = likely; 5 = very likely) Will South Africa's decision to invest in mega-power projects be influenced by an economic sublime*?

"the delight business people (Contractors, bankers, engineers, lawyers, developers and trade unions) get from making lots of money and jobs off megaprojects."

Question 20

On a scale of 1 – 5 (1 = highly unlikely; 2 = unlikely; 3 = unsure; 4 = likely; 5 = very likely) Will South Africa's decision to invest in mega-power projects be influenced by an aesthetic sublime*?

**"the pleasure designers and people who appreciate good design get from building, using, and looking at something very large that is also iconically beautiful, like San Francisco's Golden Gate bridge or Sydney's Opera House."*