BARRIERS AND DRIVERS TO THE IMPLEMENTATION OF RENEWABLE ENERGY TECHNOLOGIES IN SOUTH AFRICA'S AQUACULTURE INDUSTRY

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DECLARATION

I, Nicholas van Wyk, hereby declare that the research presented in this thesis is my own original work; does not, in its entirely or part, exist as someone else's work and was not previously submitted to any institution. All sources used have been presented and accurately acknowledged with utmost integrity.

Nicholas van Wyk

Date

ABSTRACT

South Africa is plagued by socio-economic issues of poverty, inequality and high rates of unemployment. The government of South Africa has as such launched an ambitious plan known as operation PHAKISA which will complement the National Development Plan in addressing the countries aforementioned shortcomings. In the operations first phase, the focus is on growing South Africa's ocean economy. Within the ocean economy, the growth of aquaculture has been identified as an industry with the potential to create jobs and aid in economic growth of South Africa.

Aquaculture, the farming of any aquatic organisms, has been the fastest growing food production sector for the past 50 years. While natural capture fisheries have stagnated in production capacity, aquaculture has grown exponentially in order to feed a global population which is fast approaching nine billion people. However, South Africa's aquaculture production lags significantly behind other third world countries.

The sustainability of aquaculture has frequently been called into question due to the possibility of various detrimental environmental effects it may cause. To further complicate the matter, Climate Change is today an overarching threat to life as we know it, and must be taken into account if we plan to keep growing our populations and economies. As such, if South Africa wants to grow its aquaculture sector, it must be done so in a sustainable manner.

This research thus sought to investigate one aspect which may increase the sustainability of aquaculture in South Africa, that being the implementation of renewable energy in the sector. Renewable energy has been identified by the United Nations Intergovernmental Panel on Climate Change as key to mitigating the effects of climate change.

In order to aid Renewable Energy (RE) implementation in South Africa's aquaculture sector, this research aimed to identify the barriers and the drivers to implementing renewable energy within aquaculture. To do this, a literature review was conducted to identify possible barriers and drivers to renewable energy implementation. These were then drafted into an online questionnaire and sent via Email to all the aquaculture organisations in South Africa that could be contacted (n = 195). Respondents were

asked to rank the proposed barriers and drivers to renewable energy according to their perceived importance on a Likert Scale. A total of 18 responses could be analysed with descriptive statistics. Further, three structured interviews were conducted with members of South African aquaculture organisations who had implemented some form of Renewable Energy Technology (RET). These interviews provided in-depth insights into the importance of the various proposed barriers and drivers.

The results revealed the most important barriers to RE implementation were: *High Initial investments, Utility monopoly of production, Lack of RE experts on a governmental level, Lack of incentives/subsidies from government, Lack of legal framework for Independent Power Producers and Power Purchase Agreements,* and *Diseconomy of scale* respectively.

The most important drivers to RE implementation were ranked as: *Long term cost benefits, Reduction in cost of RETs, Innovation / advancement of RET's, Incentives or subsidies to implement renewable energy, Adequate legal framework and legislation for Power Purchase Agreement* and *Preference for environmentally-friendly electricity generation.*

Importantly, it was found that barriers and drivers are dependent on the type of RE being implemented. A Photo Voltaic (Solar Power) system will not necessarily experience the same barriers or drivers that a Wave Energy Converter system would.

In order to drive investment in RE and remove the barriers that may be preventing its implementation in aquaculture, policy will have to be adapted. Particularly in terms of legislation around Power Purchase Agreements. Further, by providing subsidies for RE implementation, it is possible to sustainably grow South Africa's aquaculture industry.

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LIST OF ABREVIATIONS

°C – Degrees Celsius

BBBEE- Broad Based Black Economic Empowerment

CO_2 – Carbon Dioxide

DAFF – Department of Agriculture, Forestry and Fisheries of South Africa

DoE – South African Department of Energy

FAO – Food and Agriculture Organisation of the United Nations

GHG's – Green House Gases

IPCC – Intergovernmental Panel on Climate Change

IPP – Independent Power Producer

KW – Kilo Watt (Measure of power)

KW/h – Kilo Watt per hour (Composite unit of energy)

LOCE - Levilised Cost of Electricity

MEC – Minerals-Energy Complex

NERSA – National Energy Regulator of South Africa

PPA – Power Purchase Agreement

PPM – Parts Per Million (Unit of measurement for gases in the atmosphere)

PV – Photo Voltaic (Solar Power)

RAS – Recirculating Aquaculture Systems

RBT – Resource Base Theory

RE – Renewable Energy

RET – Renewable Energy Technology

RETs – Renewable Energy Technologies

SPV – Special Purpose Vehicle

UNFCCC – United Nations Framework Convention on Climate Change

ZAR – South African currency denomination, the Rand

LIST OF APPENDICES

“WE ARE RUNNING THE MOST DANGEROUS EXPERIMENT IN HISTORY RIGHT NOW, WHICH IS TO SEE HOW MUCH CARBON DIOXIDE THE ATMOSPHERE CAN HANDLE BEFORE THERE IS AN ENVIRONMENTAL CATASTROPHE”

ELON MUSK

CHAPTER 1: INTRODUCTION

A growing need for both energy and food security are driving the notion that sustainable food production methods are essential, a concept that will steadily increase as the human population continues to grow (Cochrane, et al., 2009; Godfray, et al., 2010). Coupled to this, the overarching threat and possible effects of climate change further illustrate the essential need to think critically about the sustainability of human kind's food production operations.

1.1 Aquaculture

Aquaculture, the farming of any aquatic organisms, has been the fastest growing food production sector in the past 50 years (Little, Newton and Beveridge, 2016) and contributes to 50% of global fish supply (Hobday, et al., 2016). In the same period, the human population has increased drastically while numerous fish stocks across the globe have collapsed (Pauly, et al., 2002; Little, Newton and Beveridge, 2016). Both fisheries and aquaculture form important components of food supply, food security as well as, income generation (Cochrane, et al., 2009), but with a projected growth in demand for food predicted for at least the next 40 years (Godfray, et al., 2010) with substantial challenges in meeting these requirements from natural harvested fisheries, sustainable aquaculture production is viewed as key to the future of human food security (Little, Newton and Beveridge, 2016; Fisher, et al., 2017).

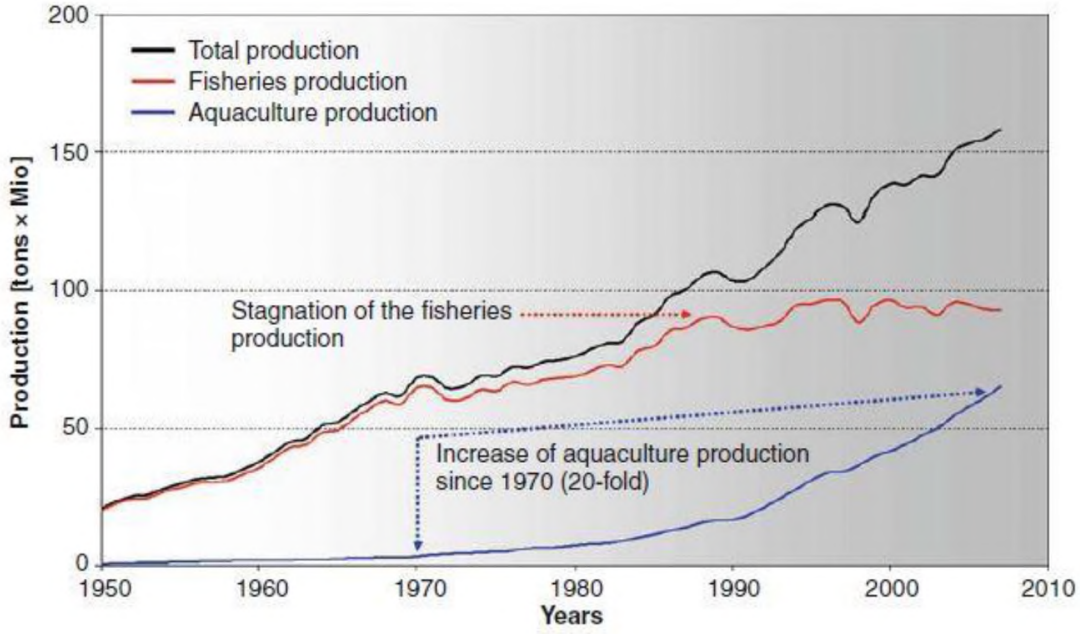

Figure 1: Wild capture fisheries stagnation versus the increase in production of aquaculture. Adapted from Buck and Krause (2012)

Figure 1 graphically displays the rise of aquaculture to continue to increase production of aquatic organisms while wild fisheries captures has stagnated (Buck and Krause, 2012). At a local, South African level however, aquaculture production lags significantly behind countries such as China and India and even in an African context is ranked only as the 10th largest producer (Bostock, et al., 2010; Mathiesen, 2012; Mahieu, 2015).

The South African aquaculture sector is divided broadly into the culture of freshwater species and marine species (known as mari-culture) (FAO, 2017). The industry produces various species with farms ranging in design and scale. The freshwater sector is comprised of farms culturing species such as rainbow trout, Mozambique tilapia and various ornamental fish species. Table 1 depicts the freshwater cultured species in South Africa and the number of farms producing those species in 2012 from records of the Department of Agriculture, Forestry and Fisheries (DAFF) in 2012 (FAO, 2017).

Table 1: Freshwater cultured species of South Africa. Adapted from FAO (2017).

Common name	Scientific name	No of farms	Province
North African catfish	*Clarias gariepinus*	13	all provinces except FS
Nile crocodile	*Crocodylus niloticus*	7	GP, KZN, LP, NW
Common carp	*Cyprinus carpio*	6	FS, GP, WP
Marron Crayfish	*Cherax tenuimanus*	3	WP, LP
Ornamentals	(Multiple)	19	all provinces
MozambiqueTilapia	*Oreochromis mossambicus*	28	EC, GP, KZN, LP, MP, WC
Trouts	*Oncorhynchus mykiss* & *Salmo trutta*	52	EC, FS, GP, KZN, MP, NP, WC

DAFF 2012 records
Eastern Cape (EC), Free State (FS), Gauteng (GP), Kwazulu Natal (KZN), Limpopo (LP), Mpumalanga (MP), North West Province (NW), Northern Cape (NC), Western Cape (WC)

The mari-culture sector of South Africa consists mainly of the culture of molluscs (FAO, 2017). Chief among which is the culture of abalone, a highly valued and endangered species that is exported to far East Asian nations (Troell, et al., 2006; FAO, 2017). This species is farmed in tanks on land where marine water is constantly pumped through the farm in high volumes, an energy intensive process (Troell, et al., 2006). Other cultured species include molluscs such as oysters and mussels, as well as finfish such as dusky kob and cape yellowtail as depicted in Table 2.

Table 2: Marine cultured species in South Africa in 2012. Adapted from FAO (2017).

common name	Scientific name	Number of farms	Provinces
Perlemoen abalone	*Haliotis midae*	14 (1)	EC, NC, WC
Mussels	*Mytilus galloprovincialis, Choromytilus meridionalis, Perna perna*	3	WC
Oysters	*Crassostrea gigas, Striostrea margaritacea, Pinctada capensis*	8 (2)	EC, WC
Finfishes	*Argyrosomus japonicus, Seriola lalandii, Pomadasys commersonnii* (experimental), *Atractoscion aequidens*	4	EC, WC
Seaweeds	*Gracilaria verrucosa, Ulva* spp.	3	EC, WC
Ornamentals	*Amphiprion ocellaris, Premnas biaculeatus, Amphiprion allardi, Amphiprion frenatus, Amphiprion percula, Amphiprion clarkii, Amphiprion perdarion, Pterapagon kaudneri, Sphaeramia nematoptera, Coryphopterus personatus, Pomacentrus coelestis, Amphiprion polymnus, Calloplesiops altivelis, Lysmata grabhami, Artemia,Patiella exigua*	1	KZN

DAFF records 2012
Eastern Cape (EC), Kwazulu Natal (KZN), Northern Cape (NC), Western Cape (WC)

Figure 2 depicts total aquaculture production (tonnes) in South Africa and showcases the growth and fluctuation of the industry since 1984.

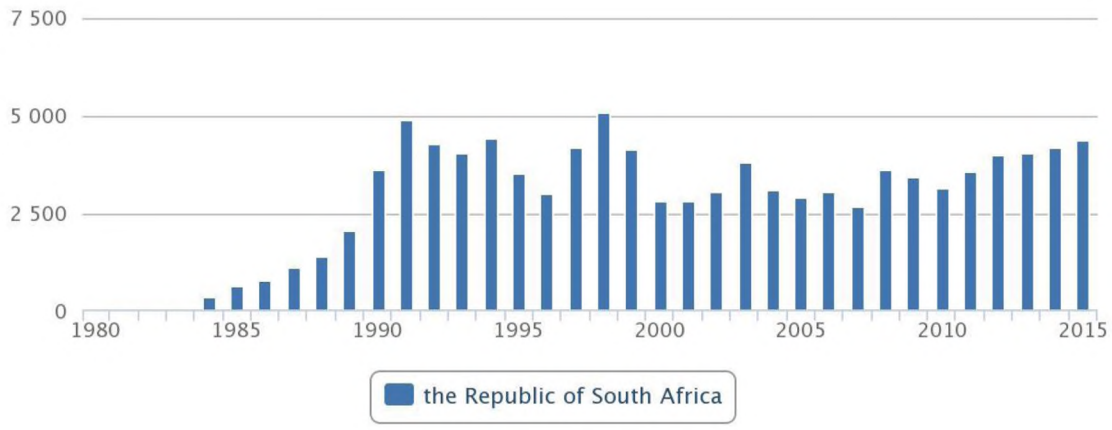

Figure 2: Total aquaculture production for the republic of South Africa. Source: FAO (2017)

Due to these low aquaculture production values, the South African Government has launched an ambitious plan known as *Operation Phakisa*, which in its first phase of implementation will focus on 'unlocking the ocean's economic potential' (DEA, 2016). Specifically, the operation will aim to increase revenue obtained from aquaculture processes from around R500 million to R1,4 billion by 2019 (DEA, 2016). As South Africa's current aquaculture production accounts for less than 1% of total national fish supply, and demand for fish has risen considerably, the sector offers significant potential for growth (DEA, 2016). Operation Phakisa thus predicts that an estimated R4-6 billion and 140,000-210,000 jobs could be created in marine aquaculture alone by 2033 (DEA, 2016).

1.2 Detrimental Impacts of Aquaculture

It is important to note that the practice of aquaculture and its environmental sustainability have frequently been called into question due to factors such as pollution and degradation of ecosystems as well as the use of fish meal in aquaculture feeds (Naylor, et al., 2000; Little, Newton and Beveridge, 2016). However, not all aquaculture

systems have such adverse environmental effects and there is a growing initiative to ensure that aquaculture is developed to be as sustainable as possible (Engle and D'Abramo, 2016).

Various types of aquaculture systems are used throughout South Africa. These range from highly sophisticated intensive systems where environmental conditions are optimised and controlled to aid growth of the species being cultured, to extensive systems where little to no human input is provided (FAO, 2017). It is the intensive systems that require large amounts of electricity to supply equipment such as pumps, vital filtration devices and water temperature control units (Lekang, 2008). It is these intensive aquaculture systems that could increase their sustainability by implementing RE and thus decreasing their GHG's emissions (Badiola, et al., 2017).

Although the sector contributes relatively little to global greenhouse gas emissions, there is scope for improvement (Cochrane, et al., 2009). If aquaculture is set to truly become a major contributor to food security as well as an industry that contributes meaningfully to economic growth and social upliftment, then it is critical that the industry be built in a sustainable manner (Elkington, 1997; Weybrecht, 2010).

1.3 Water-Energy-Food Nexus

The inextricable link between the world's water, energy and food security result in an interconnected system where the use of one resource is likely to result in interactions or trade-offs between other sectors or interest groups (Biggs, et al., 2015; Flammini, et al., 2017). This is known as the Water-Energy-Food Nexus (Conway, et al., 2015).

The effects of climate change are predicated to further exacerbate challenges faced by South Africa in terms of its water, energy and food security (Carter and Gulati, 2014). Aquaculture, by its fundamental nature requires the use of water. Water supply is affected by various facets that are affected by climate change. These include rising temperatures, changes to the frequency and intensity of rainfall and rising sea level (Carter and Gulati, 2014). Such changes to the supply and accessibility of water could further increase energy inputs as water may need to be pumped further or purified (Carter and Gulati, 2014). Such actions will inevitably have knock-on effects as well

as increase competition for resources. The root of the Water-Energy-Food Nexus is thus to balance the various uses of ecosystem resources (Flammini, et al., 2017) and take climate change into account in order to better protect against risks of water, energy and food security (Biggs, et al., 2015).

1.4 Climate Change

Growing evidence suggests that the earth's climate is changing due to anthropogenic activity (Stern, 2006). In fact, Svante Arrhenius in 1896 predicted that the burning of fossil fuels could increase the concentration of carbon dioxide (CO_2) in the Earth's atmosphere to the point where we would see warming of the Earth (Arrhenius, 1896; Hoffert, et al., 2002). Today it is well established that the burning of fossil fuels such as coal and natural gas are leading to increased concentrations of greenhouse gases (GHGs) which are in turn a major contributing factor to the warming of the Earth (IPCC, 2014). This enhanced greenhouse effect results in higher quantities of radiative energy being absorbed in the Earth's atmosphere, essentially leading to a trapping of heat within the troposphere (Seinfeld and Pandis, 2016).

Global warming is defined by the United Nations International Panel for Climate Change (IPCC) as "the gradual increase, observed or projected in global surface temperature, as one of the consequences of radiative forcing caused by anthropogenic emissions" (Pachauri, et al., 2014 p. 124). Where global warming refers to the average increase in the Earth's surface temperature due to an enhanced greenhouse effect, climate change refers to the Earths response to this warming (Pachauri, et al., 2014).

The IPCC have defined climate change as "a change in the state of the climate that can be identified (through statistical tests) by changes in the mean/or the variability of its properties and that persists for an extended period, typically decades or longer (Pachauri, et al., 2014 p. 124). For the purposes of this thesis, the definition of climate change will be that of the IPCC's (2014).

1.5 Effects of Climate Change

Global warming and climate change have resulted in the increased volatility of the Earth's climate, alternations to the hydrological cycle and predicted increases in severe heat waves and droughts (Allen, et al., 2010). It has caused acidification of the ocean as well as predicted alterations to ocean currents and wind patterns and range shifts of various animal and plant species (Allen, et al., 2010; Walther, et al., 2002; Pachauri, et al., 2014).

In South Africa, the year 2015 and 2016 produced some record high temperatures and a major drought brought on/enhanced by of one of the strongest El Niño's in recorded history (Baudoin, et al., 2017). It is clear that there is a need for change.

1.6 What is Being Done to Combat Climate Change

The United Nations Framework Convention on Climate Change (UNFCCC) was established in 1994 and is one of the three Rio Conventions that was adopted at the Rio Earth Summit in 1992. The UNFCCC is today an overarching framework for climate change with 197 countries which have ratified the convention (UNFCCC, 2016).

The ultimate objective of this body was to "stabilise GHG's concentration at a level that would avoid dangerous anthropogenic interference with the climate system" (UNFCCC, 2016). This level should further be achieved within a specific time frame that would allow for ecosystems to naturally adapt to the effects of climate change, ensure that global food production is not put at risk all the while allowing economic growth and development in a sustainable manner (UNFCCC, 2016).

The level at which GHG's are to be stabilised is informed chiefly by the United Nations Intergovernmental Panel on Climate Change (IPCC) who have set a target threshold limit of 2°C and an average concentration of 400 parts per million (ppm) of carbon dioxide (UNFCCC, 2016). However, recent reports detail the surpass of this threshold (Climate Central, 2016).

It was noted that in the month of September 2016, a period of the year which usually displays the lowest carbon dioxide concentration, that the concentration of this gas still exceeded 400ppm and predictions are that this threshold has now been broken indefinitely (Climate Central, 2016). The year 2016 was the hottest year in human history and currently the average global temperature increase is at 1.5°C (UNFCCC, 2016). As such, drastic efforts will need to be made to reduce emissions of GHG's to ensure climate change will not progress to the point where sustainable development is no longer possible.

1.7 Mitigation of Climate Change

Mitigation means to make something less severe or harmful. Thus, the IPCC (2014 p. 121) have defined mitigation of climate change as "A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHG's)."

Governing bodies such as the IPCC have identified various pathways in which to mitigate the overriding effects of climate change, chief of which being implementation of renewable energy technologies (RETs) to reduce emissions of GHG's.

1.8 Renewable Energy Introduction

South Africa's cabinet has endorsed a National Strategy for Sustainable development and Action Plan (2011-2014) that describes its short, medium and long-term vision to have a low carbon economy, be environmentally sustainable and climate change resilient. Such a notion is further supported in the Integrated Resource Plan for Electricity (2011) and the National Climate Change Response White Paper (2012). The requirement to switch from fossil fuel derived energy generation to Renewable Energy Technology (RET) is due to the mitigating factors to greenhouse gas emissions as identified by the IPCC.

Renewable Energy (RE) is defined by the IPCC (2007, p.814) as "renewable is obtained from the continuing or repetitive currents of energy occurring in the natural environment and includes non-carbon technologies such as solar energy, hydro-

power, wind, tide and waves and geothermal heat, as well as carbon neutral technologies such as biomass".

Renewable Energy Technologies have been classed into six main groups; bioenergy, direct solar, geothermal, hydropower, ocean and wind energy (Hohmeyer and Trittin, 2008). Each of these may then be further sub-divided according to the relevant technologies used in converting energy into electrical power for human use (Verbruggen, et al., 2010). For example, photovoltaic technology converts solar energy into direct current by the photovoltaic effect. Or ocean energy may be subdivided into wave energy, hydrokinetic energy, ocean thermal energy and osmotic energy (Soerensen and Weinstein, 2008; Verbruggen, et al., 2010).

Renewable energy has historically been more expensive than fossil fuel-based energy conversion (Prakash, 2010; de Jongh, Ghoorah and Makina, 2014), but recent trends are showing increased investment in these technologies. While the price of oil, natural gas and coal have crashed in the period of 2014-2016, investment in solar and wind energy has surged and currently accounts for double the global funding of fossil fuel derived energy (Randall, 2016). Figure 3 displays the growth of RE globally with South Africa seen to have increased RE to 3% of total electricity generation, but still lags significantly compared to other third world countries such as Brazil (Randall, 2017).

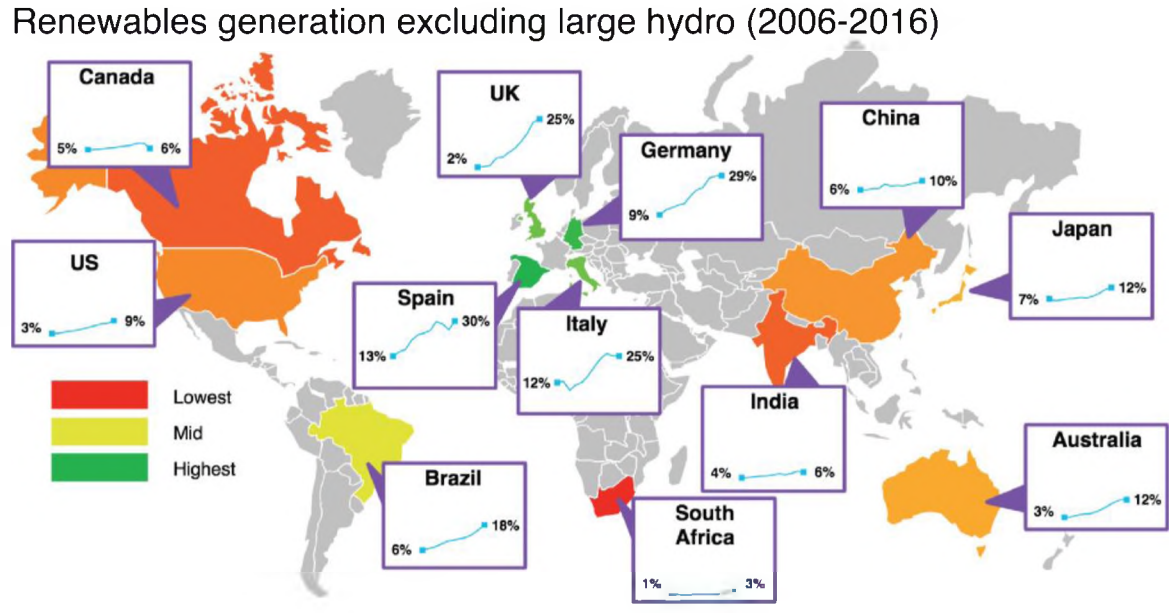

Figure 3: Global RE growth. Source Bloomberg Finance (Adapted from Randall, 2017).

Unfortunately, South Africa still lags behind other developing countries such as China and South Korea in having energy policies that provide attractive financial incentives to promote investment in RE (de Jongh, Ghoorah and Makina, 2014).

South Africa's reliance on coal powered electricity generation is unsustainable and the cause of various detrimental environmental effects (Blignaut, et al., 2011). To add to this, it contributes significantly to climate change through the release of greenhouse gases (GHG's) (Pachauri, et al., 2014).

1.9 Benefits of the proposed study

The current research will focus on aspects of sustainability and look specifically into the integration of the use of sustainable energy generation procedures within aquaculture farms.

In order to inform policy makers and economic decision makers and prioritise the various barriers and drivers affecting the implementation of RET, a study to identify and rank these barriers and drivers will be required (Mirza, et al., 2009; Blechinger, Richter and Renn, 2015; Nasirov, Silva and Agostini, 2016).

The threat of climate change is advancing every single day and it is our responsibility to ensure that our farming practices can be accomplished in such a way that it creates valuable socio-economic effects while being environmentally-friendly. As of the 4th of November 2016, the Paris Agreement to combat climate change has become International Law (UNFCCC, 2016). As such, it is only a matter of time before governments and regulators will place carbon taxes and water usage taxes on industries such as aquaculture due to some of their negative environmental impacts. It is thus of paramount importance to enhance the industry's environmental awareness and mitigate its impacts to ensure the long-term viability and sustainable growth of the industry in South Africa and globally.

Research Objectives

This study aims to contribute meaningfully to practical issues surrounding renewable energy implementation in South Africa's growing aquaculture sector. There are limited peer reviewed publications relating to renewable energy implementation in the aquaculture sector, not only on a local scale, but globally. This study will be the first to aim to identify the barriers and drivers to RET's implementation in the aquaculture sector and thus contribute to filling the gap in this field of knowledge.

The **goal(s) of the research**.

Aim: To identify the barriers and drivers to the implementation of renewable energy technologies within the aquaculture industry of South Africa.

Objectives:

- Review, consolidate and describe the identified barriers and drivers to renewable energy implementation in South Africa to compare the theoretical literature of the subject to the current research and the following objectives.
- Identify the barriers to the implementation of renewable energy technologies in South Africa's aquaculture industry in order to facilitate the possible removal of these barriers.
- Identify the drivers to the implementation of renewable energy technologies in South Africa's aquaculture industry in order to aid policy design to increase effective implementation of these technologies.

CHAPTER 2: LITERATURE REVIEW

This chapter reviews barriers and drivers to RET implementation at a global level, and sequentially reviews these at a local level. Peer reviewed literature discussing barriers and drivers to RE implementation in aquaculture was found to be uncommon. As such the literature reviewed mostly comprised of studies reviewing RE implementation at a country wide approach.

The literature falls within the broader context of resource-based theory (RBT) (Grant, 1991; Barney, 1991). Within this field of strategic management, RBT is a prominent theory used to explain and predict organisational relationships (Akio, 2005; Barney, Ketchen Jr and Wright, 2011). Traditional research in strategic management attempts to find and explain the opportunities and threats arising from the firm's external environment, and strengths and weaknesses arising from the firm's internal resources, to understand a firm's competitive advantage (Hart, 1995). A resource-based view instead ascertains that organisations/firms with strategic resources will have competitive advantages over those that don't (Barney, Ketchen Jr and Wright, 2011). Resources are said to be strategic if it is valuable, rare, difficult to imitate and non-substitutable (Barney, 1991; Carter and Gulati, 2014).

Along with the development of RBT since its inception in 1991, there has been a growing notion that business needs to be environmentally sustainable (Weybrecht, 2010). Hart (1995)., ascertained that in years to come, strategy and competitive advantage will be grounded in capabilities that enable environmentally sustainable economic activity. This was termed a natural-resource-based view of the firm.

Within the context of the current study, organisations implementing RE in an industry that makes use of large amounts of natural resources such as water, can be seen as having a sustainable competitive advantage over their peers.

2.1 Barriers Introduction

A barrier defined in the conventional sense, refers to something that prevents movement from one area to another, for example an obstacle. Looking specifically at

a barrier in the context of this study, it is defined by the IPCC (2007, p.180) as "any obstacle to reaching a goal, adaption or mitigation potential that can be overcome or attenuated by a policy, program or measure". Verbruggen, et al. (2010) highlight that barriers are man-made, and as such removable.

In order to remove a barrier, the IPCC (2007) advocate the following; market failures could be corrected directly. Through a reduction in the transaction costs for both public and private sectors by refining institutional capacity or reducing risk (IPCC, 2007). Further, barrier removal may be aided by enabling market transactions as well as enforcing regulatory policies (Solomon, 2007).

Barriers to the implementation of RE vary between countries owing to their diverse economic states, political agendas and policies as well as the natural geography of countries which can limit certain RE technologies (Painuly, 2001). Further, barriers may be specific to a technology, area or region (Mirza, et al., 2009).

2.2 Barrier Classification

Painuly (2001) classified barriers broadly to the following; Market Failure, Market Distortions, Economic and Financial, Institutional, Technical and Social, Cultural and Behavioural. The categories are further unpacked to reveal a host of possible barriers. De Jongh, Ghoorah and Makina (2014) alternatively placed barriers into four categories namely; Political, Economic, Technological and Social. These authors focused their study on the barriers affecting investment in RETs from a South African perspective. As such these categories of barriers will be used as the framework upon which comparisons with literature will now be made, first from a global context, then narrowing down to barriers faced in the South African environment.

2.2.1 Economic Barriers

Painuly (2001), found that a highly-controlled energy sector can cause a lack of investments in RET's. Further, a lack of information and awareness of RET increases costs due to uncertainty (Painuly, 2001). Similarly, in South Africa the market for RETs

is still fairly young and thus unpredictable which deters investment in RET (Pegels, 2010). Added to this is the reputational risk involved, financial institutions factor such risks into their lending conditions which will increase the cost of capital and thus reduce the viability of investment in RETs (Pegels, 2010). Similarly, Mirza et al., (2009), found that a lack of familiarity and awareness of technologies lead to a high-risk perception and consequently difficulty in obtaining finance for RET projects in Pakistan. However, South Africa's RE market has grown dramatically in recent years and there is evidence of increased investor confidence in RETs (Walwyn and Brent, 2015).

A restriction in access to technologies (Painuly, 2001), and the challenges certain technologies will face such as concentrating solar power are not yet known for South Africa (Pegels, 2010). Fossil fuel technologies are considered mature in most countries, and yet they still entice substantial research (de Jongh, Ghoorah and Makina, 2014). In South Africa, coal is an abundant source of energy and is used in the generation of both electricity and fuel (Pegels, 2010; Baker, 2015). The two main producers of energy in South Africa, Eskom and Sasol, fund considerable research in their primary means of energy production, fossil fuels (Pegels, 2010; de Jongh, Ghoorah and Makina, 2014). Due to their monopolistic market structure and their considerable influence in South Africa's energy sector, an extreme bias arises towards the research and development of fossil fuel technology compared to RETs (Pegels, 2010). This lack of innovation has been identified as one of South Africa's main barriers to the implementation of RETs (Pegels, 2010; de Jongh, Ghoorah and Makina, 2014).

A lack of competition as well as high transaction costs causes increases in product costs and adversely affects the economic viability of the project (Painuly, 2001; Baker, 2015). The issue of Eskom and its monopolistic market structure again arises for the South African perspective. It was suggested that a deregulated mixed public/private business model would be best suited to overcoming this barrier (Sebitosi and Pillay, 2008).

The economic barriers to implementation of RET are numerous and consist of aspects ranging from high costs of capital to high initial investments deterring investors (Painuly, 2001; Pegels, 2010; de Jongh, Ghoorah and Makina, 2014). Although costs

of RET's have decreased significantly in recent years (Walwyn and Brent, 2015), in South Africa there is still a cost bias towards fossil fuel derived energies resulting in less attractive RE options (de Jongh, Ghoorah and Makina, 2014; Walwyn and Brent, 2015). Baker (2015), provides an extensive review of the role of finance within South Africa's renewable energy sector.

2.2.2 Political Barriers

The energy industry forms the basis of any stable economy (Kebede, Kagochi and Jolly, 2010), as such it is frequently the focus of political intervention by governments seeking to stabilise their respective economy's (de Jongh, Ghoorah and Makina, 2014). A lack of government support has thus been identified as one of the key barriers to the implementation of RE both globally (Painuly, 2001; Mirza, et al., 2009; Richards, Noble and Belcher, 2012; Gullberg, Ohlhorst and Schreurs, 2014) and locally (Sebitosi and Pillay, 2008; Pegels, 2010; Krupa and Burch, 2011; de Jongh, Ghoorah and Makina, 2014; Baker, Newell and Phillips, 2014).

South Africa has a history of an economy based on a Minerals-Energy Complex (MEC) (Fine and Rustomjee, 1996). It is physically dependent on low cost coal to produce electricity (Baker, Newell and Phillips, 2014). However, the price of electricity has increased drastically, and is projected to keep doing so (van Zyl, 2017). The MEC of South Africa and the history of the country's power generation, continues to be a barrier to RE implementation (Baker, Newell and Phillips, 2014). An extensive overview of the political economy of South Africa and the transition of the country's MEC to one of renewable energy implementation is provided by Baker, Newell and Philips (2014).

Policies have the ability to influence the implementation of RET's to mitigate the effects of fossil fuel derived energies (Mandle, 2008; de Jongh, Ghoorah and Makina, 2014), the authors go on to state that legislation and policies can be influential tools that the state may use to steer the economy.

The use of legislation to promote renewable energy investment is not new and has been proposed as an effective mechanism to overcome barriers to investment in

RET's by Pegels (2010). Both Sebtsosi and Pillay (2008) and Verbruggen, et al., (2010), argue that due to the relatively young age of RET's compared to fossil fuel derivatives, governments do not yet have the correct policies in place to support implementation of RE.

Where developing countries such as China and South Korea have energy policies that provide attractive financial incentives to invest in RET, South Africa is seen to lag behind due to "misaligned environmental and energy policies" (de Jongh, Ghoorah and Makina, 2014; Walwyn and Brent, 2015).

2.2.3 Technological Barriers

Painuly (2001) indicates that a lack of standards, codes and certification results in the low perception of the product's quality and thus acceptability being affected, thus increasing purchase and commercial risk. For example, the issue of a lack of standards was considered one of the main technical barriers facing implementation of biogas energy in Thailand (Prasertsan and Sajjakulnukit, 2006). A general lack of resource assessments and data banks in the renewable energy sector further highlights the problems encountered with risk and perception of RET's (Mirza, et al., 2009).

Innovation and technological development were found to be substantial barriers across various instances of RET implementation (Painuly, 2001; Mirza, et al., 2009; Pegels, 2010; de Jongh, Ghoorah and Makina, 2014). In Chile, a country that possesses one of the highest potentials in renewable energy resources, technical and infrastructural barriers were ranked as the second biggest barriers to RET investment (Nasirov, Silva and Agostini, 2016).

South Africa suffers from a lack of research and development in RETs due to energy suppliers Eskom and Sasol monopolising the employment of university graduates in the energy sector as well as being the largest suppliers of funds for research and development in energy in South Africa (Pegels, 2010). As such there is an extreme bias toward research and development in fossil fuel technology (Pegels, 2010; de Jongh, Ghoorah and Makina, 2014). In order to reduce costs of RETs, innovation

thorough research and development is required (Manne and Richels, 2004). As such, policies and measures must be put in place to increase funding towards innovation in the RE sector to increase the cost competitiveness of RETs in South Africa (de Jongh, Ghoorah and Makina, 2014).

South Africa's lack of infrastructure and technological know-how to produce certain RETs cheaply and of sufficient quality such as solar panels, concentrated solar power equipment and wind turbine blades results in increased cost of equipment hindering investment in RETs (de Jongh, Ghoorah and Makina, 2014).

The problems with storing electricity once generated by RE, remains a problem and is another barrier to implementation of RETs (Denholm, et al., 2010). Many view the variable supply of electricity from technologies such as wind or solar to be a limiting technological factor and as such it is a barrier to implementation of RET (Denholm, et al., 2010).

2.2.4 Social Barriers

The social acceptance of RE policies are key to the implementation of RETs (de Jongh, Ghoorah and Makina, 2014). Further, a lack of acceptance of the RETs by consumers reduces the market size thus reducing the economic viability of the RET implementation (Painuly, 2001). A study by (Mallett, 2007), looked at the social acceptance of solar water heaters implementation in Mexico City and found that the Mexican public at large were uniformed about the technology and thus didn't accept it as it was unknown compared to the traditional gas heating technology. This finding thus confirms a statement by (Pegels, 2010), that a lack of education can be a barrier to the implementation of RET's.

Three dimensions of social acceptance to RE implementation have been defined, these are; socio-political, community and market acceptance (Wüstenhagen, Wolsink and Bürer, 2007). These authors argue that for a RE initiative to be successful, policies and technologies first need to be accepted by the public. Social acceptance to RETs was not something that was taken into account when RE policies were drafted and is

a particular problem for wind farms where turbines may have been considered unsightly (Wüstenhagen, Wolsink and Bürer, 2007).

In the South African context, de Jongh, Ghoorah and Makina (2014) point out that the country is in a different situation to other developing nations in that a vast majority of the population cannot even afford basic cheap electricity. As such, implementing measures to mitigate climate change is not of concern to someone who struggles to afford any form of electricity in the first place.

Drivers

2.3.1 Drivers Introduction

A driver can be seen as a force that is providing reason or incentive for something to happen. A driver in this context can also be described as promoter to the implementation of RE. As such a driver to the implementation of RE can in this instance be seen as some factor that is helping to increase investment in RE in South Africa. The literature around this subject sometimes refers to potentials (Pegels, 2010), rather than drivers as have been classified here. The different terms however have been taken to be synonymous in the context of this literature review.

A key concept highlighted by Verbruggen, et al. (2010) is the need for a common conceptual framework and definitions of barriers and drivers/potentials. The authors argue that perceptions of drivers and potentials influence how policies may be implemented and it is these policies that "shape energy systems".

De Jongh, Ghoorah and Makina (2014) do not specifically classify drivers to the implementation of RE. They do however classify factors that influence investment in RE under the same categories of; Economic, Political, Technological and Social. For the purpose of uniformity, these categories will once again be used as the framework upon which the literature review of the drivers will be based.

The literature around drivers to implementation is far less substantial than that of barriers to implementation of RETs with few studies taking a systematic approach to identifying drivers (Ahlborg and Hammar, 2014). Literature around drivers of RET is focused mainly on investment decisions in RET for instance that of (de Jongh, Ghoorah and Makina, 2014; Bucher, et al., 2016).

2.3.2 Economic Drivers

Globally various government initiatives have been created to provide financial incentives for investors in RETs (Painuly, 2001). Such schemes may involve the

provision of capital subsidies for installation as well as tax exemption, credit facilities and third-party financing (Painuly, 2001).

The volatility of oil prices has contributed significantly to the global energy crisis (Nakumuryango and Inglesi-Lotz, 2016). However, in South Africa electricity generation is based mainly on the use of coal as it is seen as the cheapest way to produce electricity (Walwyn and Brent, 2015). These authors illustrate that when externalities to coal powered electricity generation are taken into account, coal is no longer the cheapest. The inclusion of environmental externalities in cost assessment of fossil fuel derived energy can illustrate the economic benefit of various RETs implementation (Mezher, Dawelbait and Abbas, 2012; Walwyn and Brent, 2015).

Costs of RETs have decreased dramatically over the past decade and this trend is predicted to occur until 2030, this is in stark contrast to trends observed in fossil fuels such as coal (Walwyn and Brent, 2015). For example, the levelised cost of electricity (LOCE) of solar photovoltaic (PV) installations have declined substantially with prices of PV modules dropping by over 60% in the period January 2011 to December 2012 (Walwyn and Brent, 2015). Although total cost of generating energy by technologies are available, care should be taken as direct comparisons of LOCE can be misleading as these values may be site specific (for example wind turbines producing varied energy outputs due to their location) (Walwyn and Brent, 2015).

2.3.3 Political Drivers

As RET implementation has been identified as a key mitigation strategy for climate change (Solomon, 2007; Pachauri, et al., 2014), policy planning should be based upon drivers and potentials that have been assessed as accurately as is possible (Verbruggen, et al., 2010). Thus, the importance of studies to identify and accurately describe potentials and drivers of successful RET implementation.

Energy sector liberalisation is a mechanism whereby the efficiency of the energy sector is increased through a facilitation of market competition (Painuly, 2001). Examples of specific policies used include allowing private sector entry and creating separate entities for the generation and the distribution of energy (Painuly, 2001).

Another driver of RETs is institutional isomorphism, or the tendency for those in political power to follow trends within their institutional environment (Masini and Menichetti, 2013). Today's climate is all about being environmentally conscious and political leaders want to be seen to be moving in the correct direction towards mitigating climate change impacts and globally this is done by implementing RETs.

In South Africa, various policies and mechanisms have been put in place to attempt to drive investment in the RE sector. Extensive reviews on the success and failures of the various policy plans in South Africa and the extent of their operation were carried out by (Sebitosi and Pillay, 2008; Pegels, 2010; Baker, Newell and Phillips, 2014; Walwyn and Brent, 2015; Nasirov, Silva and Agostini, 2016; Nakumuryango and Inglesi-Lotz, 2016). Briefly, the first policy was the National Integrated Resource Plan (NIRP) that was approved by cabinet in 2002, the aim of which was to steer South Africa in the correct direction to reach its electricity requirements using the Renewable Energy Feed-in-Tariff (REFIT) programs.

In 2003, the White Paper on Renewable Energy was approved by cabinet and had a set target goal of 10000GWh of RE production by 2013, only 4% of total electricity generation (Nakumuryango and Inglesi-Lotz, 2016). The REFIT program was implemented in 2009, this policy seeks to increase RET investment by guaranteeing a fixed price for a fixed period that is set to cover the cost of electricity and includes a justifiable profit (Nakumuryango and Inglesi-Lotz, 2016). The system is based on the success of that achieved in Germany, Spain and the United States using such policy measures (Nakumuryango and Inglesi-Lotz, 2016). However, this programme was largely unsuccessful in South Africa (Walwyn and Brent, 2015), and as such South Africa implemented the REIPPP program based on competitive tenders and to attract Independent Power Producers (IPPs) (Nakumuryango and Inglesi-Lotz, 2016). This policy has been noted to be successful as it has provided 3920MW of electricity from renewable energy sources in three years (Papapetrou, 2014; Nakumuryango and Inglesi-Lotz, 2016).

2.3.4 Technological Drivers

Masini and Menichetti (2013), found that the technical capability of RET's are much more important in driving investment of RETs than the apparent capabilities of existing policies to drive RETs investment. This illustrates that a technology has to have been proven to be technologically sound for investment to occur, policies and market functioning can then be corrected by appropriate policies (Masini and Menichetti, 2013).

Technologically, RETs have advanced tremendously in the past 20 years (Wee, et al., 2012; Walwyn and Brent, 2015). With this advancement in technology, costs of RET's have also drastically reduced which increases the viability of RE projects (de Jongh, Ghoorah and Makina, 2014; Walwyn and Brent, 2015). Crucially, RET's have proved that they are able to produce power outputs comparable to fossil fuel technologies (Walwyn and Brent, 2015).

Reliability of RETs has increased over time (Walwyn and Brent, 2015), and perhaps more importantly, investors are realising that the technologies are proven to work and reliable over long periods of time which has further increased investment into these technologies (de Jongh, Ghoorah and Makina, 2014; Bucher, et al., 2016).

2.3.5 Social Drivers

Climate change and its effects have a growing social awareness (Pachauri, et al., 2014). To add to this, a culture of environmental consciousness and growing public and governmental knowledge on the detrimental effects of fossil fuel energy generation have led to the drive for RETs implementation (Painuly, 2001; Baker, 2015; DoE, 2015).

Social acceptance is an often-overlooked barrier to RETs investment, but can also be a driver to RE implementation (Wüstenhagen, Wolsink and Bürer, 2007). An extensive review is covered by Wüstenhagen, Wolsink and Bürer (2007). The authors cover

various technologies and countries and indicate the importance of social acceptance of RET's to their implementation.

RETs have significant potential for employment (Walwyn and Brent, 2015). For example, conservative estimates of PV associated jobs are 8-10 jobs/MW (Walwyn and Brent, 2015). The possibility of creating industries to develop, construct and service RET's in South Africa can become significant drivers to RE implementation in the future.

2.4 Renewable Energy in Aquaculture

There are limited studies on the implementation of RET's in the aquaculture industry (Ronde, et al., 2011; Ioakeimidis, Polatidis and Haralambopoulos, 2013; Kim, et al., 2015; Badiola, et al., 2017). Further, various studies regarding the integration of RE and aquaculture have focused on offshore wind farms that can be integrated with cage culture of fish or molluscs (Menicou and Vassiliou, 2010; Buck and Krause, 2012; Stuiver, et al., 2016). Thus far no literature on the barriers and drivers to the implementation of RETs in the aquaculture industry have been located. The current study can as such effectively fill this gap in the literature. It can also contribute valuably to those in the South African aquaculture industry, especially for land based recirculating water systems that are energy intensive.

CHAPTER 3: METHODS, MATERIALS AND TECHNIQUES

3.1 Aims and Objectives of the Research

This study aims to contribute meaningfully to practical issues surrounding renewable energy implementation in South Africa's growing aquaculture sector. There is a scarcity of peer reviewed publications relating to renewable energy implementation in the aquaculture sector. This study will be the first to aim to identify the barriers and drivers to RETs implementation in the aquaculture sector and thus contribute to filling the gap in this field of knowledge.

The **goal(s) of the research**.

Aim: To identify the barriers and drivers to the implementation of renewable energy technologies within the aquaculture industry of South Africa.

Objectives:

- Review, consolidate and describe the identified barriers and drivers to renewable energy implementation in South Africa to compare the theoretical literature of the subject to the current research and the following objectives.
- Identify the barriers to the implementation of renewable energy technologies in South Africa's aquaculture industry in order to facilitate the possible removal of these barriers.
- Identify the drivers to the implementation of renewable energy technologies in South Africa's aquaculture industry in order to aid policy design to increase effective implementation of these technologies.

3.2 Methodological Basis of Research

The methodology of this study was based upon that used by Blechinger, Richter and Renn (2015). These authors evaluated the barriers to implementing renewable energy in the Caribbean Islands. There methods were chosen due to the similarities of the

proposed study. The Caribbean, similar to South Africa in the fact that it uses predominantly fossil fuels to generate electricity, but have abundant renewable energy supply sources (Blechinger, Richter and Renn, 2015; Walwyn and Brent, 2015).

Further, the numerous islands/study sites resulted in difficult sampling conditions. Through evaluation of individuals across the islands, a regional narrative of barriers to renewable energy could be established by the authors. Similarly, the current study evaluates a national industry through a sample of individual aquaculture farms that produce various species and differ significantly in design.

This study will evaluate both the drivers and barriers to the implementation of RET in South Africa's aquaculture industry. By establishing the importance of both barriers and drivers, the synergy between these polar opposite concepts may be used to further validate the arguments formed within the research. As such, certain barriers and drivers seem very similar. It could also be that some barriers, are also drivers. These categories may then be seen as critical to alter into a form where it can be a bigger driver and less of a barrier.

3.3 Research Paradigm

The research paradigm for the proposed study is post-positivism (Guba and Lincoln, 1994). Ontologically, post positivism has shifted from what was perceived as an immature realist posture to what is now viewed as critical realism (Guba, 1990). In essence, the paradigm recognises that 'although a real world exists', it is not possible for humans to truly observe it as we have flawed senses and 'intellective mechanisms' (Guba, 1990 p. 20).

As such, the post positivism paradigm acknowledges that the researcher has a modified objectivity, but by striving to be as neutral as possible and by conceding the researchers own predispositions, the 'regulatory ideal' of being 'objective' can be achieved 'reasonably closely' (Guba, 1990 p. 21). The methodology of this paradigm hence relies on methods of triangulation to ascertain the validity of findings through various data sources (Guba, 1990).

3.4 Triangulation of Data Collection

The methodology for this study thus consists of mixed methods research. It consists of a literature review, in depth interviews and quantitative techniques obtained using survey questionnaires with a Likert scale (Likert, 1932). Questions in the questionnaires are based on a literature review of peer reviewed papers and reports detailing currently identified barriers and drivers to the implementation of renewable energy technologies in South Africa and Globally. These barriers and drivers were then modified and adapted to suit the aquaculture industry of South Africa. See Appendix 1 for the questionnaire outline (discussed further below).

3.5 Literature Review

The literature review served as a 'heuristic-analytical framework' that aided in the production of questions in the questionnaire (Blechinger, Richter and Renn, 2015 p. 270). Broadly the questions in the questionnaire fell into four categories, namely: Financial, Political, Technological and Social as per the study conducted by de Jong, Ghoorah and Makina (2014). These authors conducted a study on the barriers to renewable energy investment in South Africa. Their framework was relevant, simple and coherent and thus considered ideal to base the current study on.

In addition to the literature forming the framework to the development of the questionnaire, certain practical barriers and drivers pertaining specifically to South Africa's aquaculture industry were developed.

3.6 Questionnaire Design

The questionnaire (see Appendix 1) contained a list of barriers and drivers to the implementation of RET's. Respondents were asked to rank these on a Likert scale from 1-6. The Likert scale is a psychometric summated scale used to measure the research participants view on the importance of the various barriers and drivers through their 'intensity of feelings' about each proposed barrier and driver (Likert, 1932; Blechinger, Richter and Renn, 2015). Further a "*not applicable*" category was

placed on the Likert scale to ensure respondents answer only what they are familiar with.

Due to the wide variety of organisations that were sampled, some with annual turnover of hundreds of millions while others are still start-ups with very low profit margins, the questionnaire contained a brief section of demographic style questions to broadly separate organisations according to their organisational background.

3.7 Research Participants

Research participants in the study consisted of high level managers of aquaculture farms within South Africa. Labourers on the farms were excluded from data gathering as it is likely that questions may be misunderstood and lead to skewed results. Further it is unlikely that most labourers will fully comprehend the benefits as well as the difficulties arising from implementing renewable RET's at the organisation they are a part of.

3.8 Sampling Procedure

Questionnaires were distributed via an email link to an online google form. Using a data base containing all mari-culture organisations within South Africa (n = 55) and another data base of all listed freshwater aquaculture operations in South Africa (n = 181). Both data bases were provided with consent from the Aquaculture division in the Department of Agriculture, Forestry and Fisheries (DAFF) (see Appendix 3). The entire population was sent the questionnaire.

However, a large number of the organisations could not be contacted as the email addresses were no longer in use. Over 20 of the emails bounced back, indicating that the email address was incorrect or no longer in use. Furthermore, various respondents were listed more than once with different email addresses. Finally, of all the organisations contacted, a total of 6 respondents replied to the mail informing me that they are no longer involved in aquaculture. As such, the original population taken at 236, was essentially reduced to 195 respondents.

Every effort was made to obtain correct and up to date email addresses. Further, it was attempted to contact respondents on three different occasions in order to obtain

as many responses to the questionnaire as was possible. An email tracker was used to track responses and revealed that only 38 of the emails sent to participants still in aquaculture in South Africa had been opened/viewed. In total 20 responses were obtained.

3.9 Questionnaire Data Analysis

Data analysis for the questionnaires involved simple descriptive statistics. Due to the low number of responses (n=20), simple descriptive statistics such as average importance was used to rank barriers in a matrix of importance. Further, sample variance was used to indicate the reliability of the average importance result for each barrier and driver. The sample variance was used to indicate respondent's deviation from the average (Johnson, et al., 2001). A low sample variance in this case indicating that respondents gave similar weightings of importance to a barrier or driver. A high sample variance indicating that respondents gave a wider range of perceived importance rankings to barriers and drivers.

3.10 Structured Interviews

In order to gain a deeper understanding of the barriers and drivers affecting renewable energy implementation in South Africa's aquaculture industry, a total of three purposeful interviews were conducted. The respondents for the interviews were selected due to their increased expertise on the subject of RET implementation relative to the population sampled as they had been involved with the implementation of RE at an aquaculture organisation in South Africa.

The techniques used in the interview process included Witzel's conceptualisation of the problem centred interview (Witzel and Reiter, 2012), as well as techniques used in expert interviews such as a discursive interview structure (Meuser and Nagel, 1991). The expert interview methodology was chosen due to its efficient approach to data gathering (Bogner and Menz, 2009).

The interview basis followed the same structure as that of the questionnaire (Appendix 1) but allowed respondents to elaborate on the proposed barriers and drivers to RET implementation. As such, a holistic understanding of barriers and drivers to RET

implementation could be achieved (Blechinger, 2015). The purposeful interviews were analysed using thematic analysis (Aronson, 1995).

3.11 Research Validity

To ensure validity of the research, analysis recognised that there may be a bias of some respondents due to a social desirability to represent an organisation in a favourable light (Blechinger, Richter and Renn, 2015). The methods of triangulation served to provide a holistic and contextual understanding of the barriers and drivers affecting RET implementation in the aquaculture sector of South Africa (Guba, 1990; Guba and Lincoln, 1994; Blechinger, Richter and Renn, 2015).

The end product of this research culminated in a ranking matrix of the identified barriers and drivers to the implementation of RET in South Africa's aquaculture sector. The ranking will thus serve to illustrate the importance and impacts of the various barriers and drivers and will as such serve as a valuable tool to policy makers and economic decision makers to ensure barrier removal (Blechinger, Richter and Renn, 2015; Blechinger, 2015).

3.12 Ethical Considerations

The researcher is not part of any of the organisations that were sampled and will be as objective as is possible. Ethical approval was received from the Rhodes Business School's internal ethics committee, as well as the relevant university approvals. The researcher recognises that he may still be biased and in favour of RET implementation and states this from the outset as per the post positivism paradigm (Guba, 1990). To manage these possible biases, interviews were recorded and transcribed (see Appendix 2). Further, anonymity of all respondents' answers to questionnaires was and will continue to be preserved. Contact details for aquaculture organisations in South Africa were obtained through official channels via the DAFF (Appendix 5).

CHAPTER 4: RESULTS

4.1 Literature Review

The comprehensive literature review provided the basis of this research and culminated in the production of 25 barriers (Table 1) and 22 drivers (Table 2) to RET implementation. Further, these barriers and drivers were modified to fit the aquaculture industry of South Africa.

Table 3: Unranked barriers to the implementation of renewable energy in South Africa's aquaculture industry (Adapted from: (Blechinger, Richter and Renn, 2015).

1. Technological barriers
1.1.1. Natural attributes of the farm, for example; not enough space for solar panels or insufficient wind speed for wind turbines
1.1.2. RE implementation will have detrimental impacts on landscapes and ecosystems
1.1.3. Threat of natural disasters such as flooding/large storms causing damage to RET's on farm
1.1.4. Lack of evidence-based assessment of RE potentials
1.2. *Technical constraints*
1.2.1. Lack of technical expertise and experience
1.2.2. Low availability of RE technologies
1.2.3. Low Storage capability
2. Economic barriers
2.1. *Price/cost*
2.1.1. High initial investments
2.1.2. Diseconomy of scale
2.2. *Financial aspects*
2.2.1. Lack of access to low cost capital or credit
2.2.2. Lack of understanding of project cash flows from financial institutions
2.2.3. Lack of private capital to fund proposed RET
2.3. *Market failure/distortion*
2.3.1. Utility monopoly of production, transmission and distribution of electricity (Eskom's reluctance to enter into power purchase agreements and/or buy electricity back from IPP's)
2.3.2. Fossil fuel subsidies and fuel surcharge (inexpensive electricity)
3. Political barriers
3.1. *Policy*
3.1.1. Gap between policy targets and implementation
3.1.2. Lack of incentives or subsidies from government for RE implementation
3.1.3. Distrust of PPA with utility monopoly (Eskom)
3.2. *Institutional capacity*
3.2.1. Lack of formal RE institutions to aid individuals in RE implementation
3.2.2. Lack of RE experts on governmental level
3.3. *Regulatory*

3.3.1. Lack of legal framework for IPP's and PPA
3.3.2. Lack of legal framework and legislation for private investors
4. Social barriers
4.1. *Interaction networks*
4.1.1. Lack of RE initiatives/drives from a governmental level
4.1.2. Lack of local/national champions/entrepreneurs to showcase the capability of RET
4.2. *Cultural*
4.2.1. Dominance of cost over environmental issues fossil fuel power generation creates
4.3. *Psychological/moral*
4.3.1. Preference for status quo

Table 4: Unranked drivers to the implementation of renewable energy in South Africa's aquaculture industry (Adapted from: (Blechinger, Richter and Renn, 2015).

1. Technological
1.1.1. Natural attributes of the farm that are advantageous for RE electricity production
1.1.2. Technological Innovation/advancement of RET's
1.1.3. Availability of new technologies in South Africa
1.1.4. Growing local expertise on technological infrastructure
1.2 Evidence of capabilities of RE
1.2.1. Growing evidence showcasing capabilities of RE
1.3 Mitigation of risk of municipal power malfunction
1.3.1. Ability of RET to mitigate against the impacts of municipal electricity outages
2. Economic Drivers
2.1 *Price/cost*
2.1.1. Long term cost benefits
2.1.2. Reduction in cost of RET
2.1.2. Cost of alternative electricity supply (eg. diesel generator)
2.2 *Financial aspects*
2.2.1. Access to low cost capital
2.2.2. Availability of private capital, growing investor confidence in RE
3. Political Drivers
3.1. Policy
3.1.1. Favourable governmental policy to implement RE
3.1.2. Incentives or subsidies to implement RE
3.2. Institutional capacity
3.2.1. Adequate formal institutions to promote RE
3.2.2. Adequate experts in RE on governmental level
3.3 Regulatory
3.3.1. Adequate legal framework and legislation for Independent Power Purchase Arrangements
4. Social drivers
4.1.1. Drive towards sustainable energy production becoming the norm
4.1.2. Growing educational awareness of the benefits of RE
4.2. Interaction networks
4.2.1. Adequate RE initiatives
4.2.2. Benefits of national champions in the industry
4.3. Cultural
4.3.1. Environmental issues of electrical energy generation by fossil fuels

4.4 Phycological/moral
4.4.1. Preference for environmentally friendly electricity generation

4.2 Questionnaire Results

The responses of 20 participants (10% of the population that could be contacted) were empirically weighted according to their average perceived importance as barriers (Figure 1) and drivers (Figure 2). Further, the sample variance for each barrier and driver was calculated to numerically and graphically display respondent's deviation from the average (Johnson, et al., 2001). A low sample variance in this case indicating that respondents gave similar weightings of importance to a barrier or driver.

Where sample variance was more than the average weighting of a barrier or driver, it indicated that that particular category received a wide range of perceived ranking importance. This could indicate that the particular category was misunderstood/misinterpreted by respondents. Alternatively, it could indicate that it is a category that may in actual fact be irrelevant on the ranking matrixes produced.

Of the 20 responses received, 6 have implemented some form of renewable energy technology. These ranged from solar power (n=1), to solar geysers (n=2) and hydroelectric power generation (n=3). Further one more respondent replied that their farm was interested in implementing solar power.

All the aquaculture farms that responded had annual turnover of over 500,000.00 ZAR and had been in operation for over 5 years. As such, the organisations were deemed to be of reputable stature and considered satisfactory to provide data towards this study.

Of the 20 responses received, two had to be omitted as these respondents answered not applicable for every barrier and driver listed. These two responses would have skewed the average perceived importance' of barriers and drivers listed, leaving the final total of 18 responses which were analysed.

4.2.1 Results of Barrier Section of Questionnaire

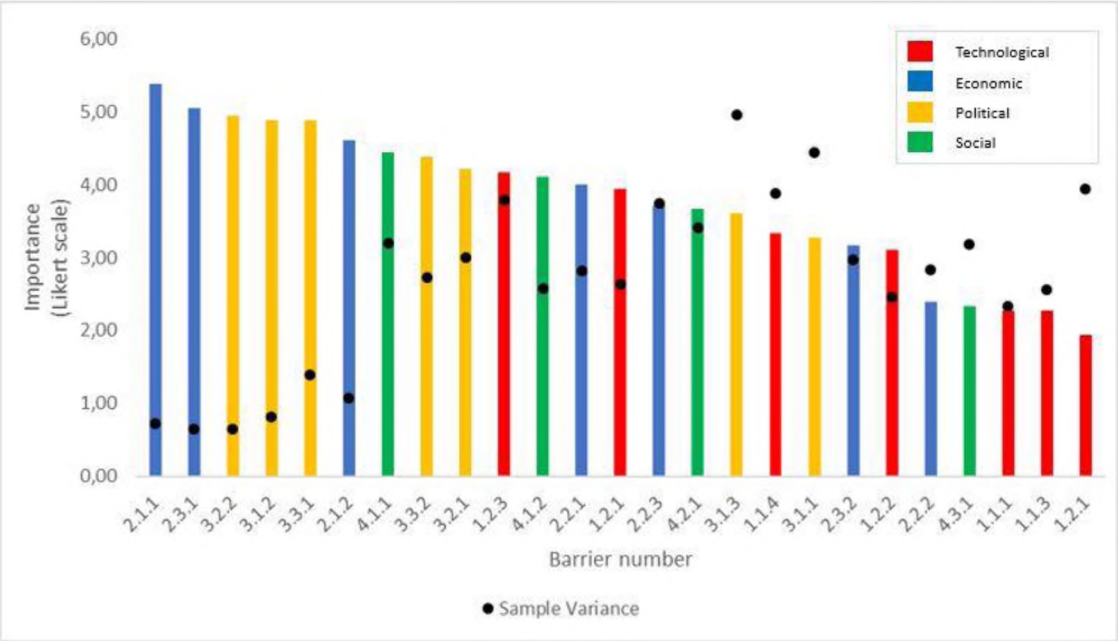

Figure 4: Empirical weighting of Barriers ranked according to perceived importance. Bars indicate the average importance for each separate barrier, while dark circles indicate the variance of responses for each barrier. The Likert scale for this study worked as follows: 0- Not Applicable; 1- No Importance; 2- Very Low Importance; 3- Low Importance; 4- Moderate Importance; 5- High Importance; 6- Highest Importance.

Table 5: Results of assessment of barriers perceived importance and variance by aquaculture organisations in South Africa. Dark blue shading indicates barriers of high importance, blue indicating barriers of moderate importance, light blue indicating barriers of low importance and no shading indicating barriers of the least importance.

Barrier Category	Average Importance	Sample Variance	Barrier Name
2.1.1	5,39	0,72	High initial investments
2.3.1	5,06	0,64	Utility monopoly of production, transmission
3.2.2	4,94	0,64	Lack of renewable energy experts on government level
3.1.2	4,89	0,81	Lack of incentives or subsidies from government
3.3.1	4,89	1,40	Lack of legal framework for IPP and PPA
2.1.2	4,61	1,08	Dis-economy of scale
4.1.1	4,44	3,20	Lack of re initiatives/drives from a government level
3.3.2	4,39	2,72	Lack of legal framework and legislation for private investors
3.2.1	4,22	3,01	Lack of formal renewable energy institutions

1.2.3	4,17	3,79	Low storage capacity of electrical energy
4.1.2	4,11	2,58	Lack of local/national champions/entrepreneurs
2.2.1	4,00	2,82	Lack of access to low cost capital or credit
1.2.1	3,94	2,64	A lack of technical expertise and experience
2.2.3	3,72	3,74	Lack of private capital
4.2.1	3,67	3,41	Dominance of a least cost objective over environmental issues
3.1.3	3,61	4,96	Distrust of power purchase agreement (PPA) with utility monopoly
1.1.4	3,33	3,88	A lack of evidence-based assessments of RE potentials
3.1.1	3,28	4,45	Gap between policy targets and implementation
2.3.2	3,17	2,97	Fossil fuel subsidies and fuel surcharge
1.2.2	3,11	2,46	Low availability of RET's
2.2.2	2,39	2,84	Lack of understanding of project cash flows
4.3.1	2,33	3,18	Preference for status quo
1.1.1	2,28	2,33	Natural attributes of the farm, for example; not enough space for solar panels or insufficient wind speed for wind turbines.
1.1.3	2,28	2,57	Threat of natural disasters such as flooding/ large storms causing damage to renewable energy technologies on farm.
1.2.1	1,94	3,94	RE implementation detrimental impact on landscapes/ecosystems.

The top six of the barrier ranking matrix were identified as: *High Initial investments, Utility monopoly of production, Lack of RE experts on a governmental level, Lack of incentives/subsidies from government, Lack of legal framework for IPP and PPA,* and *Diseconomy of scale* respectively. These barriers all had a low sample variance ranging from 0.72 – 1.08 (Table 3). After these barriers, sample variance increased to a range of 2.46 – 4.96 indicating that respondents did not perceive barrier importance in similar manners. Where sample variance was higher than the actual average importance ranking of a barrier as is most accentuated for the barrier of *RE implementation having detrimental impacts on landscapes/ecosystems,* it can be stated with confidence that the particular barrier was not considered important or was misunderstood and should be removed from the list of barriers.

The five lowest ranking barriers all had variances higher than their average perceived importance rating (Figure 4). In general, the variance increased as the average barrier

ranking decreased. This suggests that although the top half of the ranked barriers with low variance are considered reliable and accurate indications of importance, the lower half of ranked barriers are considerably less accurate and less reliable.

Overall, the financial and political categories were ranked as the most important barriers, while technological and social barrier categories were ranked as less important.

4.2.2 Results of Drivers Section of the Questionnaire

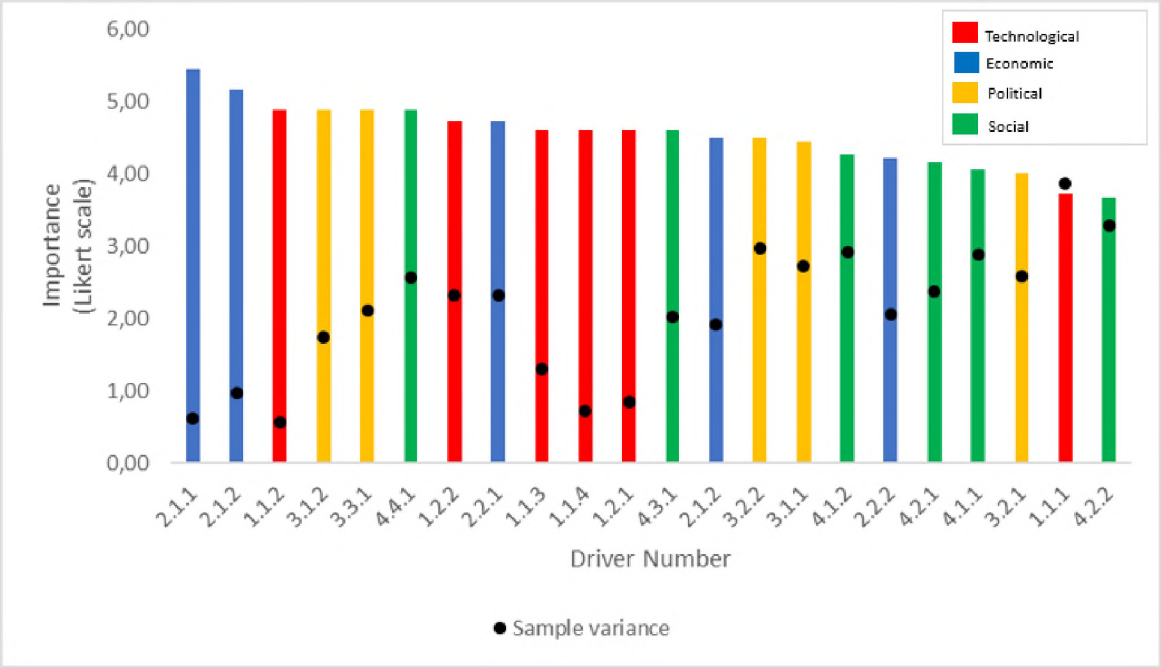

Figure 5: Empirical weighting of drivers ranked according to perceived importance. Bars indicate the average importance for each separate driver, while dark circles indicate the variance of responses for each driver.

Figure 5 displays the average perceived importance of drivers to RE implementation in South Africa's aquaculture sector. The colour coding of the bars illustrates the importance of financial category drivers.

Table 6: Results of assessment of drivers perceived importance and variance by aquaculture organisations in South Africa. Dark blue shading indicates drivers of high importance, blue indicating drivers of moderate importance, light blue indicating drivers of low importance.

Driver Category	Average Importance	Sample variance	Driver Description
2.1.1	5,44	0,61	Long term cost benefits
2.1.2	5,17	0,97	Reduction in cost of RET's
1.1.2	4,89	0,58	Innovation / advancement of RET's
3.1.2	4,89	1,75	Incentives or subsidies to implement renewable energy
3.3.1	4,89	2,10	Adequate legal framework and legislation for PPA
4.4.1	4,89	2,58	Preference for environmentally friendly electricity generation
1.2.2	4,72	2,33	Ability of RET to mitigate against the impacts of municipal electricity outages
2.2.1	4,72	2,33	Access to low cost capital
1.1.3	4,61	1,31	Availability of new technologies in South Africa
1.1.4	4,61	0,72	Growing local expertise on technological infrastructure
1.2.1	4,61	0,84	Growing evidence showcasing capabilities of RET
4.3.1	4,61	2,02	Environmental issues of electrical energy generation by fossil fuels
2.1.2	4,50	1,91	Cost of alternative electricity supply (eg. diesel generator)
3.2.2	4,50	2,97	Adequate expertise in RE on a governmental level available
3.1.1	4,44	2,73	Favourable governmental policy to implement RET
4.1.2	4,28	2,92	Growing educational awareness of the benefits of RE
2.2.2	4,22	2,07	Availability of private capital, investor confidence growing in RE
4.2.1	4,17	2,38	Adequate RE initiatives
4.1.1	4,06	2,88	Drive towards sustainable energy production becoming the accepted norm
3.2.1	4,00	2,59	Formal institutions to promote renewable energy
1.1.1	3,72	3,86	Natural attributes of the farm that are advantageous to use RE sources.
4.2.2	3,67	3,29	Benefits of national champions in the industry

The quantitative results of the drivers section of the questionnaire resulted in average importance rankings that ranged between 5.44-3.67 (Table 4). This range is markedly narrower than that revealed in the barriers section (Range of 5.39-1.94). Further, the

sample variance results obtained in the drivers section are lower and more consistent than that revealed in the barriers section. This indicates that average importance rankings of drivers were more reliable than average importance rankings of barriers.

Similar to the barriers section, only two drivers were ranked as having high importance (more than 5 on the *Likert* scale). These being: *Long term cost benefits* and *Reduction in cost of RET's.* Following these two top ranked drivers: *Innovation / advancement of RET's; Incentives or subsidies to implement renewable energy; Adequate legal framework and legislation for Power Purchase Agreement* and *Preference for environmentally-friendly electricity generation* were ranked as the top six drivers consecutively. The last four of these all receiving the same average importance ranking of 4.89 (Moderate Importance on the Likert scale) with consecutively increasing values of sample variance of up to 2.58.

The six lowest ranked drivers included: *Availability of private capital and Investor confidence growing in RE, Adequate RE initiatives, Drive towards sustainable energy production becoming the accepted norm, Formal institutions to promote renewable energy, Natural attributes of the farm that are advantageous to use RE sources* and *Benefits of national champions in the industry* consecutively (Table 4). Only the driver of *Natural attributes of the farm that are advantageous to use RE sources* received a sample variance above the actual average perceived importance of the driver.

The drivers section revealed that the category of *Finance* was ranked the most important and the *Social* category as least important overall. However, in contrast to the barriers section, there was less distinction between both the importance of divers overall as well as the ranking of importance between the categories of *Finance, Political, Technological* and *Social.*

4.3 Structured Interviews

Structured interviews were conducted to gain a deeper understanding of the proposed barriers and drivers described in Table 1 and 2 respectively. The three interviewees were asked to describe how they felt about the proposed barriers and drivers and to elaborate on key points as they saw fit. All interviewees were chosen due to their knowledge of the aquaculture industry and experience in implementing one or more RET's in an aquaculture organisation in South Africa.

The questions follow the same sequence of Table 1 for the barriers section and Table 2 for the drivers section.

Interviewee One:

The first interviewee practices as an engineer who formed a company with the specific aim of implementing renewable energy within the aquaculture sector. He specialises in marine hydroelectricity projects. He is currently involved in the design, construction and implementation of a wave energy converter at a large abalone farm in the Western Cape of South Africa.

Interviewee Two:

The third respondent is an aquaculture farmer who farms various species such as; rainbow trout (*Oncorhynchus mykiss)*, Mozambique tilapia (*Oreochromis mossambicus)* and sharptooth catfish (*Clarias gariepinus*). The farm uses integrated methods of production including an aquaponics system where various vegetables and Mozambique tilapia are grown in an integrated system. The farm makes use of solar energy to offset electricity costs. Interviewee Two has a MSc degree in Ichthyology and also practices as an aquaculture consultant.

Interviewee Three:

The second interviewee works as a researcher at a large abalone (*Haliotis midae*) farm in South Africa's Western Province. The interviewee holds a Doctorate degree and has extensive experience in estuarine ecology and microalgae.

4.4 Thematic Analysis of Interviews

4.4.1 Technological Barriers Section

Interviewee One described natural attributes of the farm to be perhaps one of the most important factor to consider and could be the single biggest barrier to a RE project implementation. Interviewee Two further corroborates this statement by adding that certain technologies such as solar panels do not fare well in the marine coastal environment. The location of the farm would further have an effect on barriers such as natural disasters and RET having a detrimental impact on landscapes with the example of wind turbines not being allowed in picturesque towns being given.

The theme of barriers and drivers being technologically dependent i.e. certain types of RET have certain attributes that lend themselves to be optimal in some environments while detrimental in others, was a constant notion throughout the interview process.

Availability of RETs was not considered to be a barrier, but was technology dependent. Certain hydro-electric generating modules were noted to be in scarce supply in South Africa.

The storage of electricity generated by RE was noted to be a significant barrier by all three interviewees. Comments were given regarding the extra cost incurred to store electricity with batteries as a consequent barrier.

4.4.2 Economic Barriers Section

Interviewee One is under the opinion that high initial investments and access to capital is not a significant barrier. The Interviewee argues that financial institutions understand the particulars around renewable energy investment. Interviewee One states that if a project is viable and can be proved to be so, obtaining finance is no longer an important barrier, although some of the smaller organisations may still struggle to provide the requisites to obtaining finance. In contrast to this, Interviewee Two describes this barrier as perhaps the most limiting factor to RE implementation within aquaculture.

Interviewee Three conversely ascertains that RET such as solar have become much more affordable and that this trend is likely to continue.

The theme of technological dependence was again evident in the Economic section of the barriers. Particularly with regards to economy of scale as a barrier. Installing solar is a technology that can be scaled up or down and will still produce the same price per KW/h where as a technology such as hydroelectric/wave energy power generation can take advantage of factors of economy of scale. As such, technologies such as hydro-electric/wave-energy power generation will experience a barrier to implementation from an initial investment, and diseconomy of scale perspective.

The barrier of Eskom's monopoly and subsequent reluctance to enter into power purchase agreements was viewed as a barrier of high importance to Interviewee One and Two. Interviewee One acknowledges that Eskom needs certainty about the price they are offering to buy electricity from IPP for the typical contract periods of 20 years. Interviewee One believes that this uncertainty arises out of much broader economic, political and social issues that South Africa faces. However, Interviewee Three notes that Eskom's monopoly may even be a driver to go "off-grid" and be independent of Eskom.

Fossil fuel subsidies and consequent relatively cheaper electricity obtained from sources such as coal continues to be a major barrier to RE implementation and this is especially evident in third world countries.

With regards to a lack of access to funding, both Interviewee Two and Three stated that this would be a bigger barrier to some of the smaller aquaculture farms operating in South Africa. Broad Based Black Economic Empowerment (BBBEE) restrictions were also noted to be a factor limiting access to funding.

4.4.3 Political Barriers Section

The main barriers established in the political section revolve around PPA and Eskom's bureaucratic processes. There are a wide range of viable projects being tendered but are not accepted by Eskom. This relates back to the previously mentioned economic

considerations required by Eskom to enter into PPA. Further the distrust of government run institutions is higher due to political instability and South Africa's recent investment status downgrade.

A lack of incentives and subsidies to implement RE was noted to be one of the biggest barriers by Interviewee Three. Interviewee Two further noted that incentives may be tied to certain conditions that make accessing subsidies or funds difficult. Interviewee One corroborates this by stating that bureaucratic processes makes access to subsidies/incentives difficult to attain.

With regards to the legislation around PPA and IPP Interviewee One does not see these as a barrier and goes on to state that the legislation is good. However, it is the lack of understanding and confusion of the agreements between IPPs and Eskom where the barrier to RE implementation seems to arise.

RE institutions and experts on a governmental level were not considered to be important barriers by Interviewee One and Two, Interviewee Three stated that expert on RE on a governmental level was important.

4.4.4 Social Barriers Section

The most important barrier established in the social section is the dominance of cost over the detrimental environmental issues that fossil fuel power generation creates.

The rest of the barriers in the social section were not perceived to be important barriers to RE implementation.

4.5.1 Technological Drivers Section

All the drivers listed in the technological section were perceived to be important drivers, including the increased availability of RETs in South Africa, as well as the growing expertise on RE. Further the growing evidence of RE capabilities was also thought to have driven RET implementation.

RETs ability to mitigate against municipal electricity outages was also thought to be an important driver with Interviewee One feeling that this was particularly applicable to the smaller aquaculture organisations of South Africa.

As previously mentioned in the technological barriers section, the natural attributes of the farm may not only be a barrier but may also serve as a driver to RE implementation.

4.5.2 Economic Drivers Section

Similar to the technological drivers, all of the economic drivers were viewed as important. The combination of growing utility costs versus the declining cost of RETs was a particularly important driver, as was cost effectiveness of RE in the long run. Further access to capital was another important driver. Investor confidence in RE has been noted as increasing for RE and as such more capital may be available which is an important driver.

4.5.3 Political Drivers Section

The most important drivers were listed as favourable governmental policy as well as incentives or subsidies to implement RE. Interviewee One notes that favourable governmental policy is not evident in South Africa and thus not a driver in this country yet. Further, the Interviewee states that the most important policy reform should be in regards to underwriting the PPAs with Eskom.

Adequate formal institutions promoting RE was viewed as a driver, and an element that had already sufficiently worked to implement RE. Experts on a governmental level was not viewed as a necessary or important driver by Interviewee One and Two stating instead that the policy just needs to be favourable to implement RE. Interviewee Three states instead that it is very important to have expert in RE on a governmental level.

Finally, the legislation around PPA's was considered to be adequate, but once again the implementation and bureaucratic process around this were felt to be hindering RE implementation rather than driving it.

4.5.4 Social Drivers Section

Educational awareness and the drive of sustainable energy production becoming the norm were viewed as the most important drivers to RE. Further the preference for environmentally friendly electricity generation was regarded as a growing driver in South Africa, especially in the Aquaculture industry where research such as that conducted here will promote RE implementation.

The benefits of national champions in the industry was considered to be an important driver by Interviewee Two and Three.

It was also noted that South Africa's possible decision to adopt nuclear power as an environmentally friendly means of electrical energy generation would be a major barrier to RE implementation.

CHAPTER 5: DISCUSSION

The research aimed to address the issue of renewable energy implementation within South Africa's aquaculture industry. To do this the barriers and drivers to renewable energy implementation were evaluated according to perceived importance by members of South Africa's aquaculture industry.

The following discussion will compare the results obtained directly from the quantitative questionnaire, to the information obtained in the qualitative interview sections. The discussion will focus on the most important barriers and drivers identified through the data collection process. These will then be compared to peer reviewed literature and discussed.

5.1 Validity of results

The sample obtained for the quantitative research section, i.e. the online importance ranking questionnaire represents approximately 10% of the entire population. A sample of 32% of the population is suggested for a population size of 200 participants (De Vos, et al., 2011), similar to the total population of South Africa's aquaculture sector. As such, the sample size is insufficient to accurately form generalisations of the entire aquaculture population of South Africa. However, all the farms sampled had revenues of over 500,000.00 ZAR per annum and have been in operation for over 5 years. The results were thus obtained from farms that may be deemed successful in their operations. Given the high rates of failure of aquaculture operations (James, 2016), the results of the quantitative survey can as such be regarded as an accurate representation of the successful aquaculture sector of South Africa.

The wide variety of South Africa's aquaculture farms with regards to their scale of production, species cultured and revenue, may result in varying opinions of the importance of the proposed list of barriers (Table 1) and drivers (Table 2) to RE implementation. This heterogeneity of the sample further complicates the validity of the results obtained (De Vos, et al., 2011). However, the top six barriers and drivers

all had a low sample variance indicating that respondents felt similarly about the importance of those barriers and drivers. A small sample would exacerbate sample variance. Thus, the results of the top six barriers and drivers can be considered reliable and valid.

5.2 Barriers Discussion

The most important perceived barrier was identified as *High Initial Investments* through the questionnaire data collection method. Interviewee Two regards the high initial investments as the most important barrier in RE implementation in aquaculture. This is further substantiated by that written by Toner (2002). The author concludes that the initial cost is a factor that deters most aquaculture organisations from implementing RETs. However, a case study is provided of a marine finfish recirculating system that is energy intensive in its use of pumping and filtration of water. It is suggested that wind and wave energy generation may be viable options for that particular case study and it was found that finance may be recouped in six years (Toner, 2002). Similarly, a study conducted by Ioakeimidis, Polatidis and Haralambopoulos (2013) on a RAS in Greece, found that a PV and combined Solar-Thermal panel RE system could be economically viable if financial resources were available. This illustrates the importance of accurate financial planning when considering RE implementation within aquaculture.

High initial investment has been found to be a substantial barrier to RE investment in various studies conducted across the globe (Painuly, 2001; Pegels, 2010; de Jongh, Ghoorah and Makina, 2014; Luthra, et al., 2015; Blechinger, Richter and Renn, 2015; Nasirov, Silva and Agostini, 2016). However, Interviewee One argues in stark contrast to High Initial Investments being a barrier. The interviewee argues that today investor confidence has grown in RE and that financing mechanisms such as special purpose vehicles are available. The interviewee believes that as long as the project can be proved to be viable, obtaining finance for the large initial investment should not be a problem. However, later in the interview process, a comment was made that obtaining

such finance may still be an issue for the smaller aquaculture organisations. This statement is corroborated by both Interviewee Two and Three.

The next most important barrier from the quantitative questionnaire was *Utility monopoly of production and Eskom's reluctance to enter into PPA with IPP.* Both Interviewee One and Two agree that this is a very important barrier. Interviewee One states that it is understandable from Eskom's point of view as the utility provider needs to be sure that it can afford to pay the tariff agreed upon to the IPP as per the PPA. Interviewee One further argued that such conditions are affected by the larger macroeconomic environment and that social and political factors all need to be taken into account by Eskom. Given South Africa's recent credit down-rating to "junk status" in 2017 (Bonorchis, 2017), it is likely that distrust of government institutions will only decrease and thus this barrier will become even more important.

Utility monopoly of production was found to be an important barrier to RE implementation in the Caribbean islands (Blechinger, Richter and Renn, 2015). Similarly, a highly-controlled energy sector and a lack of competition results in market failures noted by Painuly (2001) to be a barrier to RE investment. In South Africa, Pegels (2010) states that Eskom as a monopoly producer of electricity with a core competency in electricity generation from coal power, do not foster a favourable environment for RE producers.

Lack of experts on a governmental level was ranked as the third most important barrier to RE implementation by the respondents in the quantitative questionnaire. This is substantiated by Interviewee Three but contradicted by Interviewees One and Two. Interviewee Three maintained that expert knowledge on a governmental level would 'filter' down to the various levels such as provincial, regional and municipal. A study by Blechinger, Richter and Renn (2015) found this barrier to rank as only moderately important in the Caribbean.

Lack of incentives from government was ranked fourth most important and viewed as very important by Interviewee Two and Three. Interviewee One however is of the opinion that there isn't a lack of incentives or subsidies, but rather that bureaucratic processes hinder the access to these incentives or subsidies. International studies on barriers to RE implementation have frequently highlighted the importance of incentives

and subsidies to implement RE (Painuly, 2001; Mirza, et al., 2009; Blechinger, Richter and Renn, 2015; Luthra, et al., 2015). While on a local South African base, it was mentioned as a barrier by Pegels (2010) and De Jong, Ghoorah and Makina (2014).

A lack of legal framework for IPP and PPA was ranked as the fifth most important barrier to RE implementation in South Africa's aquaculture sector by the quantitative assessment. Both Interviewee One and Three rated this as very important and critical to address to aid RE implementation. Similarly, a lack of regulatory framework for private investors was ranked as the most important barrier to RE implementation in the Caribbean by Blechinger, Richter and Renn (2015). Painuly (2001) identified a lack of legal frameworks as a barrier, commenting that RE producers could face market/financial barriers due to this. In South Africa, this barrier was also identified by Pegels (2010) and De Jong, Ghoorah and Makina (2014).

The barrier of *Diseconomy of Scale* was ranked as the sixth most important barrier by the quantitative questionnaire. All three interviewees agree that this is a barrier with Interviewee One commenting that it may be technology specific. Interviewee One gives the example of how solar power may be simply installed for small aquaculture systems. Diseconomy of scale would not have a major effect with solar as the costs per KW/h for such a system would be fairly linear. Other technologies such as wave energy generation would need to be of a certain size before it is economically viable.

Diseconomy of scale was also found to be a barrier to RE implementation by Blechinger, Richter and Renn (2015). Here this barrier was ranked as the fifth most important barrier in their study on barriers to RE implementation in the Caribbean islands. There is also a link between diseconomy of scale and the high initial investments barrier. Certain technologies such as the wave energy generator built at an abalone farm in the Western Cape of South Africa (Anchor Environmental Consultants CC, 2012), need to be built to a certain size to be economically viable. This diseconomy of scale consequently results in high initial investments.

5.3 Drivers Discussion

Long term cost benefits were ranked as the most important driver to RE implementation in South Africa's aquaculture industry through the quantitative

questionnaire. This was further corroborated by all three interviewees. Interviewee One commented that this driver is further increased by growing utility costs. While Interviewee Three commented that this driver will still be dependent on the technology that is being implemented. Ioakeimidis, Polatidis and Haralambopoulos (2013) performed an energy audit for a Mediterranean based fish hatchery. The authors performed an economic evaluation of a proposed photo voltaic and solar thermal panel and found the project was economically viable retuning a pre-tax Internal Rate of Return of 9.4% for the photo voltaic system and 22.2% for the solar thermal panel projects. This study illustrates the possible long-term cost benefits of RE implementation within aquaculture.

The *Reduction in cost of RETs* was found to be the second most important driver in the quantitative questionnaire. This was further substantiated by all three interviewees who viewed this driver as very important. Interviewee Two commented that this was the fundamental reason that investment in RE is increasing in the aquaculture sector. Continued research and development has resulted in the price of RETs falling drastically over the past two decades and this is particularly the case for Photo voltaic and wind power generation (Walwyn and Brent, 2015; Randall, 2016). Various authors have argued that for a RE project to be implemented it must be economically viable and this will be a direct result from the price of RETs decreasing (Pegels, 2010; de Jongh, Ghoorah and Makina, 2014; Walwyn and Brent, 2015). This has also been illustrated as a driver for RE implementation in the aquaculture sector (Toner, 2002; Ioakeimidis, Polatidis and Haralambopoulos, 2013).

The next four highest ranking drivers as per the quantitative questionnaire, all received an average importance of 4,89 (Table 4). However, the drivers had sequentially higher sample variance values. *Innovation/ advancement of RET* was as such ranked as the third most important driver. The interviewees all agreed that it is an important driver. Both Interviewee One and Two commented that the advancement of RETs has resulted in their increased cost effectiveness and that this was also consequently driving investment in RE in the aquaculture sector. Further Interviewee Three commented that an abalone farm in the Western Cape of South Africa had very recently installed a proto-type solar panel to test its durability. It appears that

innovation/ advancement of RETs and reduction in cost of RETs are inextricably linked.

Incentives/subsidies to implement RE was ranked as the fourth most important driver. The importance of this driver was corroborated by all the interviewees, but Interviewee Two comments that the process of deciding who gets what incentives should be transparent and fair. Incentives and subsidies have been described to be key to implementing RE by various authors (Painuly, 2001; Mirza, et al., 2009; Pegels, 2010; Luthra, et al., 2015), and also for South Africa (de Jongh, Ghoorah and Makina, 2014; Walwyn and Brent, 2015).

Adequate legal framework and legislation for PPA and IPP was ranked as the fifth most important driver in the quantitative questionnaire. Similarly, Interviewee Three commented that it is very important. Interviewee One however states that the legislation is adequate, but it is the application of legislation that is not driving RE implementation. Interviewee One states that bureaucratic processes are hindering the implementation of RE. However, the interviewee does comment in another part of the interview process that in terms of policy to drive RE implementation, underwriting the current PPA from Eskom is key. Literature from a South African perspective corroborates these findings (Pegels, 2010).

Preference for environmentally friendly electricity generation was ranked as the sixth most important driver by the quantitative questionnaire. This was corroborated by all three interviewees. Further the interviewees commented that this was becoming more important in the aquaculture industry. As education around the subject of GHG emissions due to fossil fuel electricity generation and climate change increase, it was noted by Interviewee Two and Three that this will become a bigger driver in the future.

CHAPTER 6: CONCLUSION

South Africa is plagued by socio-economic issues of poverty, inequality and high rates of unemployment. The government of South Africa has as such launched an ambitious plan known as operation PHAKISA which will complement the National Development Plan in addressing the countries aforementioned shortcomings (DEA, 2016). In the operations first phase, the focus is on growing South Africa's ocean economy. Within the ocean economy, the growth of aquaculture has been identified as an industry with the potential to create jobs and aid in economic growth of South Africa (DEA, 2016). However, the growth of aquaculture organisations needs to be carefully planned to ensure the sector is environmentally sustainable (Little, Newton and Beveridge, 2016). As such, this study set out to investigate one component of increasing aquacultures environmental sustainability in South Africa, that being the integration of RE and aquaculture.

6.1 Main Findings

Through the identification of various barriers and drivers to RE implementation in South Africa's aquaculture industry, their perceived importance to the industry was evaluated. The most important barriers to RE implementation within South Africa's aquaculture industry were identified as the following: *High Initial investments, Utility monopoly of production, Lack of RE experts on a governmental level, Lack of incentives/subsidies from government, Lack of legal framework for IPP and PPA,* and *Diseconomy of scale* respectively.

The drivers to RE implementation in South Africa's aquaculture industry displayed much less variation between respondents and interviewee's perceived importance ratings compared to the barriers to RE implementations rankings. Overall, most drivers identified from literature review regarding RE implementation were found to be important. The most important drivers to RE implementation in South Africa's aquaculture industry were found to be the following: *Long term cost benefits,*

Reduction in cost of RETs, Innovation / advancement of RET's, Incentives or subsidies to implement renewable energy, Adequate legal framework and legislation for Power Purchase Agreement and *Preference for environmentally-friendly electricity generation* respectively.

From the results, a colour coded ranking matrix was drafted (Table 7). The table displays the perceived importance of Barriers and Drivers to RE implementation within aquaculture. Both the Economic and Political categories were found to be the most important categories of barriers and drivers.

Throughout the research process, it was found that both barriers and drivers were dependent on the type of RE technology being implemented. This notion was frequently highlighted in the interview process. As such caution should be taken when attempting to derive generalisations from the results. Further due to the heterogenous nature of aquaculture organisations within South Africa regarding their size, species cultured and their methods of cultivation, it is suggested that thorough due diligence be conducted before any attempt of RE implementation. Any RE project considered should first take note of the aquaculture farms locality as this may limit certain RETs.

The *Natural attributes of the farm* were listed both as a barrier and possible driver to RE implementation within aquaculture but was not ranked as important in the quantitative questionnaire section. However, it was described by Interviewee One as being the most important barrier or in fact driver to RE implementation within South Africa's aquaculture industry. The natural location and attributes of the farm could either lend itself to being highly advantageous for RE implementation for certain technologies, while in some instances it may completely limit certain RETs. An example may be of a farm situated deep within a mountains valley that receives little sunlight. In such an instance, a PV system may be almost completely redundant.

As such the barriers and drivers to RE within aquaculture will always be dependent on the farm's site locality and the environmental conditions associated with it. Sequentially, the type of RE being implemented will further have an effect due to technology dependence as previously discussed.

	HIGH IMPORTANCE	MODERATE IMPORTANCE	LOW IMPORTANCE	LEAST IMPORTANCE
Barriers	High initial investments	Lack of renewable energy experts and advisors on government level	A lack of technical expertise and experience	Lack of understanding of project cash flows from financial institutions
	Utility monopoly of production	Lack of incentives or subsidies from government	Lack of private capital to fund RET projects	Preference for status quo
		Lack of legal framework for IPP and PPAs	Dominance of a least cost objective over environmental issues	Natural attributes of the farm, for example; not enough space for solar panels
		Dis-economy of scale	Distrust of power purchase agreement (PPA) with utility monopoly (Eskom)	Threat of natural disasters
		Lack of RE initiatives/drives from a government level	A lack of evidence-based assessments of RE potentials	RE implementation will have detrimental impact on landscapes and ecosystems
		Lack of legal framework and legislation for private investors	Gap between policy targets and implementation	
		Lack of formal renewable energy institutions	Fossil fuel subsidies and fuel surcharge (inexpensive electricity obtained from Eskom)	
		Low storage capacity of electrical energy	Low availability of renewable energy technologies	
		Lack of local/national champions		
		Lack of access to low cost capital or credit		
Drivers	HIGH IMPORTANCE	MODERATE IMPORTANCE		LOW IMPORTANCE
	Long term cost benefits	Innovation/advancement of RETs	Environmental issues of electrical energy generation by fossil fuels	Natural attributes of the farm that are advantageous to use RE sources.
	Reduction in cost of RETs	Incentives or subsidies to implement RE	Cost of alternative electricity supply (eg. diesel generator)	Benefits of national champions in the industry
		Adequate legal framework and legislation for PPA	Adequate expertise in RE on a governmental level available	
		Preference for environmentally friendly electricity generation	Favourable governmental policy to implement RET	
		Ability of RET to mitigate against the impacts of municipal electricity outages	Growing educational awareness of the benefits of RE	
		Access to low cost capital	Availability of private capital, investor confidence growing in RE	
		Availability of new technologies in South Africa	Adequate RE initiatives	
		Growing local expertise on technological infrastructure	Drive towards sustainable energy production becoming the accepted norm	
		Growing evidence showcasing capabilities of RET	Formal institutions to promote renewable energy	

Table 7: Barriers and Drivers to RE implementation in aquaculture importance ranking matrix. Blue indicating Economic category, Yellow indicating the Political Category, Red indicating the Technological category and Green indicating the Social category.

6.2 Recommendations

The results have highlighted the fact that there are indeed various important barriers to RE implementation in South Africa's aquaculture sector. The barrier of High Initial Investment is of particular concern to some of the smaller aquaculture organisations. However, with careful financial planning, RE projects within aquaculture have been shown to be economically viable (Toner, 2002; Ioakeimidis, Polatidis and Haralambopoulos, 2013; Kim, et al., 2015). Further by using mechanisms such as special purpose vehicles, financing for such projects may be obtained.

While Eskom's monopoly of the electricity sector and reluctance to enter into new power purchase agreements was identified as important barrier to RE implementation, the Government of South Africa has recently pledged its commitment to RE implementation. President Jacob Zuma stated in the 2017 State of the Nation Address that there will be continued investment in RE and that the government was dedicated to the IPP program (Le Cordeur, 2017). The governments intentions towards RE should boost investor confidence in RETs and in this way perhaps aid aquaculture farms in obtaining funding and thus partially alleviating the barrier of High Initial Investments as well as the barrier of Diseconomy of Scale as these two barriers are inextricably linked as discussed in the discussion chapter.

With regards to PPA, there seems to be a misconception by various aquaculture organisations on the subject. Most aquaculture organisations in South Africa, apart from the abalone farming organisations are relatively small (FAO, 2017). As such, it is unlikely that they would need to install RETs that are capable of producing significantly more energy than the farm would require, and thus not need to feed electricity back into the municipal grid. However, farms installing PV systems may be put at a disadvantage by not being able to feed electricity back into the grid and gain revenue from this as PV systems will generate electricity only during the day. Further, a RE feed in tariff has recently been gazetted by the South African government. This will further limit the profitability of installing such RE systems.

It is suggested that aquaculture organisations, particularly the smaller organisations who have been unsuccessful in raising capital to invest in RET for their respective farms, make use of PPAs with private companies who specialise in RE implementation (IPPs). In this way, no upfront capital is required, instead the private RE company will own the RET implemented at the farm, and the farm will pay a predetermined escalation rate (determined by example through South Africa's Consumer Price Index) per KW/h (van Wyk, 2017). By making use of such arrangements, aquaculture farms would be able to save on their electricity overheads and implement a form of RE without having to pay the high initial costs of RETs. Further, the price for electricity will through such agreements, not see drastic increases. This is especially relevant when compared to Eskom's recent proposed price increase of 19.9% (Slabbert, 2017).

Various political barriers and drivers have been identified in the research. It is clear that there needs to be favourable policy drafted and implemented to effectively drive RE implementation within the aquaculture sector. This will include allowing for fair and transparent tendering processes for IPPs and PPA. It is suggested that the process around tender processes for IPPs be streamlined and simplified to aid the bureaucratic processes.

The BBBEE Codes of Good Practice, could be updated to include an element of environmental best practice. This element could in accordance with the BBBEE points system drive large private enterprises to invest money towards environmental best practise which could include facets such as RE implementation. This would not only drive RE implementation, thus mitigating the effect of GHG production, but grow the green sector of electricity generation is South Africa and so contribute to economic growth.

As aquaculture is a food producing sector with the capability of employing large amounts of people, similar funding mechanisms to that provided to the agricultural sector may aid the industry. Funding should as such be made available to aquaculture farms willing to implement RE to grow their enterprises sustainably.

Winkler (2005) argued that if South Africa wants to increase its RE production, only setting targets or regulating prices will be insufficient. Rather adequate PPAs, a

consequent market for green electricity and access to the municipal power grid will be required (Winkler, 2005).

The benefits of the integration of RE and aquaculture reach beyond the premise of improving an aquaculture organisation's environmental sustainability. Recent studies have found that integrating aquaculture into a RE project can be beneficial. For example, the recent progression of Aquavoltaics (Pringle, Handler and Pearce, 2017). Here PV systems that float in large bodies of water are combined with aquaculture practices to increase the economic viability of such infrastructure. Similarly, a recent study found that the integration of Wave Energy Converters and aquaculture could offset the high initial capital expenditure on such RETs (Foteinis and Tsoutsos, 2016). The integration of RE and aquaculture could prove to be key in the sustainable growth of aquaculture in South Africa and drive this sector to meaningfully contributing to food security and growth of the South African economy.

6.3 Limitations of the study

Due to the heterogeneity of the aquaculture sector in South Africa, it is difficult to derive conclusions that will be applicable to all of the various types of aquaculture organisations throughout the country. Further, systems that are extensive, meaning they require less human input will mostly not have the high energy requirements of intensive systems, such as land based recirculating systems. These less intensive systems will as such most likely experience barriers and drivers to a different extent. The results presented in this research are perhaps more applicable to the intensive aquaculture systems of South Africa.

6.4 Recommendations for further research

Due to the limitations of this study, future research on this topic could categorise different aquaculture cultivation systems and examine the barriers and drivers between the various systems. Future research could also compare the barriers and

drivers to RE implementation between established aquaculture ventures and organisations just starting.

Finally, a detailed study of how specific policy mechanisms influence RE implementation will be key to understanding what is required to substantially increase the integration of RE in South Africa's aquaculture industry.

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APPENDICIES

APPENDIX 1: Online questionnaire sent to prospective respondents

Barriers and drivers to the implementation of renewable energy technologies in South Africa's aquaculture industry

The following questionnaire will be used as a tool to collect data for a Masters in Business Administration thesis at Rhodes University and Rhodes Business School. The study aims to rank various barriers and drivers that may be affecting the implementation of renewable energy technologies in South Africa's aquaculture sector. Once barriers and drivers have been ranked, policy recommendations can be made to effectively enhance the implementation of renewable energy technologies in order to aid South Africa's aquaculture industry in sustainable growth.

All participants' data will be kept anonymous and used purely for academic purposes. Contact details for participants were obtained through a national data base at the Department of Agriculture, Forestry and Fisheries.

* Required

1. **Please tick the following boxes as consent of your participation in this project** *
   Check all that apply.

   ☐ I freely agree to participate in the aforementioned study as per the above considerations.

   ☐ I give permission for the data generated through my responses to this questionnaire to be used for the purposes of the aforementioned study.

2. **How much time have you spent in South Africa's aquaculture industry** *
   Mark only one oval.

   ◯ Less than a year
   ◯ Between 1-5 years
   ◯ More than 5 years

3. **Please indicate your organisation' approximate annual revenue**
   Mark only one oval.

   ◯ Less than R 500 000. 00
   ◯ More than R 500 000. 00

4. **Have you implemented any form of renewable energy at your organisation? If so, please briefly describe what technology has been implemented (ie. solar, wind, geothermal or wave energy etc)** *

   _____

   _____

   _____

   _____

   _____

Technological Barriers to implementation of renewable energy

Please rank the following technological barriers to the implementation of renewable energy technologies as you perceive them to hinder their implementation at your aquaculture organisation.

The scale works as follows;
0- Not Applicable
1- No Importance
2- Very low Importance
3- Low Importance
4- Moderate Importance
5- High Importance
6- Highest Importance

5. **Natural attributes of the farm, for example; not enough space for solar panels or insufficient wind speed for wind turbines.** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

6. **Renewable energy implementation will have detrimental impact on landscapes and ecosystems** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

7. **Threat of natural disasters such as flooding/ large storms causing damage to renewable energy technologies on farm.** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

8. **A lack of evidence based assessments of renewable energy potentials** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

9. **A lack of technical expertise and experience** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

10. **Low availability of renewable energy technologies** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

11. **Low storage capacity of electrical energy** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

Economic Barriers

Please rank the following economic barriers as you perceive them to hinder the implementation of renewable energy technology at the aquaculture organisation you are a part of.
0- Not Applicable
1- No Importance
2- Very low Importance
3- Low Importance
4- Moderate Importance
5- High Importance
6- Highest Importance

12. **High Initial Investments** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

13. **Dis-economy of scale (meaning that small installations of the proposed renewable energy technology are not financially viable)** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

14. **Lack of access to low cost capital or credit** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

15. **Lack of understanding of project cash flows from financial institutions** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

16. **Lack of private capital to fund the proposed renewable energy technology** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

17. **Utility monopoly of production, transmission and distribution of electricity (Eskom's reluctance to enter into power purchase agreements and/or buy electricity back from Independent power producers)** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

18. **Fossil fuel subsidies and fuel surcharge (inexpensive electricity obtained from Eskom)** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

Political Barriers

Please rank the following political barriers as you perceive them to hinder the implementation of renewable energy technology at the aquaculture organisation you are a part of.

0- Not Applicable
1- No Importance
2- Very low Importance
3- Low Importance
4- Moderate Importance
5- High Importance
6- Highest Importance

19. **Gap between policy targets and implementation** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

20. **Lack of incentives or subsidies from goverment for renewable energy** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

21. **Distrust of power purchase agreement (PPA) with utility monopoly (Eskom)** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

22. **Lack of formal renewable energy institutions to aid individuals in renewable energy implementation** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

23. **Lack of renewable energy experts and advisors on government level** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

24. **Lack of legal framework for Independent power producers and power purchase agreements** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

25. **Lack of legal framework and legislation for private investors** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

Soclal Barrlers

Please rank the following social barriers as you perceive them to hinder the implementation of renewable energy technology at the aquaculture organisation you are a part of.
0- Not Applicable
1- No Importance
2- Very low Importance
3- Low Importance
4- Moderate Importance
5- High Importance
6- Highest Importance

26. **Lack of renewable energy initiatives/drives from a government level** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

27. **Lack of local/national champions/entrepreneurs to showcase the capability of renewable energy technology** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

28. **Dominance of a least cost objective over environmental issues fossil fuel power generation creates** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

29. **Preference for status quo** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

Technological Drivers

Please rank the following technological DRIVERS as you perceive them to advance the implementation of renewable energy technology at the aquaculture organisation you are a part of.
0- Not Applicable
1- No Importance
2- Very low Importance
3- Low Importance
4- Moderate Importance
5- High Importance
6- Highest Importance

30. **Natural attributes of the farm that are advantageous to use renewable energy sources. For example; large open spaces with high solar radiation that will be beneficial for solar panel installation** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

31. **Innovation / advancement of renewable energy technologies** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

32. **Availability of new technologies in South Africa** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

33. **Growing local expertise on technological infrastructure** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

34. **Growing evidence showcasing capabilities of renewable energy technologies** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

35. **Ability of renewable energy technology to mitigate against the impacts of municipal electricity outages within your aquaculture organisation** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

Economic Drivers

Please rank the following economic drivers as you perceive them to advance the implementation of renewable energy technology at the aquaculture organisation you are a part of.
0- Not Applicable
1- No Importance
2- Very low Importance
3- Low Importance
4- Moderate Importance
5- High Importance
6- Highest Importance

36. **Long term cost benefits** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

37. **Reduction in cost of renewable energy technology** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

38. **Cost of alternative electricity supply (eg. diesel generator)** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

39. **Access to low cost capital** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

40. **Availability of private capital, investor confidence growing in renewable energy** *

Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

Political drivers

Please rank the following political drivers as you perceive them to advance the implementation of renewable energy technology at the aquaculture organisation you are a part of.
The scale works as follows;
0- Not Applicable
1- No Importance
2- Very low Importance
3- Low Importance
4- Moderate Importance
5- High Importance
6- Highest Importance

41. **Favourable governmental policy to implement renewable energy technologies** *
Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

42. **Incentives or subsidies to implement renewable energy** *
Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

43. **Formal institutions to promote renewable energy** *
Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

44. **Adequate expertise in renewable energy on a governmental level available** *
Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

45. **Adequate legal framework and legislation for Independent Power Purchase Agreements** *
Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

Social Drivers

Please rank the following social drivers as you perceive them to advance the implementation of renewable energy technology at the aquaculture organisation you are a part of.
The scale works as follows;
0- Not Applicable
1- No Importance
2- Very low Importance
3- Low Importance
4- Moderate Importance
5- High Importance

6- Highest Importance

46. **Drive towards sustainable energy production becoming the accepted norm** *
Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

47. **Growing educational awareness of the benefits of renewable energy** *
Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

48. **Adequate renewable energy initiatives** *
Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

49. **Benefits of national champions in the industry** *
Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

50. **Environmental issues of electrical energy generation by fossil fuels** *
Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

51. **Preference for environmentally friendly electricity generation** *
Mark only one oval.

	0	1	2	3	4	5	6	
Not Applicable	◯	◯	◯	◯	◯	◯	◯	Highest Importance

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APPENDIX 2: Interview transcriptions

Barriers to renewable energy implementation in South Africa's aquaculture section.

Section 1. Technological barriers

1.1.1. What do you think of natural attributes of the farm, for example; not enough space for solar panels or insufficient wind speed for wind turbines as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Probably one of the biggest factors hindering RET implementation. For example; some areas simply do not allow for certain RET's such as wind turbines. A town such as Hermanus in the Western Cape of South Africa where various abalone farms are located would never allow for wind turbines to be constructed in the areas where the abalone farms are built. This will then limit the use of certain technologies such as wind turbines. Solar energy will also have different capabilities in different areas. A wave energy project has other types of limitations. For example, constructing a wave energy generator in the area of Durban in South Africa's Kwazulu Natal province would yield half the wave energy resource seen in the town of Hermanus. If it's a marine farm located in a sheltered bay, this would again limit the available wave energy resources.

Various other physical factors would affect the applicability of RET's such as; height above sea level for a marine farm and the height water needs to be pumped to from sea level (head) will affect the ability to generate electricity from water flowing back towards the sea after it has been used by the farm. If a farm is for example pumping water at a head height of 30 meters, it makes sense for the farm to use hydroelectricity generators to generate energy from the water flowing back down to the sea.

Solar power for aquaculture farms on land is fantastic as there is so much space above the tanks for implementation. However other factors then need to be considered such as the physical structures that would need to be put above the tanks adds to the cost as these structures need to be made safe as people will constantly be working below them.

Interviewee 2:

Yes, I think this is a barrier, but a minor one. If for instance if you have built against a south facing slope it will limit solar technologies. Actual space on the farm can be an issue, but it generally isn't. So generally, I wouldn't say this is a major barrier.

Interviewee 3:

Due to the proximity to the marine coastal environment, salt spray and high humidity are two key factors to consider when looking at alternative energy sources. Solar panels, in particular, do not fare well against high salt loading and require additional

maintenance to ensure that all components are working optimally at all times. The same is true for wind turbines along areas prone to salt spray. In addition, municipal by-laws need to be considered when wind turbines want to be employed within urban areas and are in many instances not allowed.

1.1.2. What do you think of renewable energy implementation having detrimental impacts on landscapes and ecosystems as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

The previous comment about the implementation of wind turbines in certain areas applies to this barrier. Wind power generation is one of the technologies that is the most visually obtrusive and impacting on landscapes. Generally, though, since renewable energy is good for the environment, this is not really a big barrier.

Interviewee 2:

I don't think this is a barrier at all. In my view, the technologies are not having a detrimental impact to the landscapes at all.

Interviewee 3:

Solar panels can easily be installed on already built infrastructure such as roofs and would not pose a considerable visual impact to the surrounding landscape. Wind turbines however, have a severe impact on the aesthetics of an area and often do not conform to the surrounding areas.

1.1.3. What do you think of the threat of natural disasters such as flooding/large storms causing damage to renewable energy technologies on farms as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

This again goes along well with the location of the farm as mentioned previously. There was an example of a farm in Gansbaai that a few years ago had half of its tanks washed away by a big storm.

From an energy perspective, the lower you are to the sea, the less energy will be required to pump water to the tanks. But this will put the structures of the farm at a higher risk to damage due to storms.

Interviewee 2:

I think this will depend on your farms location. In some instances, it could be a major barrier, while in others the risk of natural disasters occurring is fairly low.

Interviewee 3:

I think this risk is very site specific and would require a risk assessment by any farm/industry when looking at the suitability of any alternative energy source. Storm

risk to wind turbines may be higher than for solar panels, but hail events would also pose a risk to solar installations. South Africa does not experience severe weather events often, so the risks are lower than in other parts of the world. Again, however, site specific conditions would need to be considered.

1.1.4. What do you think of a lack of evidence-based assessments of renewable energy potentials as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

This is not considered a barrier to me. Today it is easy to hire someone to prepare an evidenced based assessment of the renewable energy potential at your farm and I do not consider this to be a barrier.

Interviewee 2:

I think there are plenty of examples that show that renewable are effective already. So, I don't think it's a big barrier.

Interviewee 3:

The South African aquaculture industry is relatively young and mostly based on what is being done internationally. Consequently, many farms will look at which alternative energy sources are used globally (and specific to their sector, e.g. abalone, fish, oysters) and decided if those can be used in the South African context. The risk of not having access to reliable energy (e.g. ESKOM load-shedding) will drive many industries, including aquaculture, to look at alternative sources.

1.2.1. What do you think of a lack of technical expertise and experience as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

In South Africa, today there are adequate experts on solar and wind technologies, but hydro expertise is lacking in the country especially experts on wave energy. The barrier is then dependent on the type of technology that is to be used.

Interviewee 2:

I don't think it's a big issue as I can think of a number of firms that could be consulted on RE issues.

Interviewee 3:

I think there is a lot of knowledge on renewable energy sources in South Africa, however, implementing these on the scales required by an abalone farm for instances, is were knowledge is lacking. This is where more effort should be placed in developing technologies applicable to industry requirements.

1.2.2. What do you think a low availability of renewable energy technologies as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Again, it is technology dependent with hydro technologies being particularly expensive and can thus be a barrier.

Interviewee 2:

I don't think this is a barrier, there are many companies that are able to supply various technologies quickly in South Africa at the moment.

Interviewee 3:

Again, the technology is there it just needs to be streamlined for the aquaculture industry. Especially looking at in-flow turbines and wave-energy along the coastline.

1.2.3. What do you think of the low electrical storage capability of renewable energy as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Intensive aquaculture typically requires electrical usage 24/7. So, technologies such as solar only provide electricity during the day, wind similarly does not always produce sufficient electricity. It is as such a definite barrier.

Interviewee 2:

This is definitely a barrier. A typical example is solar power not providing energy 24 hours a day. Having to then install batteries to overcome this means there is a major cost consideration.

Interviewee 3:

This is very prevalent across different sectors and is something where technical knowledge of what can truly be implemented at farm levels needs to be developed.

<u>Section 2. Economic barriers</u>

2.1.1. What do you think of the high initial investments as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

I do not consider this to be a barrier as these days if you have a viable project, especially one off the grid, it is possible to get funding. However, when using unproven technology acquiring funding is much more difficult. There is an entire lack of funding in South Africa when it comes to unproven technologies such as wave energy generation. But for proven technologies I don't believe it is a barrier.

Interviewee 2:

This is in my opinion the vast majority, 80% plus of the barriers to implementing RE within aquaculture in South Africa.

Interviewee 3:

Certain technologies, e.g. solar, are becoming much more affordable and as the renewable energy sector grows, it is likely to become even more so.

2.1.2. What do you think of diseconomy of scale of investing in renewable energy as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

This is again per technology. For solar it is simple to install smaller systems, but they do still have high costs per KW/h. Much higher than for instance large concentrated solar power plants. But this barrier is technology dependent.

Interviewee 2:

Yes, this is also a barrier. And again, is related to the previous statement.

Interviewee 3:

Again, as the costs of technology goes down and the 'risk' of load-shedding increases, more and more farms will look at alternative energy sources. They cannot risk not operating and those 'losses' will be weighed against the initial higher cost of renewable energy.

2.2.1. What do you think of a lack of access to low cost capital or credit as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

This is similar to what was said previously about receiving funding. When new renewable energy projects are to be implemented, then typically special service vehicles or new companies are started and project finance is received if a case can be made for guaranteed future income and thus repayment of the initial project finance.

Interviewee 2:

Yes, this is definitely a barrier and even more so in South Africa if you do not fit certain BBBEE conditions.

Interviewee 3:

Smaller farms will most probably be affected by these, however, larger farms that have been in operations for more than 10 years should not be affected.

2.2.2. What do you think of a lack of understanding of project cash flows from financial institutions as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

I think financial institutions are today understanding of the technicalities of renewable energy implementation. This might have been a barrier ten years ago, but not anymore.

Interviewee 2:

I think this could be, but I don't think I can comment on this specifically.

Interviewee 3:

Same answer as previous question.

2.2.3. What do you think of a lack of private capital as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

It is difficult to get private capital as it is a very small market. It is a definite issue for the smaller organisations.

Interviewee 2:

Yes absolutely. Comes back to the initial question of capital being the problem.

Interviewee 3:

Same answer as previous question.

2.3.1. What do you think of utility monopoly of production, transmission and distribution of electricity (Eskom's reluctance to enter into power purchase agreements and/or buy electricity back from independent power producers) as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Definitely a barrier. Eskom needs certainty that they will be able to pay for/buy back electricity on the long power purchase agreements. This ties in to a much larger economic, social and political problems facing South Africa but is a barrier to renewable energy implementation.

Interviewee 2:

It is to me fundamentally discouraging to RE implementation if Eskom is holding the monopoly. I think it suffocates the RE industry.

Interviewee 3:

I think it would be more of a motivation for many to go 'of-grid' and become independent of Eskom.

2.3.2. What do you think of fossil fuel subsidies and fuel surcharge (inexpensive electricity) as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Definitely a barrier. It can make renewable energy more expensive. This I think will continue to be a problem in third world countries.

Interviewee 2:

I think this is definitely a barrier. If fossil fuels are subsidised, RE should be given even more subsidies.

Interviewee 3:

Although 'cheaper' fossil fuels are available, industries are targeted in terms of greenhouse gas emissions and air quality licences.

Section 3. Political barriers

3.1.1. What do you think of a gap between policy targets and implementation as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Here I think a gap exists with regards to the power purchase agreements. There are many more applications for viable projects than are actually approved by Eskom. This I think is due to Eskom not having the ability to take on that amount of commitment.

Interviewee 1:

Policy plays a massive role. It becomes a problem when there is a mismatch between policy. If a certain policy says 'x' units of RE should be implemented, but to access finance to actually implement the RE projects certain requirements such as BBBEE etcetera again need to be met, it is limiting the implementation drastically.

Interviewee 3:

Policies are often based on international agreements, but it must be remembered that South Africa is a developing country and cannot always meet these targets (although we can strive for them).

3.1.2. What do you think of a lack of incentives or subsidies from government for renewable energy as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I think there isn't a lack of incentives, but I think it's difficult to access from a bureaucratic perspective.

Interviewee 2:

I think this is another barrier yes. Funds to implement projects are tied to various conditions and difficult to access.

Interviewee 3:

This is probably one of the biggest barriers, especially in light of the monopoly a parastatal such as Eskom has on the sector.

3.1.3. What do you think of the distrust of power purchase agreements with utility monopoly (Eskom) as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Yes, I think this is true. Especially now that South Africa's credit rating has been downgraded, the level of trust with government run institutions is going to be lowered. So, I think this is a barrier yes.

Interviewee 2:

It may be the case but is something I can't comment on.

Interviewee 3:

My comment on the previous question answers this question.

3.2.1. What do you think of a lack of formal renewable energy institutions to aid individuals in renewable energy implementation as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I don't think institutions are really needed any more as it is the private sector who are developing and implementing renewable energy projects. At the start of new technology projects, associations are important as government won't usually commit to helping companies or individuals.

Interviewee 2:

I think the technology is there, so I don't see this as major barrier.

Interviewee 3:

Not applicable

3.2.2. What do you think of a lack of renewable energy experts on governmental level as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: No, I don't think this is a barrier at all.

Interviewee 2:

To me this is irrelevant. The government should just put the correct policies in place. I think government should facilitate, but not manage RE implementation.

Interviewee 3:

Very much a lack of adequate knowledge at government level which filters down to all levels (provincial, regional and municipal).

3.3.1. What do you think of a lack of legal framework for independent power producers and power purchase agreements as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: From the utility scale with Eskom yes this is a barrier because there is a lot of confusion between individuals/ independent power producers and Eskom. But the actual legislation in South Africa I think is good.

Interviewee 2:

Yes, this is definitely a hurdle.

Interviewee 3:

This can have a big impact on renewable energy sources. Just last week it was Gazetted that 'generators of electricity' must pay a fee per Kw produced.

3.3.2. What do you think of a lack of legal framework and legislation for private investors as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I think it's the same case the previous question. So yes, it is a barrier.

Interviewee 2:

Yes, I again think this will be a barrier.

Interviewee 3:

Same as my previous questions comment.

<u>Section 4. Social barriers</u>

4.1.1. What do you think of a lack of renewable energy initiatives/drives from a governmental level as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I don't think this is a big barrier no.

Interviewee 2:

I can't really comment. I think government should have policies in place to in order not to slow down or frustrate the process of RE implementation.

Interviewee 3:

I think government is trying to make people aware of energy saving, but one would need to determine the reason behind this. Already we do see solar geysers in informal settlements and several wind farms, but think people need to be educated more about the waste of energies.

4.1.2. What do you think of a lack of local/national champions/entrepreneurs to showcase the capability of renewable energy technologies as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: No, I don't believe this is a barrier.

Interviewee 2:

I think there are champions of the industry such as the abalone farms that are implementing RE. But I don't believe this is a barrier.

Interviewee 3:

This is changing, but again we are a developing country with a high percentage of the population who still do not have access to basic infrastructure.

4.2.1. What do you think of the dominance of cost over environmental issues fossil fuel power generation creates as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I think this is a problem and a barrier in South Africa.

Interviewee 2:

I think it is a barrier, but not a major restricting to factor to RE implementation.

Interviewee 3:

This is will always be an issue (wars are thought about it!)

4.3.1. What do you think of the preference for status quo as a barrier to renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: No I don't think this is a problem. Recent power outages and all the problems Eskom has had in the past has shown people that a change is needed.

Interviewee 2:

I don't think this is a barrier as in any business environment, people are looking to try to costs where they can and will be willing to change things to do so.

Interviewee 3:

Not applicable

Drivers to the implementation of renewable energy.

The following sections detail a list of perceived drivers or promoters to renewable energy implementation.

Section 1. Technological

1.1.1. What do you think of natural attributes of the farm that are advantageous for renewable energy electricity production as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Yes, this is definitely an enabler/ driver.

Interviewee 2:

I think this is absolutely a driver. If there is a resource available, you should use it.

Interviewee 3:

Lots of open space for solar energy, close proximity to coastal region and wave energy

1.1.2. What do you think of technological Innovation/advancement of renewable energy technologies as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Yes, I definitely think so as the cost has decreased dramatically.

Interviewee 2:

Yes, I think this is a driver. Elements such as cost effectiveness could increase. Another possible example may be that water turbines working inside pipes become more efficient and effective and water moving through gravity on the farm could be used to generate electricity from the kinetic energy of the water.

Interviewee 3:

Already starting to see more robust technologies being implemented on some farms (Abagold just this week installed a proto-type solar panel to test its durability and ability to supply energy on a reliable basis).

1.1.3. What do you think of availability of new renewable energy technologies in South Africa as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Yes, this is a driver. Most of our renewable energy technologies are still imported, but South Africa is seen as a good market for these technologies, especially solar and they have become much more available over recent years.

Interviewee 2:

I don't think it's the increase of availability that is a driver, but rather the increase of the efficiency of the RETs which is driving RE implementation.

Interviewee 3:

See comment above.

1.1.4. What do you think of a growing local expertise on technological infrastructure as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Yes, this has improved significantly and is definitely a driver.

Interviewee 2:

I think South Africa has local expertise in the private sector and this is a driver of RE.

Interviewee 3:

We are seeing more and more local expertise, especially in terms of solar energy.

1.2.1. What do you think of growing evidence showcasing the capabilities of renewable energy as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Yes, I agree with this a 100%

Interviewee 2:

Yes, I think this is a driver.

Interviewee 3:

This is a very good thing. The more evidence there is, the better motivation for implementing these at large scales.

1.3.1. What do you think of the ability of renewable energy technologies to mitigate against the impacts of municipal electricity outages as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Yes, this is especially true for the smaller organisations I think.

Interviewee 2:

I think it could aid in reducing the effects of a power outage and could as such be a driver. Municipal energy could even be used as a back up to RE system failure in the future.

Interviewee 3:

This is will be a huge component/motivation for implementing renewal energy on a farm.

Section 2. Economic Drivers

2.1.1. What do you think of the long-term cost benefits as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Yes definitely, especially with growing utility costs.

Interviewee 2:

I think its improving all the time and that is why we are seeing increased investment in RE. So yes, definitely a driver.

Interviewee 3:

This will be dependent on the type of technology being used and environmental conditions at the site, as well as the application needs of the farm. But should be beneficial in the long run.

2.1.2. What do think of the reduction in cost of renewable energy technologies as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Yes, the combination of a reduction in cost of technologies as well as the increase in utility electricity costs I think makes this a big driver.

Interviewee 2:

Yes, I think this is the fundamental reason why we are seeing a growth in RE implementation.

Interviewee 3:

Very important to have a product that will be cost-effective in the long run (incl. maintenance).

2.1.2. What do you think of the cost of alternative electricity supply (example; diesel generator) as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Yes, I think there are many aquaculture organisations that need a back to municipal electricity supply and renewable energy can help in this regard. You could even have Eskom as the backup now.

Interviewee 2:

Yes, I think this is a risk to most aquaculture organisations. But our electricity is still comparatively cheaper to places such as Europe. But it is still a driver yes.

Interviewee 3:

See comment above.

2.2.1. What do you think of access to low cost capital as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I think this is definitely a driver.

Interviewee 2:

Yes, this would be a driver.

Interviewee 3:

Very important

2.2.2. What do you think of the availability of private capital and growing investor confidence in renewable energy as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Yes, I think various investors and even low risk investors are now investing in renewable energy. So, this is definitely a driver.

Interviewee 2:

This is definitely a driver.

Interviewee 3:

Very important

Section 3. Political Drivers

3.1.1. What do you think of favourable governmental policy to implement renewable energy as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I think this is a problem and still a long way off from being a real driver. I also think things such a political instability and our recent economic ratings downgrade will have knock on effects and mean that governmental policy will be even less of a driver.

Interviewee 2:

Yes, as mentioned in the barriers section, policy can either be a major barrier, or it can be a big driver to RE implementation.

Interviewee 3:

Can have a very significant impact on renewable energies, however, must work with industries when it comes to setting targets and frameworks for implementation.

3.1.2. What do you think of incentives or subsidies to implement renewable energy as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I think this used to be a problem, but it isn't anymore and it is a driver today. But the biggest policy reforms should come in regards to underwriting the power purchase agreements from Eskom.

Interviewee 2:

Yes, I think this would be a driver, but the process of deciding who gets what subsidies needs to be transparent and fair.

Interviewee 3:

Could be advantageous

3.2.1. What do you think of adequate formal institutions to promote renewable energy as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I think this is a driver, and I think formal institutions have done their required work in driving renewable energy implementation.

Interviewee 2:

I think this is irrelevant and not a driver.

Interviewee 3:

Could be advantageous

3.2.2. What do you think of adequate experts in renewable energy on a governmental level as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I don't think this is that necessary anymore. I wouldn't say that it is a real enabler, but it's also not a barrier.

Interviewee 2:

Again, as long as the policy is favourable, this would be the factor that drives investment in RE, so experts on a governmental level wouldn't be required.

Interviewee 3:

Very important

3.3.1. What do you think of adequate legal framework and legislation for Independent Power Purchase Arrangements as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I think the legislation is adequate, it's just the implementation and bureaucratic process lacking that is not driving renewable energy implementation.

Interviewee 2:

I don't think I can accurately comment on this.

Interviewee 3:

Very important

Section 4. Social drivers

4.1.1. What do you think of the drive towards sustainable energy production becoming the norm as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Definitely a driver yes.

Interviewee 2:

Yes, I think this is definitely a driver as more and more people are investing in renewables.

Interviewee 3:

It's becoming more relevant.

4.1.2. What do you think of growing educational awareness of the benefits of renewable energy as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I think education around this subject is growing and becoming part of everyday life and is definitely a big driver.

Interviewee 2:

Yes, this is definitely a driver.

Interviewee 3:

Very important, especially across all classes.

4.2.1. What do think of adequate renewable energy initiatives as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I think it has a role to play yes.

Interviewee 2:

I think this could be a driver.

Interviewee 3:

Very important

4.2.2. What do you think of the benefits of national champions in the industry as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I don't think this is a big driver, but it's certainly not a barrier.

Interviewee 2:

I think this is a driver as it can showcase how new technologies could be used in the industry.

Interviewee 3:

Very important

4.3.1. What do you think of environmental issues of electrical energy generation by fossil fuels as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: Yes, I think this is a driver. But I think the South African government's decision to adopt nuclear power would be a major barrier to renewable energy.

Interviewee 2:

Yes, this is a driver. But it will always come back down to the cost of implementing the technologies.

Interviewee 3:

Very important and considering the health implications of coal-powered generators it is becoming more evident that we should move away from fossil fuels. Also, included here are the effects of greenhouse gases and climate change.

4.4.1. What do you think of the preference for environmentally friendly electricity generation as a driver/promoter of renewable energy implementation in South Africa's aquaculture industry?

Interviewee 1:

Answer: I think this is starting to become a bigger driver in the aquaculture industry. With research such as that being done here, it will be further promoted I think.

Interviewee 2:

Yes, I think as education around the subject grows, a preference for environmentally friendly electricity generation will increase and is definitely a driver.

Interviewee 3:

Same comment as previous question.

APPENDIX 3: Informed Consent Form Draft

Consent for Participation in Interview Research

Master in Business Administration

Study Title:

Barriers and Drivers to the Implementation of Renewable Energy Technologies in South Africa's Aquaculture Industry

I volunteer to participate in a research project conducted by Nicholas van Wyk from Rhodes University. I understand that the project is designed to gather information regarding the perceived barriers and drivers to the implementation of renewable energy within South Africa's aquaculture sector.

1. My participation in this project is voluntary. I understand that I will not be paid for my participation. I may withdraw and discontinue participation at any time without penalty.

2. If I feel uncomfortable in any way during the interview session, I have the right to decline to answer any question or to end the interview.

3. Participation involves being interviewed by Mr Nicholas van Wyk. The interview will last approximately 20 – 35 minutes. Notes will be written during the interview. An audio tape of the interview and subsequent dialogue will be made.

4. I understand that the researcher will not identify me by name in any reports using information obtained from this interview, and that my confidentiality as a participant in this study will remain secure. Subsequent uses of records and data will be subject to standard data use policies which protect the anonymity of individuals and institutions.

5. I have read and understand the explanation provided to me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study.

6. I have been given a copy of this consent form.

_____ _____

My Signature Date

_____ _____

My Printed Name Signature of the Investigator

For further information, please contact:

Mr Nicholas van Wyk

0781847844

APPENDIX 4: Email Draft Sent To Prospective Respondents

The barriers and drivers to the implementation of renewable energy in South Africa's aquaculture industry

Dear <Name Surname>

This email finds you as part of a study conducted in completion of a master's in business administration degree at Rhodes Business School, Rhodes University. As part of the degree, I am completing a study looking at the barriers and drivers to implementing renewable energy in South Africa's aquaculture industry.

In order to complete the study, data needs to be collected from all aquaculture organisations in South Africa. To do this, a contact list of all registered aquaculture organisations in South Africa was obtained from a representative in the Department of Agriculture, Forestry and Fisheries (DAFF).

To collect data, a survey has been drafted, available at the link below.

It is imperative to obtain as much data as is possible to get an accurate representation of South Africa's aquaculture industry in this regard.

I thus urge you to please submit a response through the link provided.

The survey is simple and shouldn't take you more than 15 minutes to complete.

All participants' data will be kept anonymous and used only for academic purposes.

The research aims to evaluate the current perceived barriers and drivers to the implementation of renewable energy technologies (for example photo voltaic /solar power) in South Africa's aquaculture industry. Once these barriers and drivers have been evaluated, suggestions for policy reform can be made in the hope of alleviating barriers, and promoting drivers to ensure South Africa's aquaculture industry will grow sustainably.

Once the research has been completed, a link will be emailed to all respondents giving access to the full research report.

Link to survey: https://goo.gl/forms/C1mVPpdBM8Rf7XhD3

Thank you in advance for your time and valuable response.

Please do not hesitate to contact me with any queries via email or cell phone.

Kind regards

Nicholas van Wyk

Prospective MBA graduate of Rhodes Business School, Rhodes University

vanwyk.nk@gmail.com

0781847844

APPENDIX 5: Consent form from DAFF to utilise department's aquaculture database

agriculture,
forestry & fisheries

Department
Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

Office of the Chief Director: Aquaculture and Economic Development, Department of Agriculture, Forestry and Fisheries
Private Bag X2, Roggebaai, Cape Town, 8012; Tel: 021 402 3326; E-mail: KeaganH@daff.gov.za

Enquiries: Mr Keagan Halley
Tel: (021) 402 3326
E-mail: KeaganH@daff.gov.za

ATTENTION: NICK VAN WYK AND LETICIA GREYLING

RE: CONSENT TO UTILISE THE DEPARTMENT OF AGRICULUTURE FORESTRY AND FISHERIES (BRANCH FISHERIES MANAGMENT) AQUACULTURE DATABASES FOR RESEARCH PURPOSE.

This letter serves as consent provided on behalf of the Department of Agriculture, Forestry and Fisheries, Branch Fisheries Managament, for the Rhodes University Business School to utilise the aquaculture databases published by the Chief Directorate Aquaculture and Economic Development.

The Chief Directorate Aquaculture and Economic Development is the lead government agent responsible for the promotion, development, regulation, monitoring and research of the aquaculture sector in South Africa.

I Keagan Desmond Halley, in my capacity as Aquaculture Advisor for the Chief Director Aquaculture and Economic Development, is responsible for the updating of the aquaculture industry databases and the publication thereof. I hereby give permission to the Rhodes University Business School to utilise the information on the databases for research purposes.

It would be courteous if the Rhodes University Business School when called upon may make public to the Department the results of the research conducted. Please feel free to contact me if you have any queries regarding the data.

Kind Regards

MR. KEAGAN HALLEY

AQUACULTURE ADVISOR
DIRECTORATE: AQUACULTURE TECHNICAL SERVICES/OPERATION PHAKISA
DELIVERY UNIT
CHIEF DIRECTORATE: AQUACULTURE AND ECONOMIC DEVELOPMENT
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DATE: 12/12/2016