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MSc Innovation

Diesel has to go: Making the case for gas and biogas engines.

Preface

This report describes project work carried out within the Department of Management School at Lancaster University between October 2021 and October 2022.

The submission of the report is in accordance with the requirements for the award of the degree of *MSc by Research in Innovation* under the auspices of the University.

Abstract

This study explores the commercialization process of small to medium enterprises (SME's), using the case study method to delve into the unique experiences of one firm who are currently in the process of commercialising their innovative low emission engine solutions. The study reviews the existing literature, exploring the challenges associated with commercialization, focusing on the specific challenges of commercialising high technologies into the market, and how the firm can aim to address the market's needs and preferences. The gaps in the literature include a lack of knowledge on how SME's can use their network during the commercialization process. The principal theories used to underpin this study include Teece's Technological Commercialization Theory (Teece, Pisano , & Shuen, 1997), and the Network Theory (Ford & Mouzas, 2010). The SME is then situated within the context of industry, and the markets of interest are outlined, specifically the small power generation markets in Sub-Saharan Africa, India, and the United Kingdom. The study uses semi-structured interviews to gain qualitative data on the experiences of those in industry and within the SME. Through thematic analysis, the data was coded, and themes emerged. The analysis revealed a strong market need from the industry for low emission solutions to reduce carbon emissions, and a willingness to adopt high technologies, whilst also outlining the potential roadblocks of new innovations entering the market. The analysis from the participants within the SME indicate strong expertise in technological capabilities to meet the market need, whilst the challenges facing the SME surrounded financial resources and strategic direction. The study concludes by addressing the gaps in the literature through discussion of how the SME can navigate its associated challenges and access the market through its network.

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1 Introduction

1.1 Research Problem

In the face of what scientists are calling a ‘climate crisis’, the carbon challenges facing our society are more present than ever. Despite containing harmful levels of CO_2, particulates and NOx that damage air quality and health, ‘diesel is still the primary global power source for industrial machines’ (OakTec, 2021). The energy sector is a critical focus area for improvement, contributing to approximately two thirds of global CO_2 emissions with fossil fuels accounting for 80% of current global primary energy demand (Foster & Elzinga, 2013). The focus on emissions reductions has gained further momentum, with the events at COP26 pressing policy makers and business leaders across the world to focus their efforts on reducing emissions, kickstarting the global energy transition.

The UK’s Move to Net Zero greenhouse gas emissions by 2050 has outlined the actions needed to meet the 1.5^{o}C warming target in the Paris Agreement (United Nations, 2021), with nearly 30% of the UK’s FTSE100 companies signing up to the United Nation’s Race to Zero (UK Government, 2021). The energy market is already undergoing significant changes, the IEA (International Energy Agency) estimates new low-emission industries will ‘flourish’ because of Net Zero, this idea supported by the growth of the renewable energy sector during the pandemic, compared to the decline in fossil fuel market share (REN21, 2021). Despite promising reports, continued increases of CO_2 in the atmosphere stresses the need for a structural and radical transformation in the energy industry to reach targets. The need for change in the global energy landscape opens a space for OakTec’s innovative low emission engine offerings to compete in the global energy market and create a viable opportunity to infiltrate a market that is ready to move towards a cleaner future.

OakTec are an SME [small and medium sized enterprise], who have developed highly innovative small gas and biogas engines to directly displace diesel equivalents in industrial and agricultural applications. These engines have significant emissions benefits over their diesel counterparts. In order to commercialise these clean innovative engines, a global business strategy is being developed that enables

transition from the commercial demonstration to a large-scale market operation. To achieve this, OakTec needs to refine its commercialization with a clear view of broad market opportunities and priority markets to develop a realistic business plan (OakTec, 2021).

1.2 Research Aims

This study will explore the process of commercialization, offering theoretical insight into how OakTec can navigate associated challenges, such as assessing market opportunities, and gaining in-depth knowledge about the needs of the customers within the pre-defined market segments.

The existing literature explores several challenges, barriers, and solutions of commercialization, and recognizes that innovation alone cannot contribute to the economy or solve the climate crisis (Pellikka, Kajanus, Heinonen, & Eskelinen, 2012). Commercialization is, in fact, the 'gap between economic value creation and economic value realization' (Prebble, De Waal, & De Groot, 2008). The literature emphasizes the specific challenges facing SME's, innovation, and high technologies. Various theoretical ideas are put forward, principally the Network Theory, in which the firm is viewed within a web of interconnected actors (Ford & Mouzas, 2010). This theory is useful in viewing OakTec within a system, against a backdrop of influences. The Network Theory can aid in asking, who are the relevant actors? What influence do they have? How are these actors engaged in a way most beneficial to OakTec? There is also a lack of research on how an SME can utilise its network as a core strategic priority, resulting in calls for research which this study aims to address. Research questions one and four will address these gaps by incorporating the Network Theory. Teece's Technological Commercialization Theory is used in research question two to explain the choices a firm makes within this network, based on their offerings and capabilities. Despite a recognition that SMEs are critical to our national economy (Banarjee & Cole, 2010), there appears to be a lack of research on the specific

challenges of SME'S and options available to them in the commercialization process. Research question three will address this gap.

The main research aim is:

To assess market opportunities, building on previous small pieces of market research focussed on the UK and Africa and other markets where the dynamic creates a viable opportunity. Further considerations of the report will include market segmentation, targeting, and positioning, business strategy development, and an assessment of the challenges and opportunities during the commercialization process.

To achieve this, the specific research questions are:

1. Using the Network Theory, how can an SME recognize the existing and latent needs in the pre-defined market segments? (Existing and latent needs for supply power for temporary buildings and sites, the waste management industry, and the agricultural community who require small power generation)

2. How can an SME utilise its offerings and capabilities to become key innovation players in the market?

3. What are the challenges faced by SMEs when commercializing a high technology?

4. What is the role of the network during the commercialization process?

1.3 Structure of Thesis

To research the above questions, the thesis is divided into six sections:

- Section 1: Brief overview of OakTec's innovative gas engines, and the challenges they currently face regarding the commercialization process.

- Section 2: Review of the existing literature, exploring the aims and challenges of commercialization, focusing on macro-level studies, before moving onto discuss the more specific, micro-level studies, which situate commercialization within specific challenges that relate to OakTec. This section also provides a theoretical underpinning for the themes discussed throughout the thesis.

- Section 3: Situates OakTec within a wider macro context, discussing socio-economic, environmental, and technological trends affecting OakTec and the business environment. This section also provides a description of the pre-defined markets of interest to OakTec, outlining the trends within these markets.

- Section 4: Explains the methodology, and why semi-structured interviews have been chosen for this study.

- Section 5: Presents and analyses the empirical research findings from a theoretical perspective, and contributions are made to the literature.

- Section 6: Puts forward recommendations, concluding remarks, limitations of the study, and implications for future research.

2 Literature Review

This chapter will cover a broad exploration of the literature, exploring specific areas relevant to this research. The chapter will begin by explaining the importance of commercialization and go on to interpreting the process of commercialization for the purpose of this research. An overview of the key concepts related to the topic will be given, such as the challenges that SMEs face through commercialization, the commercialization of high technologies, and various solutions of commercialization put forward by researchers, such as marketing and business strategy. The chapter will move on to explore associated theories, namely Teece's Technological Commercialization Theory, and the Network Theory. The latter part of the chapter will identify gaps in the knowledge and present a conceptual framework that focuses on several key theoretical constructs which will later be used to analyse the findings.

2.1 Commercialization of Innovation

Commercialization has been recognised as an essential element of technological innovation (Dodgson, 2000). Successful commercialization is critical in business, since 'technological improvements do not contribute to growth unless they are somehow commercialized' (Pellikka, Kajanus, Heinonen, & Eskelinen, 2012). The earliest discussions of commercialization are 'grounded in the evolutionary theory of the firm' (Gbadegeshin, 2019), with more recent research linking the process to a firm's business model (Teece D. J., 2010), marketing (Gans & Stern, 2003), and also from a strategic perspective (Slater & Mohr, 2006). It's theoretical and strategic importance can help sustain a firm's competitive environment upon entering the market with a new product or service. In recent years, the topic has been growing swiftly (Gourville, 2006), with a renewed importance placed on the process as businesses are under increasing pressure to survive in an increasingly competitive and interconnected global market.

Reviewing the literature uncovered multiple constructs of the term 'commercialization', these have been summarised and organised in the table below.

Theoretical construct	Focus	Reference
'The term 'commercialization process' refers to an essential element of the management of technological innovation'	Management Technology Innovation	(Dodgson, 2000)
Commercialization 'is at the intersection of innovation and entrepreneurship. It comprises processes and activities that bridge the gap between economic value creation and economic value realization'	Innovation Entrepreneurship	(Prebble, De Waal, & De Groot, 2008)
'Commercialization refers to the moment of entering the market and the distribution of innovation'	Innovation	(Zadeh, Khalilzadeh, Mozafari, Vasei, & Ojaki, 2017)
'How organizations mobilize the dissemination phase, where they scale up production and distribution networks in the context of new market creation'	New Market Creation	(Möller, 2010)
'Commercialization should not be measured through results (revenue/profitability), but as an influencing force facilitating innovation to cross the chasm to the market'	Innovation	(Pustovrh, Jaklič, Martin, & Raškovi, 2017)
'A commercialization strategy refers to the series of financing options that a founder or management team chooses to pursue in order to bring a technology from concept to the marketplace'	Finance	(Servo, 1998)
'The commercialization process is regarded as a procedure in which discovery and new ideas are converted into real products and services'	Innovation	(Gbadegeshin, 2019)
'Commercialization of high technologies refers to a process that transforms radical and disruptive innovations into consumable products, services and solution packages'	High-tech	(Gbadegeshin, 2019)
'The process of turning an idea or invention into a useful product or service'	Innovation	(Rosa & Rose, 2007)
'The series of activities involved in taking the R&D of an organization to an industry'	Innovation	(Cornford, 2002)
'When a business identifies a way to use scientific or engineering advances to meet a market need. The process continues through design, development, manufacturing start-up, and marketing – plus all subsequent efforts to improve the product'	Innovation	(Nevens, 1990)

‘Technology commercialization refers to the translation of technological capabilities into beneficial products and services that increase profit and/or social welfare’	High-tech	(Zadeh, Khalilzadeh, Mozafari, Vasei, & Ojaki, 2017)
‘Commercialization of technology involves any possible configuration or scheme that allows those who invest in technological innovation to capture some of the economic benefits generated by their innovation’	High-tech	(Kalaitzandonakes, 1997)

Table 2.1.1 - Constructs for the term commercialization

The definition focused on high-technologies from (Gbadegeshin, 2019) was chosen for the purpose of this thesis, as it recognises the disruptive nature of innovations, whilst also separating science from business (Fletcher & Bourne, 2012). Further, (Nevens, 1990) definition encompasses all activities in and around economic value creation that are involved with introducing new, innovative, high-technology products into the market, emphasising the holistic overview needed to approach the process. During their research, (Gbadegeshin, 2019) adds that ‘establishing a sustainable business is one of the primary objectives of commercialization’ which is a critical point to keep at the forefront. Reflecting on these definitions, the terms ‘innovation’ and ‘high technologies’ crop up periodically. To prevent confusion between the two terms, both concepts are defined in table 2.1.2 below. The definition of eco-innovation has been added due to the sustainability aspect of the thesis.

Term	Definition	Reference
Innovation	‘The process of making changes to something established by introducing something that adds value to customers’	(O'Sullivan & Dooley, 2013)
Eco-Innovation	‘Any form of innovation resulting in significant progress towards the goal of sustainable development, by reducing the impacts of our production modes on the environment, enhancing nature’s resilience to environmental pressures, or achieving a more efficient and responsible use of natural resources’	(European Commision, Directorate-General for Environment, 2013)
High Technologies	‘Any industry whose new product or service could disrupt people’s lives’	(Gbadegeshin, 2019)

Table 2.1.2 - Definitions of the terms; Innovation, Eco-innovation, and High Technologies

One of the key differences to point out between the two terms is that innovation is the human-centred perspective (Callegaro, 2017) and can include intangible aspects, whereas high technologies are the tangible outcome of innovation. High technologies can introduce aspects of complexity and newness into the commercialization process, which can result in high uncertainty (Pustovrh, Jaklič, Martin, & Raškovi, 2017). As mentioned, successful commercialization is critical for the long-term sustainability of any business (Gbadegeshin, 2019). High technologies themselves cannot sustain markets or create national wealth (Zadeh, Khalilzadeh, Mozafari, Vasei, & Ojaki, 2017), but through a plan of commercialization, it must be accepted, adopted, and diffused into the market, where economic revenue can be generated.

2.2 The Challenge of Commercialization for SMEs

The success of commercialization has also been emphasised through its high failure rate (Cooper, 2011). After reviewing the literature, table 2.2.1 below outlines the main challenges associated with the commercialization process. This section informs research question three, as it discusses the various known challenges faced by SME's during commercialization.

Internal	External
Marketing	Business Environment
Resources	Increased competition
Planning and Management	Changing consumer needs
Patent Filing	Growing tech opportunities
Motivation	Policy and regulation
Human Resources	New to end users and lack standardization
Financing	Third-party certification
Failure to attract support of shareholders and stakeholders	Refusal to accept new technologies
	Interconnectedness of high-tech markets
Poor understanding of the commercialization process	High failure rate in innovation process

Table 2.2.1 - The main challenges associated with the commercialization process (Gbadegeshin, 2019), (Pellikka, Kajanus, Heinonen, & Eskelinen, 2012), (Al Natsheh, Gbadegeshin, Rimpiläinen, Imamovic-Tokalic, & Zambrano, 2015), (Talke & Hultink, 2015), (Gourville, 2006), (Meyers, 2020), (Zadeh, Khalilzadeh, Mozafari, Vasei, & Ojaki, 2017) and (Tabatabaian , Naseri, & Forghani, 2007)

(Gbadegeshin, 2019) goes further to discuss the specific challenges related to 'high tech' commercialization, which can be defined as 'the translation of technological capabilities into beneficial products and services that increase profit and/or social welfare' (Zadeh, Khalilzadeh, Mozafari, Vasei, & Ojaki, 2017). Their 'complexity and newness' can produce increased uncertainties (Steehuis & De Bruijn, 2006). Due to this elevated complexity, the process for high technologies can be resource intensive, and involve high levels of R&D (Steehuis & De Bruijn, 2006). If commercialized successfully, these technologies can become radical disruptions in the market, which can create a huge source of competitive advantage (Porter, 1990), and potentially have a discontinuous impact on other technologies in the market. In fact, it has been noted that the commercialization of high technologies plays a significant role in the national economy (Banarjee & Cole, 2010). It has been agreed that there is no 'one size fits all' approach to commercialization, as each case is 'unique in space and time' (Ford & Mouzas, 2013), however multiple solutions have been put forward to aid navigation through the process, a few of which are mentioned below.

- External links with local innovation support; inter-organizational collaboration and business networks (Pellikka, Kajanus, Heinonen, & Eskelinen, 2012)
- Provide and exchange resources through relationships (La Rocca, 2011)
- Role of external relationships and networks; dyadic partnerships and multi-actor alliances (Brunswicker & Van De Vrande, 2014)
- Alliances and partnerships, specifically useful on the global market (Meyers, 2020)
- Diverse network actors to contribute to innovation development (Ritter & Gemunden, 2003)

The solutions given above stress the need for external connections outside of the SME during commercialisation and can aid us in acknowledging the importance of the development of business networks. External connections may be especially important for an SME as, due to their size, are more likely to lack financial, material and resource factors, be lacking in marketing knowledge (Meijer, Hujiben, Van Boxstael, & Romme, 2019), and have limited contact with external stakeholders (Carayannopoulos, 2009). SMEs, especially those who specialise in technology, are often overlooked during the commercialization process (Pustovrh, Jaklič, Martin, & Raškovi, 2017), which is

puzzling due to the ‘pivotal role’ they play in the economy as the primary drivers of innovation commercialization (Meyers, 2020). Further, more than 99% of all businesses in Europe are SMEs (European Commision, Directorate-General for Environment, 2013), emphasizing the need to study them. All these factors can increase barriers to commercialization. However, some scholars have put forward that the SMEs lack of experience may be exactly what drives the firm to succeed, and the challenges that young firms face often turn into competitive advantages (Carayannopoulos, 2009). According to these solutions, external networks can aid the SME in successful commercialisation.

Larger, more established firms may be more reluctant to change, and be ‘set in their ways’ with significant investments in their current business model, strategy, and operations, which may make it difficult to implement mass change (Carayannopoulos, 2009). These firms can be described as ‘defenders of the market’, whereby the firm focuses on its existing products and tries to defend its market share by ‘offering superior quality, low prices, and strong customer service’ (Oxford References). Fiegenbaum and Karnani propose that, due to their size, young firms can explore and move faster, allowing ‘greater flexibility to perform in volatile environments’ (Fiegenbaum & Karnani, 1991). Recent research has suggested that SMEs are outpacing their larger counterparts, able to move faster, dip in and out of markets and reconfigure their structure, to move with the market. For these reasons, (Choi & Shepherd, 2005) argue that youthfulness is in fact an asset, which may attract investment and partnerships. Large firms ‘often lack scientific understanding necessary to evaluate radical new technologies’ (Kim, 2016). Due to their size, smaller firms may be perceived to lack legitimacy and not be seen as a threat, and therefore ‘maintain low visibility from the perspective of the incumbent it will eventually challenge’ (Suchman, 1995) and (Carayannopoulos, 2009).

2.2.1 Network approach to SME

Previous research has largely ignored the role of the SME in commercialization (Pustovrh, Jaklič, Martin, & Raškovi, 2017), however the literature suggests that the networking approach may be particularly useful for the SME, who may initially lack the resources necessary to commercialize. The initial connections made between actors at the early stages of commercialization are critical for obtaining experiences and knowledge, which can lead to capability developments (Ford & Mouzas, 2013).

Since lack of knowledge has been identified as one of the top reasons for failure in commercializing high technology (Tabatabaian , Naseri, & Forghani, 2007), it merits discussing the learning and knowledge aspect of networking. When immersed in a dense network of knowledge-intensive exchanges, knowledge and learning capabilities are enhanced, with the objective to provide understanding and descriptions of the focal markets of interest (Storbacka & Nenonen, 2015). This will allow the firm to develop 'network thinking' (Moller, 1992). Further, it will help the focal firm to understand systems of relationships from their perspective, and from a holistic network perspective, allowing the firm to step outside their internal bubble, and create a 'proper conceptualization of major developments in trends' (Gans & Stern, 2003).

Networks are knowledge-rich environments, with 'superior information processing capacity' (Achrol & Kotler, 1999), perhaps due to reduced barriers between actors in the interconnected network. The literature suggests that whilst established firms may prefer capital-intensive resources, young SMEs are encouraged to choose the knowledge-intensive resource (Van De Vrande, De Jong, Vanhaverbeke, & De Rochemont, 2009) with views of increasing market knowledge, and gain understanding of the unique quirks of the focus industry, which may be more valuable when formulating the business strategy. Research has also suggested that enhanced learning capability may also improve decision making, leading to quicker reaction times in the market, which can lead to a competitive advantage (Vossen, 1998) and give the SME an opportunity to spread knowledge within the network and 'educate others on the benefits of an innovation' (Kelly, 2020).

Scholars argue that internal and, perhaps more importantly, external networks facilitate marketing high technologies (Cooper L. , 2000). Networks are crucial for marketing, they are a communication channel within the network where firms can interact with actors (Knight, 2000), and provide critical connections, from a knowledge perspective. (Zadeh, Khalilzadeh, Mozafari, Vasei, & Ojaki, 2017) argue that commercialization requires collaborative efforts between actors to accomplish marketing tasks. A network can provide the firm with options for outsourcing their marketing activities, or the opportunity to form a marketing alliance to help commercialize (Giuri & Luzzi, 2005). (Borg, 2009) has emphasized that the efforts of actors within the network [suppliers, potential customers, government] can help to 'mitigate the risk of market failure of high technologies.'

2.3 Towards a Conceptual Framework

The main theories that will be used as a theoretical underpinning for the research conducted in this study are The Network Theory, and Teece's Technological Commercialization Theory, which will be discussed in the following section.

2.3.1 Markets as Networks

The Network Theory can be used as a theoretical underpinning for the research conducted in this study. It has been long understood that climate change is not a problem to be solved on an individual, firm level scale, but businesses must work together to mitigate the change. The network approach is a theoretical perspective used to capture the 'ever-increasing connectivity and interdependence in the business landscape' (Finke, Mouzas, & Gilchrist, 2015). Businesses do not operate in an isolated environment. In fact, there are multiple factors influencing business decisions and its subsequent outcomes daily. To understand business, one must first understand the environment in which it operates and the factors influencing its decisions. Network relations in commercialization have attracted 'surprisingly little

attention' (Aarikka-Stenroos & Sandberg, 2012), but it is beginning to receive more attention within fields such as entrepreneurship, strategy, and industrial network research (Tikkanen, 1998). Within the network approach, divergent actors are identified and layered, which form a 'large pattern of activities, constellation of resources and web of actors' (Ford & Mouzas, 2010). The Network Theory views the firm within this web of interconnected actors and interacting relationships through which knowledge and resources and can be exchanged in a dual-way relationship. This interaction can be explained through the ARA model, which depicts the network through a structure of Activities, Resources and Actors (Snehota & Hakansson, 1995), which is a 'model of managing in business network.'

2.3.2 Teece's Technological Commercialization Theory

Teece's Technological Commercialization Theory is a framework of dynamic capabilities which offers a detailed insight on the capabilities a firm may possess and how this may affect their choices in the commercialization process. According to Teece, a firm's dynamic capabilities are 'the firm's ability to integrate, build and reconfigure internal competencies to address, or in some cases to bring about, changes in the business environment (Teece, Pisano , & Shuen, 1997). Dynamic capabilities are multi-faceted (Teece D. , 2018), and build on a firm's core competencies, which are the everyday processes that define the firm's fundamental business as core (Teece, Pisano , & Shuen, 1997). A firm with multiple dynamic capabilities may be better prepared to respond to turbulent environments, able to reconfigure its competences to move with the speed of the market, which can lead to a competitive advantage. Dynamic capabilities can take a long period of time to form, and are likely to be inimitable, for example technical ability or strong leadership. This framework is useful in the case of commercialization because it helps to explain which opportunities a firm may seize according to their capabilities. This framework also is also important when thinking about the business strategy, in that the strategy should align with the firm's capabilities.

(Sapienza, Davidsson, & Zahra, 2006) suggest that SME's need 'unique and dynamic capabilities to survive, achieve legitimacy, and reap benefit of their innovation'. (Van

De Vrande, De Jong, Vanhaverbeke, & De Rochemont, 2009) adds that one of these capabilities which may be crucial for an SME is its learning capability, which can be defined as 'the organizational and managerial characteristics or factors that facilitate the organizational learning process or allow an organization to learn' (Goh & Richards, 1997). R&D and learning capability are significant drivers of technology commercialization, and a firm's learning capability can be viewed as an inimitable dynamic process (Pellikka, Kajanus, Heinonen, & Eskelinen, 2012). Due to lack of resources and experience in the market, young firms may be encouraged to take the learning approach, where they can develop experience which will turn into 'organizational knowledge' (Tsoukas & Vladimirou, 2001). Young firms may have learning advantages over their larger counterparts, as they have less to unlearn (Yi Renko, Autio, & Sapienza, 2001) and a high learning capability is likely to benefit the SME throughout the commercialization process, which can lead to a competitive advantage. (Calantone, Cavusgil, & Zhao, 2002) suggest that organizations with superior learning capability are more likely to meet customer demand. Further, firms who excel in learning can interpret customer responses in a culturally appropriate way (Servo, 1998), which is crucial for SME's who are looking to internationalize.

2.3.3 The ARA Model

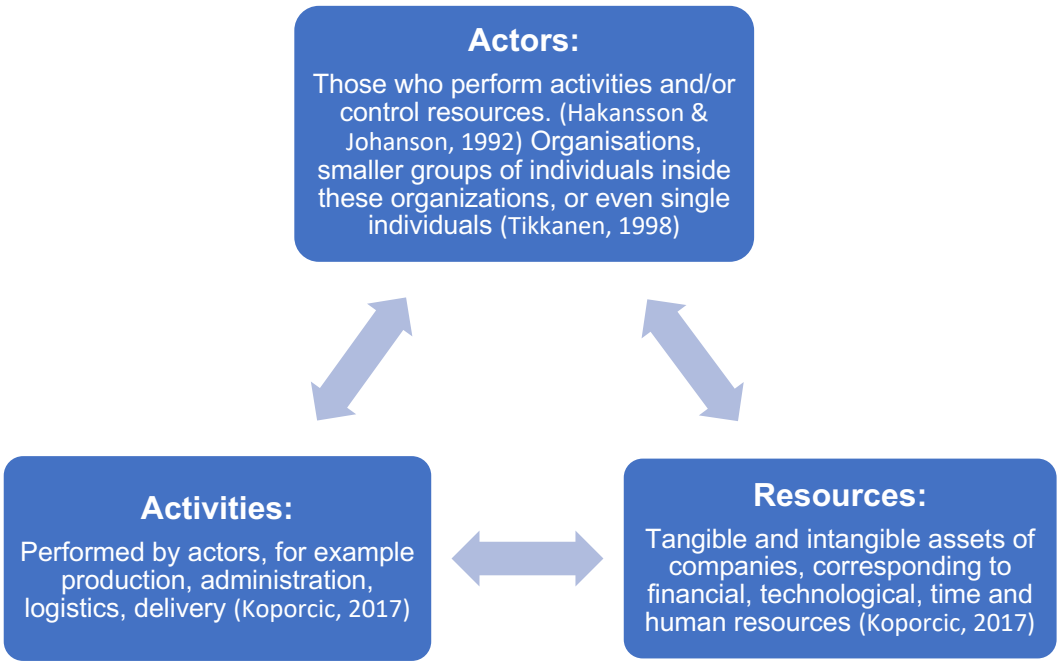


Figure 2.3.1 - Diagram of the ARA Model adapted from (Tikkanen, 1998), (Hakansson & Johanson, 1992) & (Koporcic, 2017)

The arrows in figure 2.3.1 represent the dual-way interdependence between the elements, stressing the importance of interaction within the model (Ford, Gadde, Hakansson, Snehota , & Waluszewski, 2008). It is these interactions that form the network and the environment within which the business operates. Understanding the process of networking can lead to multiple advantages for the focal firm. Viewing the firm within the network context will allow the firm to create and capture value through its interaction between network connections.

Networking is crucial during the commercialization process, as connecting with multiple actors can create options (Mouzas, 2006). Options can take the form of potential alliances, joint ventures, contracts, and other strategic moves. The business environment in which the firm operates is often extremely volatile, with the future often uncertain. This can be especially true in new, or niche markets. The sociologist Hofstede puts forward the idea of uncertainty avoidance, which relates to 'the level of stress in a society in the face of an unknown future' (Hofstede, 2011), which can be related to the Network Theory. High level uncertainty avoidance is a cross-cultural term which reflects the degree to which a firm can cope with uncertainties. The Network Theory suggests that the more connections available to the firm within the web of networks, the higher the firm's uncertainty avoidance and the better the firm will be able to navigate unpredictable environments. Options can also be viewed as capabilities (Mouzas, 2006), which may present opportunities 'down the line'. (Partanen, Chetty, & Rajala, 2014) suggest that options in a network can be sorted into a portfolio of relations, including 'suppliers, distributors, customers, and research institutes (Partanen, Chetty, & Rajala, 2014), and any other relation that may add value, which will help firms acquire resources to commercialize radical innovations. It has long been understood that there is no silver bullet solution to commercialization, therefore more options in the network may allow the firm to leverage its position in the market, uncover new opportunities, reconfigure its value chain and gain a competitive advantage.

2.4 Literature Gaps in The Commercialization of Innovative Products by SMEs

This chapter has described and summarised the major contributions to the literature surrounding commercialization of SMEs. After a thorough review of the available literature, the major gaps in the knowledge for the commercialization of high technologies for an SME have been identified.

The first gap identified was how an SME can use their network as a core strategic priority. This includes using the network to recognize the needs in the market. Research question one will aim to gain insight on how SMEs can use their network to recognize market needs.

As stated earlier in this chapter, previous research has largely ignored the role of the SME in commercialization (Pustovrh, Jaklič, Martin, & Raškovi, 2017). This gap also relates to their role as key innovation players in the market. Research question two will aim to address how an SME can utilise its offerings and capabilities to recognise and exploit the unique opportunities which may be available to them, which will allow them to learn how to become key innovation players in the market.

Scholars have recognised the important role that SMEs play in our national economy (Banarjee & Cole, 2010), and touched upon the potential challenges and solutions facing an SME during commercialization. However, there appears to be a lack of empirical evidence on the specific challenges SMEs face when commercialising high technologies, can recognise and exploit the unique opportunities which may be available to them, especially when the SME is in the process of developing high technologies, which adds a layer of volatility. Research question three will aim to address this gap by understanding the challenges faced by an SME when commercialising a high technology.

The final gap relates to understanding how an SME can use their network to enable the commercialization of their high technologies. There is a lack of empirical understanding on the role of the network during the commercialization process (Fletcher & Bourne, 2012). Whilst it is agreed that recognising the firm within the network is beneficial for providing options and enhance learning capabilities, there

appears to be a lack of empirical of evidence that SMEs are recognising their network as a core strategic priority.

3 Industry and Context

As discussed in the literature review, it is essential to understand the environment that OakTec operates in, and the many factors affecting the firm. This chapter first discusses the macro-environment, which is separated into environmental, societal, and business and technology trends. This section also describes current trends which are likely to influence OakTec and the wider world, such as the Move to Net Zero and its role in the Energy Transition, the rise of renewable energy, and the Energy Trilemma. The chapter then briefly touches upon the current markets of interest for OakTec's engine offerings, which are currently being used to power small scale applications, which are biogas generators in Sub-Saharan Africa and India, and LPG and hydrogen hybrid gensets in the UK.

3.1 Macro Trends

3.1.1 Environmental Macro Trends

Our overwhelming dependency on the environment has put a strain on the Earth's natural resources, which has undoubtedly caused the increased levels of greenhouse gas emissions we are experiencing today. The term global warming was first coined in 1975 by US scientist Wallace Broeker (Stewart & Rhodes, 2017). Since this date, the global surface temperature has risen by around 1.07 °C [Best average], the oceans have warmed, glaciers have retreated, and global average precipitation has risen, to name just a few observed effects (IPCC, 2021). These alarming, human-induced trends have created what we know today as climate change. Climate change can be defined as:

"*A broad range of global phenomena created predominantly by burning fossil fuels, which add heat-trapping gases to Earth's atmosphere. These phenomena include the increased temperature trends described by global warming, but also encompass*

changes such as sea-level rise; ice mass loss in Greenland, Antarctica, the Arctic, and mountain glaciers worldwide; shifts in flower/plant blooming; and extreme weather events." (Nasa , 2019).

The pie chart below summarises the most prominent environmental trends affecting OakTec today. The data focuses on global energy trends as they will have the most direct effects on OakTec's business activities and decisions.

Pie Chart of global greenhouse gas emissions by sector, 2016

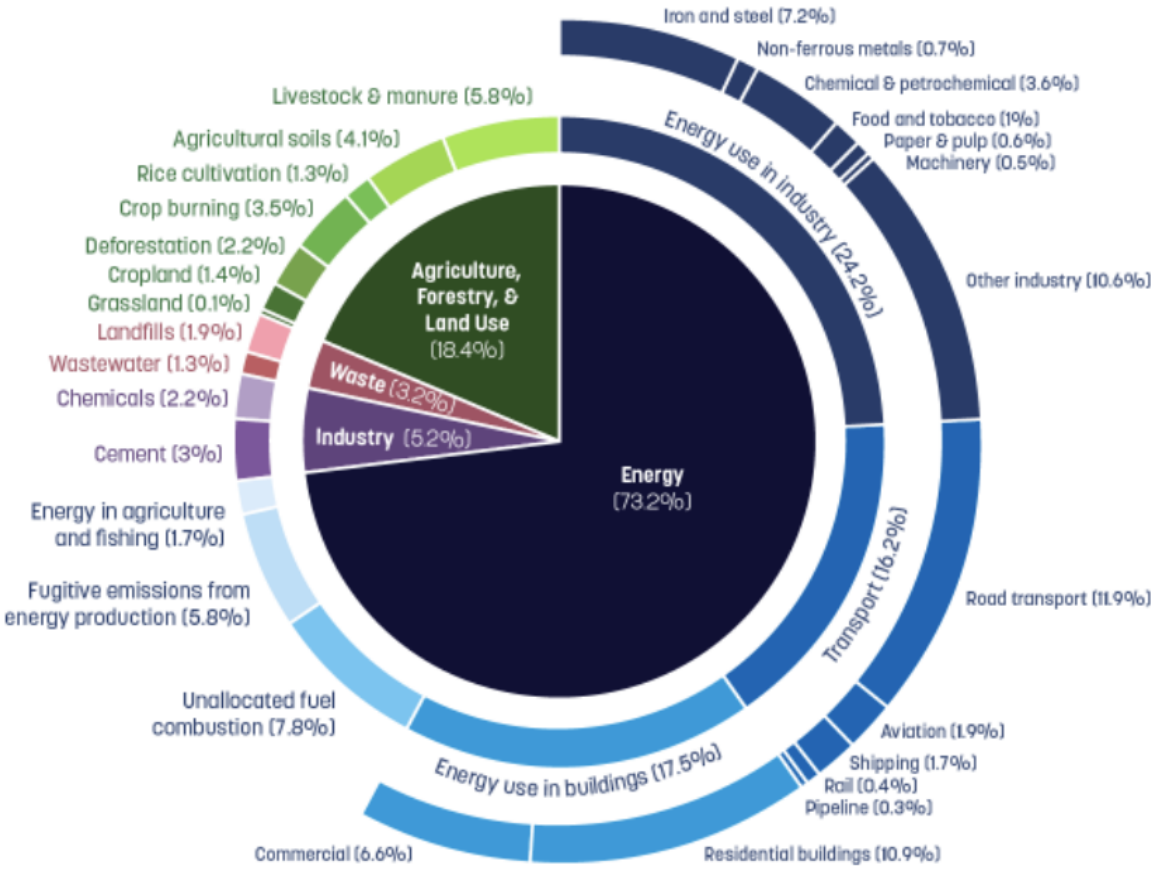


Figure 3.1.1 - Pie chart of global greenhouse gas emissions by sector and sub-sector retrieved from (Ritchie, 2020)

As can be seen in figure 3.1.1 above, energy production is by far the largest emitter of global greenhouse gases, accounting for nearly ¾ of the world's emissions. OakTec and partners aim to directly penetrate the energy generation market and reduce global

GHG emissions with their clean gas technologies, which aim to reduce fossil fuel dependency and improve modern energy access. The burning of fossil fuels for these sectors of energy production has allowed rapid development, but at a dire cost, becoming the single largest contributor of greenhouse gases, accounting for almost three-quarters of global greenhouse emissions since pre-industrial levels (Ritchie, 2020).

Regional Electricity Generation by Fuel 2020

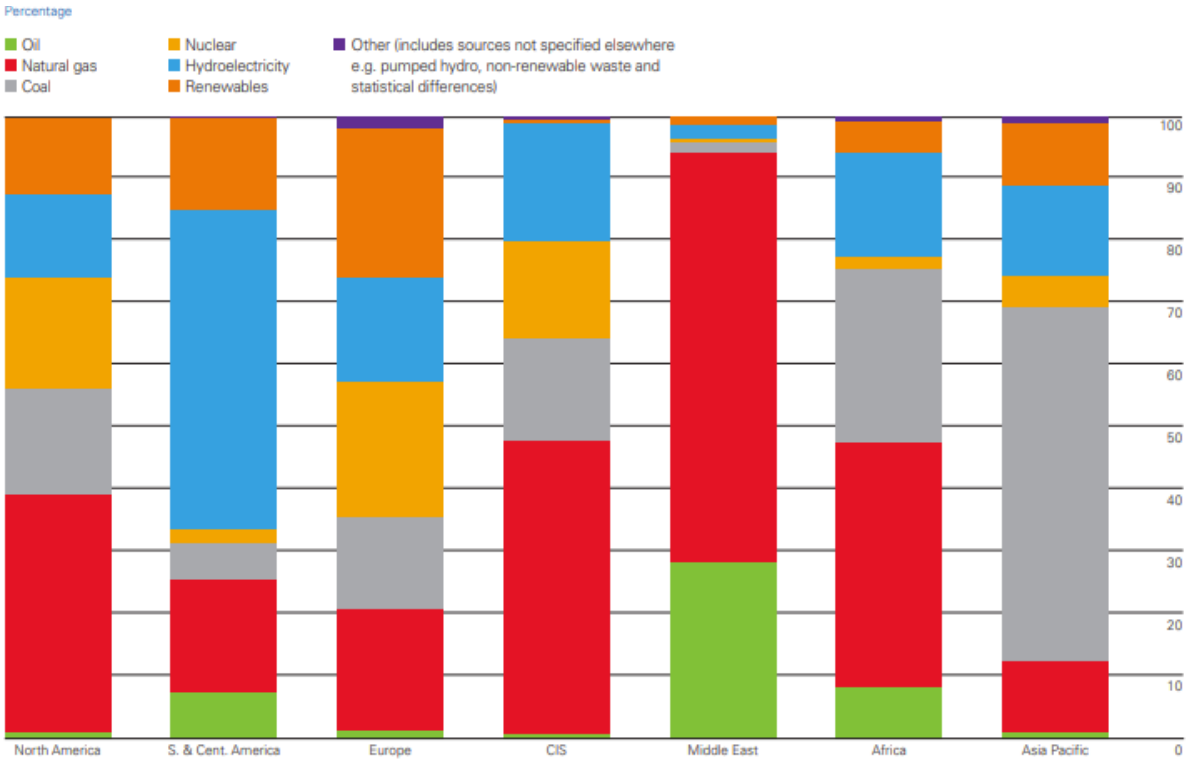


Figure 3.1.2 - Graph of regional electricity generation by fuel 2020 retrieved from (British Petroleum , 2021)

Figure 3.1.2 depicts the carbon intensity of electricity generation in 2020. In the Asia Pacific region, coal is the most common fuel used, generating over half of the region's electricity. Whereas energy production in Africa, North America, CIS, and the Middle East is dominated by natural gas. The figure clearly shows that a large portion of the world's electricity is produced using fossil fuels. The United Nations IPCC Special Report 2021 gives us 'until 2030 before climate change becomes irreversible' (IPCC, 2021). Concentration of CO_2 reached 413.2ppm in 2020, with half of all CO_2 emitted by humans today remaining in the atmosphere, straining carbon sinks (World

Meteorological Organization, 2021). Further adverse effects include '*sea*-level rise; ice mass loss in Greenland, Antarctica, the Arctic, and mountain glaciers worldwide; shifts in flower/plant blooming; and extreme weather events' (Nasa , 2019). Climate change concerns everyone, and if systematic change is not implemented on a global scale, a world 2 °C hotter could see millions living in a hostile environment. The recent events at the COP26 meeting in Glasgow have amplified the need for action amongst nations, in the emerging era scientists are now calling a 'climate emergency' (Ripple W. , et al., 2019).

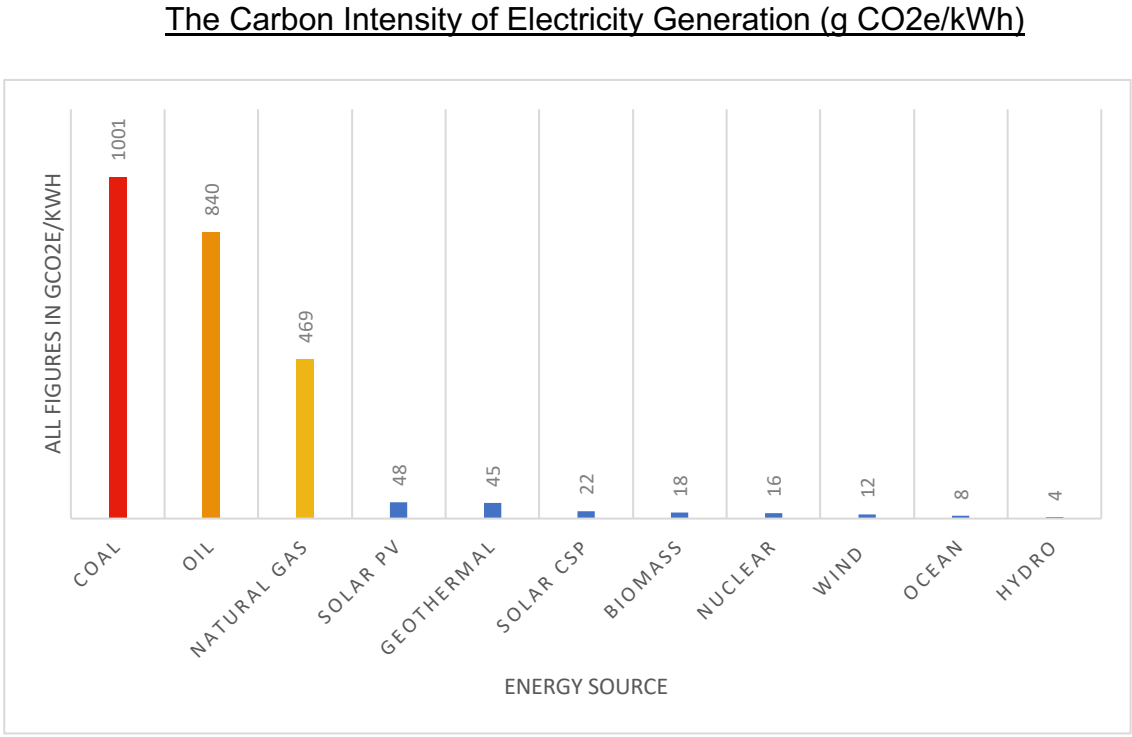


Figure 3.1.3 - Bar chart of the carbon intensity of different types of energy generation (Edenhofer, Madruga, & Sokona, 2012)

Figure 3.1.3 depicts the level of CO_2 per kWh of electricity produced, by each type of energy generation. Coal, oil, and natural gas are seen to emit substantial amounts of CO_2 per kWh of electricity produced, compared to other electricity generation methods.

Despite a 1.1% decrease in global electricity consumption in 2020, demand is beginning to rise again (International Energy Agency, 2020), with fossil fuels still leading the energy supply significantly. According to the IEA, nearly three-quarters of

global emissions reductions between 2020-2025 will take place in this sector, with predictions that 'half of our improved carbon efficiency in energy by 2050 will use technology that exists now as prototypes'. Consumption of solar and wind energy has increased by 57% between 2018-2021 but is still 19 times smaller than fossil fuel consumption. Hydropower, bioenergy and geothermal combined will increase nearly 2.5 times from 2020-2050 (Ripple W. , et al., 2021).

3.1.1.1 Phase 4: Energy Trilemma and Renewable Energy

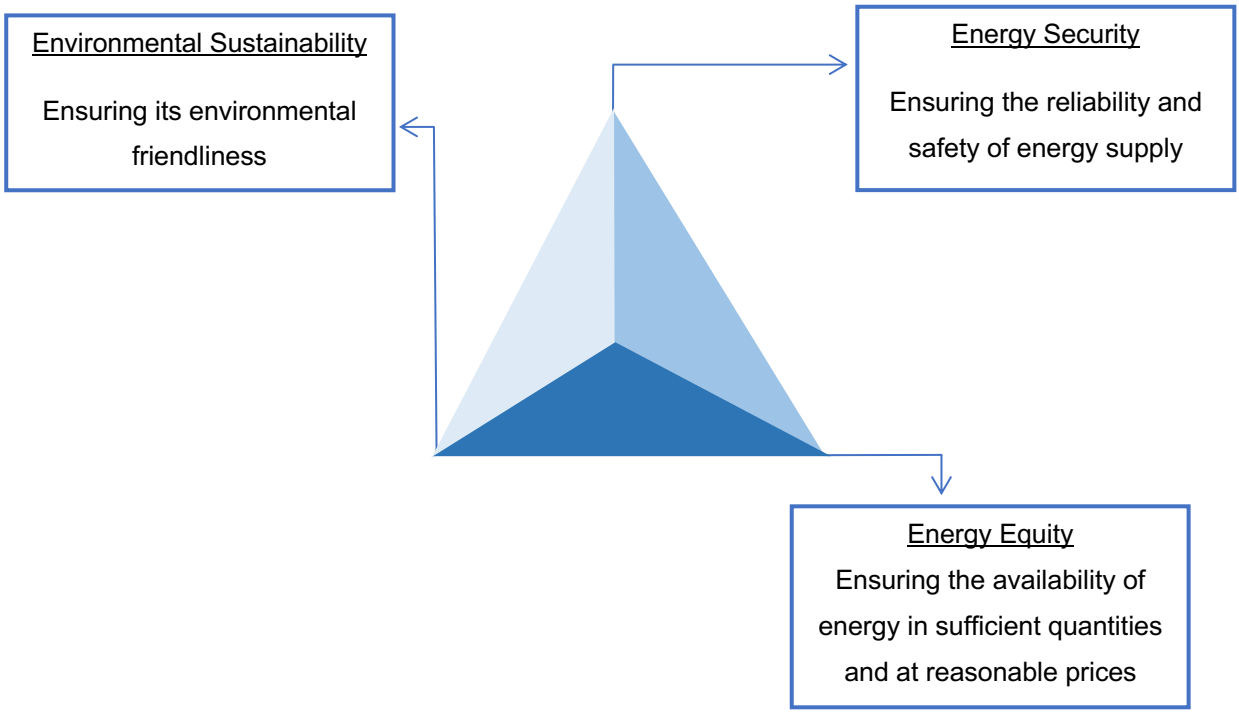


Figure 3.1.4 - Diagram of the energy trilemma (Grigorvev & Mezhidova, 2020)

Figure 3.1.4 demonstrates the three pillars of the Energy Trilemma, and the often-competing demands named in the diagram. The Energy Trilemma is especially relevant for developing countries, such as Sub-Saharan Africa, a market of interest for OakTec, that experiences higher levels of energy poverty. Energy poverty defined as inaccessibility to modern energy services (Dong, Jiang, Shahbaz, & Zhao, 2021). Global energy targets, forecasts, and scenarios often take into account the energy

balances listed in the diagram, along with ‘inherent natural resources, invested physical capital, and accumulated human capital‘ (Grigorvev & Mezhidova, 2020).

3.1.2 Societal Macro Trends

This section will briefly discuss changing global demographics, and how this is likely to impact the global energy market, digitalization, and rapid urbanization, and how these will impact the energy market.

The global population currently stands at 8 billion and is expected to rise by a further 2 billion in the next 30 years (United Nations, 2019). Estimates suggest that global GDP could double by 2050, with the economic centre of gravity shifting towards Asia and Africa (PWC, 2017). These regions are also expected to witness the highest levels of population growth, with the Sub-Saharan population expected to double in this time frame (United Nations, 2019), resulting in rapid urban development and increasing numbers of megacities. The ‘sustained increases in both human and ruminant livestock populations’ (Ripple W. , et al., 2021) will create increased pressures on the environment and increase the demand for energy. Fuel is vital for this progress, and the challenge of achieving this development sustainably is the focus of many global societies. Further, climate change is set to push over 132 million people into poverty (International Finance Corporation, 2019), stressing the need for sustainable energy solutions. Whilst it is generally agreed that the world is becoming more interconnected through globalization, many aspects of our societies are still divided. Through increasing urbanization, over 5 billion people are expected to live in towns and cities by 2030 (United Nations, 2019). Simultaneously, by 2030, 359 million people [63% of the world’s poor] will be living in extreme poverty (Baier, Kristensen, & Davidsen, 2021), predominantly in rural areas. This is likely to intensify the Energy Trilemma and emphasize the urgent need for clean energy solutions.

3.1.3 Business and Technological Macro Trends

The increasing threat of fossil fuel depletion combined with the social and environmental impacts of climate change, means that 'business as usual' is no longer an option. Friedman argues (Friedman, 2007) that the main function of a business is to create profits. However, because of increasingly stringent emissions policies and heightened consumer awareness surrounding the real effects of business activity, those who do not consider the environment are 'accumulating steepening social and economic costs' (Harvard Business Review, 2007). Improved supply chain transparency has increased public awareness and placed environmental issues as a priority for consumers. These conscious consumers are creating an appetite for change those businesses must respond to. Since consumer demand is a major driver of the market, businesses are responding to this new held accountability in the form of sustainable innovation. Climate change is permeating every aspect of global business in the wider world and is becoming one of the most influential business trends of the recent decades. Climate change is also creating economic opportunity for business, as they seek sustainable alternative methods throughout the supply chain.

3.1.3.1 Agricultural Innovation

According to (Jenkins, 2021), 'local pollution, degradation & scarcity creates innovation'. For this reason, one of the most prominent trends in technology is innovation in the agriculture sector, a sector which accounts for 4% of global GDP (The World Bank, 2022). Over two thirds of the world rely on agricultural activity as a main source of income (The World Bank, 2022), and historical unsustainable agricultural activities have led to soil degradation, loss of natural ecosystems, and water contaminants (Donohoe, 2003). Agriculture is the second largest contributor to global GHG emissions, after energy production (Schindler & Hecky, 2006), giving further reason to focus on this sector. OakTec's innovative biogas technology could have a direct effect on lifting those in rural areas out of poverty. According to the World

Bank agriculture is ‘one of the most powerful tools to end extreme poverty, boost shared prosperity, and feed a projected 9.7 billion people by 2050’ (The World Bank, 2022).

3.1.3.2 Linear and Circular Economy

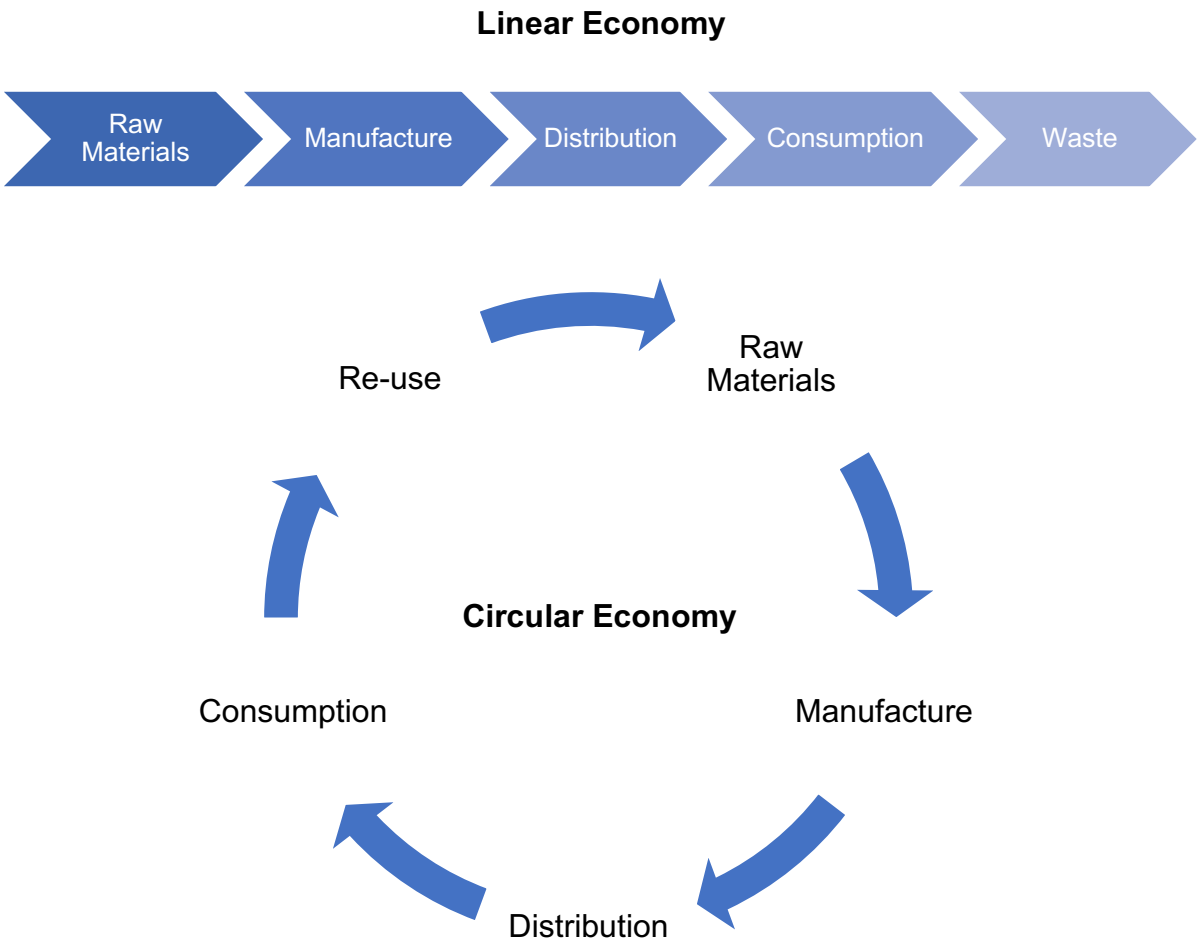


Figure 3.1.5 - Diagrams of linear and circular economy retrieved from (Task, 2018)

Businesses have historically followed the linear economy model, ‘take-make-dispose’, with emphasis on the end step, where waste is discarded (Gale, 1989), as inferenced in figure 3.1.5. The circular economy aims to redesign the product life cycle, and rethink how waste products are managed. The IPCC estimates waste accounts for 3% of GHGs, largely from methane emissions from landfill sites (Bogner, et al., 2007).

Waste management has strong links to many global challenges: ‘health, climate change, poverty reduction, food and resource security and sustainable production and consumption’ (UNEP, 2015). In 2018, poor waste management saw 146.1 million tonnes of municipal solid waste arriving in landfill (EPA, 2018). Landfill causes multiple adverse impacts on society, often causing problems like pest infestations, whilst also being a huge contributor to GHGs, with their ‘elevated’ content of methane (Balat & Balat, 2009). Methane is the second largest contributor to GHGs, after CO_2, and has 28 times the warming potential (Zhao, 2019).

The effects of waste may not be seen for many in daily life, therefore ‘out of sight, out of mind’ attitudes have been adopted, however, Zero Waste is a ‘holistic’ (Hamid, Skinder, & Bhat, 2020) approach of challenging these views and addressing unsustainable waste management, seeking to gain value from waste. The trend has become popular amongst the global waste management industry, who have sought to creates resources from this problem - ‘in nature, everything has its use’ (Gaudig, Ebersberger, & Kuckertz, 2021). Further, turning waste into a resource was one of the key objectives of the EU’s Roadmap to a Resource Efficient Europe (United Nations, 2021).

3.2 Specific Markets and Participants

The following section will give insight into the existing markets of interest and developing market segments for OakTec. The engines are currently being trialled in biogas generators, and LPG and hydrogen hybrid gensets, ranging from 3-50kW. These engines have the aim of directly displacing diesel generators. Given their power output, the product offerings will compete in the small power generation market. The first product discussed is the CAGE 6BM. The second part of this section will discuss the CAGE 6PG and the CAGE 25PG, whilst touching on OakTec’s hydrogen offerings. An overview of the global portable generator market is given below in table 3.2.1.

Fleet Size		Generation Capacity	% of fleet
Global	25 million	-	100
Small petrol	20 million	<60kW (typically < 6kW)	~80
Small diesel	5 million	< 60kW (typically > 8kW)	~20
Medium and large diesel	<500,000	>60kW	<2
75% of generators in the global fleet are in on-grid areas, serving as back up due to unreliable grid connection			

Table 3.2.1 - Global portable generator market fleet size apart from broken grid and carbon trust 2016

Market Growth

- Global portable generator market size is estimated to be around $15 billion with predicted growth by 2023 to $23 billion.
- Annual spending on diesel and petrol generators is $30-$50 billion.
- Average service cost in developing countries is $0.30kWh for fuel (double the price of electricity from the grid)
- Full cost of generator service in developing countries estimated to be between $0.40 – several dollars per kWh in the most remote locations.

(International Finance Corporation, 2019)

Key Market Drivers

- Rise in energy equipment due to rapid urbanisation and industrial development
- Rapid shift towards low emission energy equipment (Allied Market Research, 2022)
- Globally increasing fossil fuel taxes (Muvhiiwa, Hildebrandt, Chimwani, Ngubevana, & Matambo, 2017)

- Unreliable grid connection (Muvhiiwa, Hildebrandt, Chimwani, Ngubevana, & Matambo, 2017)
- Increased awareness around natural gas as a clean and reliable fuel
- Increased demand from the construction, telecom, retail, and commercial sector
- Increasing opportunities in emerging economies with increasing need for power

Globally, one billion people do not have access to electricity, with 840 million more living with unreliable grid connection. Those living with no or unreliable grid connection live primarily in developing countries, where most generators are intended to serve as back-up, however in many regions in these countries, continue to serve as the primary source of power. The fleet size in developing countries has a total capacity of 350-500GW [equivalent to 700-1000 large coal-fired power plants], occupying 20-30 million individual sites. This generates 100-170TWh of electricity annually (International Finance Corporation, 2019).

3.2.1 Market Focus for the CAGE 6BM (Biogas Generator)

Focus product	Power rating	Fuel	Current market of interest
CAGE 6BM	6kW	Biomethane [CO_2 can range from around 10-60% depending on the anaerobic digestion system, feedstocks, etc]	Sub-Saharan Africa India

Table 3.2.2 - OakTec's biogas generator (CAGE 6BM)

Market Segmentation Factors

- Need for small scale power generation
- The scale of agricultural production
- Means of financing
- Areas with high ambient temperatures

OakTec engines connect directly to the anaerobic digester that converts bio waste to gas fuel, with one generator suitable to power the energy needs of remote, off-grid communities and suited for use in a household-scale biogas generator. The current markets within OakTec's reach are accessible through Sistema Bio, a Mexican-based company who install prefabricated modular biodigester packages in Colombia, India, Mexico, and Kenya (Sistema Bio, 2022). In domestic economies, it is for a wide range of users who produce biowaste. OakTec are currently in discussion with UK waste management company Suez, with the aim of using the CAGE6BM on landfill sites, to capture the landfill gas and create electricity. The firm also currently have 5 biogas generators on trial in Kenya, through Sistema Bio, with the wider region of Sub-Saharan Africa [SSA] being a prime market of interest. India has also been noted as a market of interest due to market accessibility through Sistema Bio and factors which will be explored in the following sections.

3.2.1.1 Sub-Saharan African Market

This section will aim to outline an emerging market of interest, Sub-Saharan Africa, which includes Kenya, a market that OakTec currently operates in through their partnership with Sistema Bio.

Africa is lagging in the global energy transition, with the continent relying on fuel exports such as oil and coal, which are of decreasing importance, creating a 'real demand for alternative energy sources' (Amigun, Sigamoney, & Von Blottnitz, 2008). Further, mismanagement of solid waste and heavy dependence on fossil fuels are just some of the 'pressing social, economic and environmental problems that Africa is facing today' (Suroop, Bundhoo, & Raghoo, 2019). Table 3.2.3 categorizes SSA's market into the relevant socio-economic, environmental, and socio-cultural issues problems that Africa is currently facing.

	Factor	Effect
Economic	Cost and lack of ability to pay	High financial barriers prevent installation Minimum active funding or promotional programmes creates limited financing Cost of alternative fuel makes biogas a more attractive option
	Availability of feedstock	High levels of agricultural activity result in constant, reliable supply of feedstock for anaerobic digester
	Access and equity issues	Weak technical support
Environmental	Waste management issues	Growing awareness around waste to energy The need to dispose organic waste
	Poor air quality	'Urban outdoor air pollution is responsible for around 49,000 premature deaths annually' (Schwela, 2012) Diesel generators create noise pollution
	Improving sanitation	The biogas generator can improve levels of sanitation by removing the feedstock
Socio-Cultural	Poverty	Poverty levels in Sub-Saharan Africa continue to rise, over half of the countries in the region have poverty rates above 33% (Schoch & Lakner, 2020)
	Access to electricity	Sub-Saharan Africa experiences lowest energy access rates in the world. Around 50% of the population have access to electricity (Corfee-Morlot, Parks, Ogunleye, & Ayeni, 2020) There is a real demand for energy solutions

Table 3.2.3 - Economic, environmental, socio-cultural factors of the Sub-Saharan Africa market

The following section will describe the contents of the table in more detail and discuss how these factors have created drivers and barriers of entering the potential markets in the region. It is important to acknowledge that not every region in these countries will experience the issues discussed in the table and throughout this section, however many of the regions in Sub-Saharan Africa currently host favourable market conditions for the CAGE6BM.

3.2.1.1.1 Sub-Saharan Africa Economic Factors

SSA has some of the highest rates of generator use in the world. In half of SSA, 'installed capacity of back-up generators is greater than the capacity of power plants connected to the grid' (International Finance Corporation, 2019). In Nigeria, the installed capacity of generators is reported to be between 15-20GW, compared to a grid capacity of between 5-15GW (International Finance Corporation, 2019). Diesel generators currently hold the largest market share in the Sub-Saharan region, in applications such as a back-up to unreliable grid supply and are the primary source of electricity generation for critical infrastructure and mini grids. Nigeria dominates the small generator market, with their diesel generator capacity accounting for at least twice the installed capacity of grid-connected power plants, resulting on a national expenditure of USD 5 billion on fuel annually (International Finance Corporation, 2019). In South Africa and Nigeria, generator capacity outpaced utility scale capacity additions. By segment, the backup generator segment is expected to have the largest market share by application owing to unreliable electricity grids which has resulted in several countries relying heavily on small capacity generators to meet daily usage (Mordor Intelligence, 2021). Upkeep of these generators are costly, Nigeria spends 3x as much on back-up generator power compared to the grid, whilst the Republic of Congo spends 9x more (International Finance Corporation, 2019). Further, due to volatile costs of fossil fuels there is a 'large fiscal burden on the diesel consumption and subsidies placed on the government budgets of developing countries, estimated at $1.1–2.1 billion in 2016' (International Finance Corporation, 2019).

SSA is one of the poorest regions in the world, resulting in high financial barriers for potential customers and limited technical capabilities. Due to SSA's low GDP (Rupf, Bahri, De Boer, & McHenry, 2015), end-consumers may lack the financial means to purchase the biogas generator. To give an example using biogas digester plants, in Ethiopia over the past twenty-five years, around 1000 biogas digester plants have been built for domestic purposes [households, small communities] by 9 different GOs and NGOs. Due to a lack of financial means, '40% of those plants are non-operational today' (Smith J. U., 2011). These factors, along with the need for 'significant policy changes, improved institutional capability, new financing flows, and a general

improvement in the business sector' (Okedu, Uhunmwangho, & Bassey, 2015), are some of the current barriers to the market.

The steep costs of diesel generators are making biogas generators a more attractive financial option in the long-term. 70% of countries in Africa are landlocked and rely on energy imports (Leke, Gaius-Obaseki, & Onyekweli, 2022). Weak distribution channels due to many living in hard-to-reach areas has resulted in expensive fuel prices, double that of other developing regions (Rupf, Bahri, De Boer, & McHenry, 2015). In West Africa, the amount spent on generator fuel is 1.2 times that spent on maintaining and expanding the grid. Across the whole of Africa, the price spent on generator fuel accounts for 24% of the total amount spent on electricity, whilst only providing 7% of total electricity service. 'The amount spent by users on generator fuel alone each year is equivalent to 20% of government spending on education and 15% of healthcare in SSA (excluding South Africa)' (International Finance Corporation, 2019). In addition, 75% of the population without access to electricity live in SSA (International Energy Agency, 2020). Biogas generators can increase financial well-being, as biogas is a much cheaper option compared to the increasing costs of the diesel fuel (Smith J. U., 2011). OakTec's biogas technologies can also offer a cheap, sustainable energy source to those communities currently living without electricity (Muvhiiwa, Hildebrandt, Chimwani, Ngubevana, & Matambo, 2017).

3.2.1.1.2 Sub-Saharan Africa Environmental Factors

Over 50% of Africa's labour force is involved in the agricultural sector (Morton & Thompson, 2019) meaning feedstock for the anaerobic digester is readily available in many regions, creating a constant, reliable supply of fuel. Further, Africa's warm climate hosts favourable conditions for the use of biodigesters as the temperature allows for the anaerobic processes to occur naturally (Smith J. U., 2011). 70% of the agricultural farming in SSA is subsistence farming, hence much of methane produced 'can be attributed to rural households' (McIntyre, Herren, Wakhungu, & Watson, 2009). The biogas generators present an opportunity to remove this methane from the atmosphere.

In SSA, ‘one in every 5 litres of diesel and petrol is burned in a backup generator’ (International Finance Corporation, 2019), which contributes greatly to the greenhouse gas emissions in the region. ‘NOx from backup generators accounts for 15% of all NOx emitted in the region. PM2.5 emissions are equivalent to 35% of emissions from all motor vehicles (largest single emitting sector in region), also account for majority of fine particulate matter and black carbon’ (International Finance Corporation, 2019). Annual PM emissions from generators in SSA is equal to 35% of PM from transportation, except diesel generators are in close proximity to homes. In SSA, CO_2 emitted from generators is equal to about 20% of total emissions from vehicles, which is the environmental equivalent to adding 22 million passenger vehicles on the road (International Finance Corporation, 2019).

3.2.1.1.3 Sub-Saharan Africa Socio-Cultural Factors

Farming households ‘create suitable end-customers of a biogas household’, giving opportunity for ‘meaningful application’ of the biogas generators (Ng'wandu, Shila, & ter Heegde, 2009). One of the primary reasons for the region’s heavy dependence on diesel generators is the lack of access to electricity. As table 3.2.3 mentions, around 50% of the population have access to electricity, presenting a real need for alternative energy sources. High levels of poverty in the region also present high financial barriers for potential end-consumers in the region.

Emissions from diesel generators can lead to detrimental health effects, as the combustion process generates smoke ‘containing harmful particles’ (Piabuo & Puatwoe, 2020), These health effects are apparent within the communities. The toxic emissions contain ‘many known or suspected cancer-causing substances, such as benzene, arsenic, and formaldehyde’ (The Republic of Kenya, 2012). In Nigeria, there is indirect evidence of the impact of diesel generators through rising cases of lung cancer ‘among urban-based non-smokers less than 60 years old, in areas with high diesel generator usage’ (The Republic of Kenya, 2012). Further, asthma prevalence in adults in Nigeria is the highest in Sub-Saharan Africa, with approximately 13 million

suffering from clinical asthma, another possible indicator of the harmful effects of diesel generators.

Table 3.2.4 below summarises the relevant factors which have been uncovered.

Barriers and Drivers		
Socio-Economic	Barrier	• Upfront cost of CAGE 6BM
	Driver	• Increasing prices of alternative fuels [diesel] • Valuable fertilizer • Reduced energy costs (Global Methane Initiative, 2013)
Environment	Barrier	• Hard-to-access rural areas make implementation difficult
	Driver	• Suitable climatic conditions to host biogas generator • Biogas generators are a clean fuel alternative • Biogas as a fuel is a more sustainable option
Social	Barrier	• Lack of knowledge about operation and maintenance
	Driver	• Can increase energy independence • Reduced health risks

Table 3.2.4 - Summary of the relevant factors

3.2.1.2 Indian Market

India has also been noted as a key market of interest for OakTec. This section will outline the relevant market factors to OakTec, and the opportunities present.

In a recent survey conducted by the Dirty Footprint (International Finance Corporation, 2019), India was one of the six countries accounting for over 50% of the electricity

generated [and fuel burned] by back-up generators in the 167 modelled countries. India is one of the top two markets globally in terms of load served by generators (International Finance Corporation, 2019). Diesel is a primary fuel for these generators, and 71% of total installed capacity for electricity in the region still comes from fossil fuels (Schoch & Lakner, 2020), portraying a heavy reliance on fossil fuels. Despite this, India boasts great potential in the energy transition. Table 3.2.5 below categorizes the economic, environmental, and socio-cultural factors affecting India's energy market, specifically factors relevant to OakTec.

	Factor	Effect on OakTec
Economic	Cost and lack of ability to pay	High financial barriers prevent installation No active funding or promotional programmes, limited financing options Cost of alternative fuel makes biogas a more attractive option
	Availability of feedstock	High levels of agricultural activity create constant, reliable source of feedstock
	Rapid economy growth	Opportunity to enter the market
	Financial ability to pay	Sistema Bio provide a means of payment
Environmental	Waste Management Issues	Growing awareness around waste to energy, the need to dispose organic waste CAGE 6BM provides a solution for waste management
	Poor air quality	India experiences some of the highest pollution levels in the world, causing thousands of premature deaths each year (The World Bank, 2021)
	Climate	Ambient air temperature Constant, reliable supply of feedstock for the anaerobic digester
Socio-Cultural	Improving sanitation	The biogas generator can improve levels of sanitation by removing the feedstock
	Poverty	22% of the population live below the poverty line
	Access to electricity	Increased uptake of the biodigester improves modern electricity access
	Availability of feedstock	Agricultural land % 2018 60.4% (The World Bank, 2022)

		Rural population (2020) 65% (Macrotrends, 2022)
	Electricity theft	High levels of electricity theft - Safety factors to consider
	Market Access	Potential financial barriers

Table 3.2.5 - Economic, environmental, socio-cultural factors of the Indian market

The following sections will describe the contents of the table in more detail and discuss how these factors have created drivers and barriers of entering the potential markets in the region.

3.2.1.2.1 India Economic Factors

India's diesel generator market is expected to grow at a rate of 9.4%, from $816.0 million to $1831.2mn from 2021 to 2030, with the 5kVA to 75 kVA power output and residential area segment set to hold the largest share, due to a rise in demand of back-up power (Prescient & Strategic Intelligence, 2021). Considering the market within a larger geographical scale, Asia Pacific is expected to hold the highest revenue share of global generator sales, due to their 'paradigm shift' towards urbanization and industrialization (Imperial College London Consultants, 2019).

The demand for power in India has doubled in the last decade, expected to grow a further 80% by 2030, owing to increasing population and GDP (The World Bank, 2000). Further, the Indian economy is one of the fastest growing in the world, with the IMF predicting a staggering 8.2% growth rate in 2022 (International Monetary Fund, 2021) in its recovery from COVID-19 (Masterson, 2022). There is also a $410 billion investment opportunity for new power generation capacity, 'of which $281 billion is in renewables' (The World Bank, 2000). Despite impressive strides in the growth of the economy, 22% of the population [~270 million] still live below the poverty line, with rural areas predominantly affected (The World Bank, 2016). This may create financial barriers for the end-customers. There is also still a heavy reliance on diesel generators in the country, as generators account for 4% of India's total diesel consumption

(International Finance Corporation, 2019). To view India's market within a wider geographical context, 'in South Asia, generator fuel accounts for 4% of electricity costs but these generators only provide 2.5% of electricity service' (International Finance Corporation, 2019).

3.2.1.2.2 India Environmental Factors

Power Category	Emission Limits (g/Kw-hr)			Smoke Limit (light absorption coefficient m^{-1})
	NOx + HC	CO	PM	
Up to 19kW	≤ 7.5	≤3.5	≤ 0.3	≤ 0.7
More than 19kW up tp 75 kW	≤ 4.7	≤ 3.5	≤ 0.3	≤ 0.7
More than 75kW up to 800 kW	≤ 4.0	≤ 3.5	≤ 0.2	≤ 0.7

Table 3.2.6 - Showing how the Indian Central Pollution Control Board regulates emissions from diesel generators sourced from (Unicef, 2018)

The emissions limit for new diesel engines up to 800kW for generator set applications in India are presented in table 3.2.6. The PM2.5 concentration in India is 11.6x the WHO recommended guidelines (IQAir, 21), ranking 5th in the list of countries experiencing the worst air quality globally. A large source of air pollution is from diesel back-up generators, which account for 2-6% of total ambient PM, rising to 8-28% of PM in the cities (International Finance Corporation, 2019). India's climate hosts very favourable conditions for the CAGE 6BM, as higher ambient air temperatures facilitate the AD process. Whilst rural households are ideal end-consumers, living in hard-to-reach areas creates a potential barrier for OakTec, through which Sistema Bio create a critical access link to reach the end-consumers.

Figure 3.2.1 below shows two graphs showing the estimated design engine efficiency of 82 different generator models in India and a comparison of design engine efficiency for the same models.

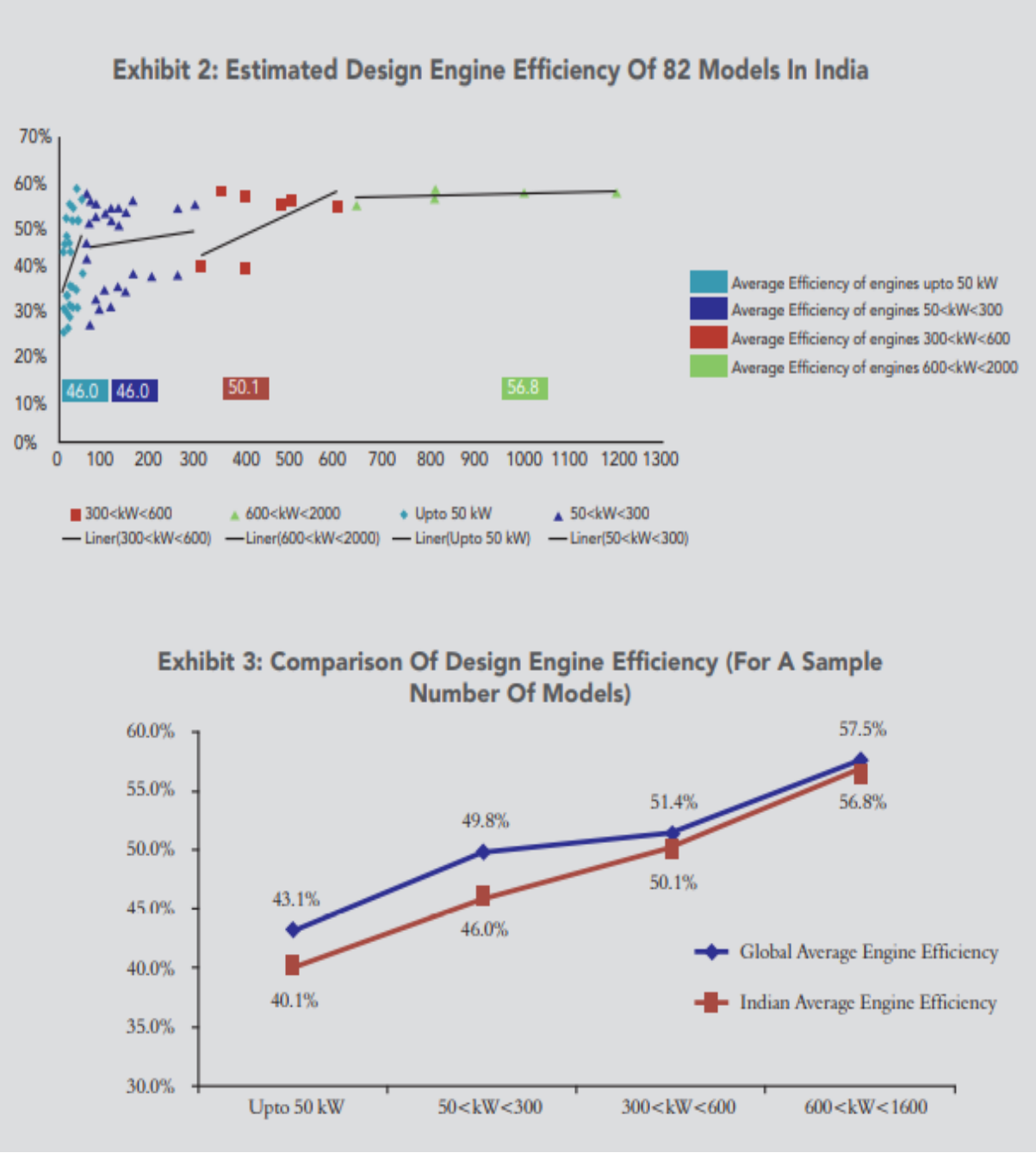


Figure 3.2.1 -Comparison graphs of 82 different generator engine models in India sourced from (Klufallah, Nuruddin, Khamidi, & Jamaludin, 2014)

Figure 3.2.1 demonstrates the design efficiency of various generator models available in India. The first graph compares these varying engine efficiencies to global averages. While the second graph portrays great variations between models, throughout all power output categories. The engines consistently score below the global average of engine efficiencies. Indian engines with power output < 300kW show the lowest efficiencies compared to the global average. These graphs demonstrate the 'huge commercial inefficiencies' (Klufallah, Nuruddin, Khamidi, & Jamaludin, 2014) apparent in India's portable generator market.

India has committed to clean energy, having been named the most attractive emerging market for clean energy investment (Davidson & Sokona, 2001). This title has the potential to attract new low carbon technologies, and direct investment into the clean energy market. 'Ambitious' renewable energy targets of 175GW by 2022 and 450GW have been set to reach by 2030 (The World Bank, 2000). India has already achieved the commitments made in Paris, pledging to have 40% installed capacity from non-fossil fuels, 2020 crossed 37%, aim 55-60% by 2030 (The World Bank, 2000). Also, home to the world's largest and competitive energy auction, India has favourable market conditions for the CAGE 6BM.

Despite most of the materials still imported, strengthened supply chains, decreased economic costs for stakeholders, and favourable investment has created an advanced market for green investment (World Health Organisation, 2018). From 2012 to 2020, India's utility-scale solar and wind capacity has increased over 3x, from 21 GW (1 GW solar and 20 GW wind) to 70 GW capacity [32 GW ground-mounted solar and 38 GW wind], as this growth begins to plateau (World Health Organisation, 2018). Further drivers of this growth have included state policies such as 'initial fiscal, financial, and tax incentive policies such as accelerated depreciation, generation-based incentives, and feed-in tariffs [FiTs]' (World Health Organisation, 2018).

S. No.	Application segment	Target for Phase I (2010-13)	Target for Phase 2 (2013-17)	Target for Phase 3 (2017-22)
1.	Solar collectors	7 million sq meters	15 million sq meters	20 million sq meters
2.	Off grid solar applications	200 MW	1000 MW	2000 MW
3.	Utility grid power, including roof top	1,000-2000 MW	4000-10,000 MW	20000 MW

Figure 3.2.2 - Stages on the Mission's roadmap

The introduction of the National Solar Mission in 2010 by the Government of India and the State Governments promoted the use of solar and increased energy-efficiency through policies such as a Renewable Purchase Obligations, which involves reduced tariffs on solar power purchase. Figure 3.2.2 shows the stages of the Mission's roadmap. The Mission also recognises opportunities in 'decentralized and off-grid applications', and the financial barriers of consumers living in these areas (Construction Equipment Association, 2022). To overcome these barriers, several proposed financing schemes have been trialled, such as micro-credit-based schemes, promotional schemes, and financial incentives. The promotional schemes have also offered opportunity to create hybrid systems to meet electricity needs. Key targets for the future include expanding and disseminating the countries manufacturing capabilities and creating a 'sector-specific legal and regulatory framework' for the sector's development (Construction Equipment Association, 2022).

3.2.1.2.3 India Socio-Cultural Factors

With a population size of nearly 1.5 billion (Macrotrends, 2022), power generation is one of the largest problems currently affecting India and its growing economy. According to (The World Bank, 2016), an estimated 200 million currently lack access to electricity, with rural areas being most affected. High levels of agricultural activity result in constant, reliable supply of feedstock for anaerobic digester. This creates a suitable market for OakTec, as high agricultural productivity indicates a reliable source of feedstock for the anaerobic digester.

3.2.1.3 Barriers and Drivers to the CAGE 6BM Market

Table 3.2.7 compiles the factors discussed in section 3.2.1.3.

Barriers and Drivers		
Socio-Economic	Barrier	• Upfront cost of CAGE 6BM
	Driver	• Increasing prices of alternative fuels [diesel] • Valuable fertilizer [63] • Reduced energy costs [63]
Environment	Barrier	• Hard-to-access rural areas make implementation difficult
	Driver	• Suitable climatic conditions to host biogas generator • Biogas generators are a clean fuel alternative • Biogas as a fuel is a more sustainable option
Social	Barrier	• Lack of knowledge about operation and maintenance
	Driver	• Can increase energy independence • Reduced health risks

Table 3.2.7 - Complied factors discussed about the Indian market.

3.2.2 Market Focus for CAGE 6PG and 25PG (LPG Generator)

Focus product	Power rating	Fuel	Current market of interest
CAGE 6PG	6kW	LPG	UK Construction sites
CAGE 25PG	25kW	LPG	UK Construction sites

Table 3.2.8 - Information on the CAGE 6PG and CAGE5PG Generators

Market Segmentation Factors

- Need for small scale power generation
- Access to LPG fuel

OakTec and partners are in the process of developing and trialling LPG engines with power rating 6kW and 25kW (OakTec, 2017). The LPG engines belong to a range of industrial engine technologies, in the range of 2-50kW, which are optimised to produce the best combination of fuel efficiency with ultra-low exhaust emissions to benefit air quality and reduce CO_2 output (OakTec). The engine technology will compete with diesel engine equivalent technologies. The current market of interest for this technology is the construction sector in the UK. The technology, which is applied to the CAGE generators, has completed trials with the HS2 rail project, using bioLPG which is supplied by project partner Calor. The following section will explore the market in more detail.

3.2.2.1 United Kingdom Market

Table 3.2.9 below outlines factors of this market that are relevant to OakTec.

Factor	Trend	Example
Economic	LPG costs compared to diesel	• Reduced running costs • Able to run on dual fuel • Ban on red diesel
Environmental	Focus on emissions reduction in the construction industry	• Ideal for emission-sensitive sites • Increasing targets for criteria pollutants
	Improving air quality	• Reduced harmful emissions
Socio-Cultural	Low noise levels	• LPG is quieter than diesel, potential to reduce noise pollution in cities
	Lack of knowledge	• Advantages of LPG not understood - lower emission profiles [vs diesel], lower full life-cycle costs, quicker lead times
	Expected growth in power demand	• As areas develop and living standards improve, the demand for power increases
Political	Government support of LPG	• Government incentives oil to gas/ coal to gas • Increasing confidence in the industry – investment in 2020 £115mn

Table 3.2.9 - Economic, environmental, socio-cultural, and political factors of the UK market data collected from (Liquid Gas UK, 2021) & (World LP Gas Association, 2013)

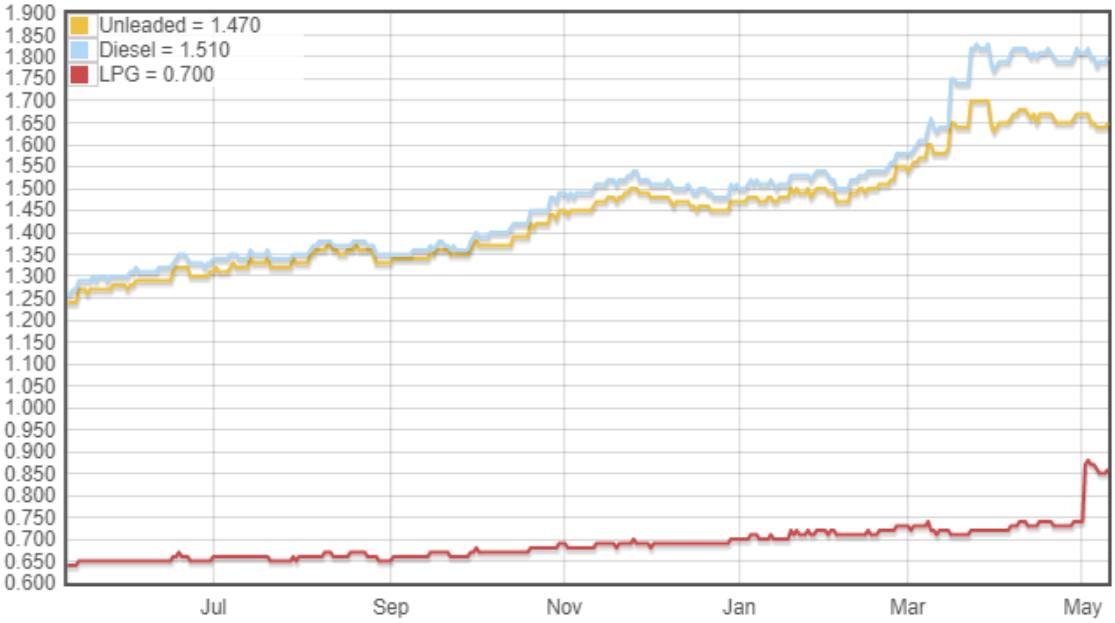
3.2.2.1.1 UK Economic Factors

Diesel gensets are the current market leaders in the UK (6Wresearch, 2021), providing a major source of power for construction activities, for uses such as charging power tools, or providing power to temporary buildings or modular sites, where power generation is required off-grid. LPG is set to compete amongst petrol and diesel product offerings in the market, as the move to Net Zero continues to apply pressure for companies to seek low emission solutions.

Drivers of the portable generator segment in the UK include the development of infrastructure and a growing consumer interest towards outdoor recreational activities, which creates a rise in demand for portable powering systems. Global market drivers include frequent power outages due to unreliable grid connection and increasing natural disasters, all which create a need for back-up power (Forutne Business Insights, 2018). The industrial sector, including agriculture, construction, manufacturing, and mining (Mordor Intelligence, 2021) will likely be a major driver of the market, which will be most notable in countries experiencing the transition phase of development.

Shown in figure 3.2.3 below are the prices of petrol, diesel, and LPG fuel in the UK from 2013 to 2022.

Fuel Prices from July 2021 to May 2022



Fuel Prices from 2013 to Present

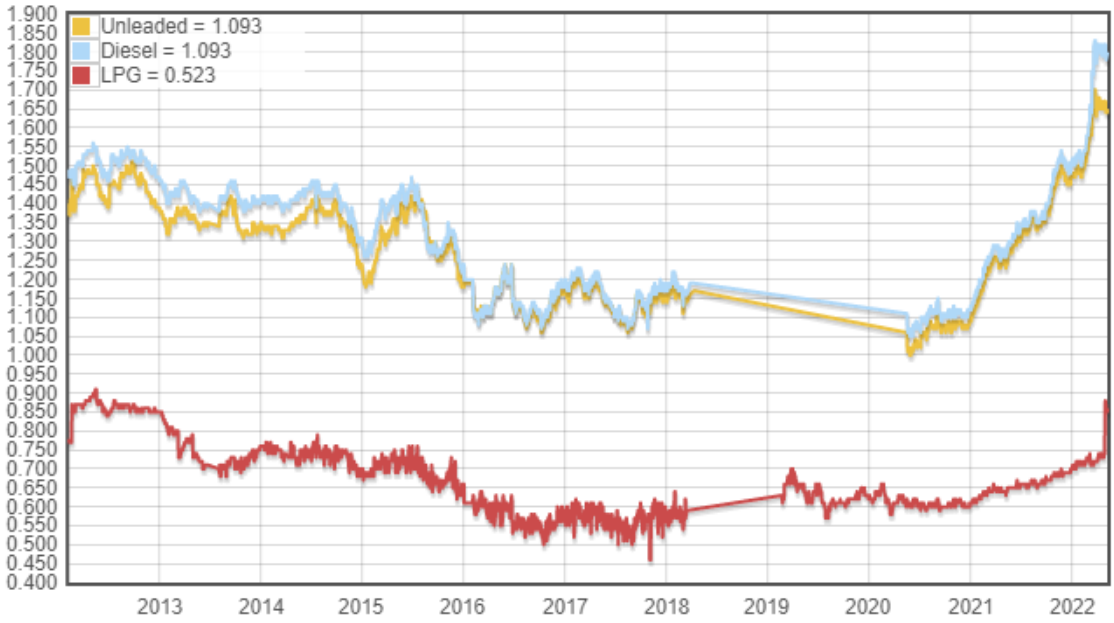


Figure 3.2.3 - UK Fuel Prices from 2013 to 2022 retrieved from (My LPG, 2022)

Historically, diesel has dominated the fuel segment (Forutne Business Insights, 2018), an efficient fuel made accessible by strong supply networks and low cost. The UK is an important market for OakTec, holding third position in terms of market size for European Diesel Genset market (6Wresearch, 2021), with 5Kva-75kvA expected to have fastest growth. However, the continued reliance on these fossil fuels 'poses a significant challenge to sustainable development' (Imperial College London Consultants, 2019), and the need to find alternative, lower emission solutions to small-scale power generation needs is a major marker driver. Further, as figure 3.2.3 demonstrates, the price of petrol and diesel is rising exponentially, showing consistently higher prices than LPG. This is perhaps why the use of LPG as a fuel is expected to grow 4.8% from 2021-2026 (Research and Markets, 2022), compared to diesel growth of 1% 2020-2025 (Mordor Intelligence, 2021). These factors create a huge opportunity for OakTec, as LPG is positioned as a highly attractive product in the UK's contemporary energy economy, its position solidified by policy and business ever-tightening emissions standards.

Another economic factor favouring the use of alternative fuel sources is the Government's ban of red diesel. Red diesel is principally used for off-road purposes, accounting for 15% of total diesel consumption in the UK, which equates to approximately 14 million tonnes of CO_2 per year (Bhat, Chanakya, & Ravindranath,

2001). Red and white diesel are chemically the same, except that red diesel contains red dye and is taxed less. From the 1st of April 2022, businesses operating in the construction industry will no longer be allowed to use red diesel in their non-road mobile machinery (including generators), and white diesel will be used as a replacement, which will be taxed at the standard rate for diesel. This strategy is part of the Government's phasing out scheme and CO2nstruct Zero, which is the construction industry's zero carbon change programme (Corfee-Morlot, Parks, Ogunleye, & Ayeni, 2020). According to the UK Government, the ban on red diesel will result in businesses paying an extra 46.81 pence per litre from the 1st of April (Bhat, Chanakya, & Ravindranath, 2001). This creates a huge fiscal incentive for businesses to switch to lower emission solutions.

3.2.2.1.2 UK Environmental Factors

UK territorial greenhouse gas emissions, 2020, mtCO2e

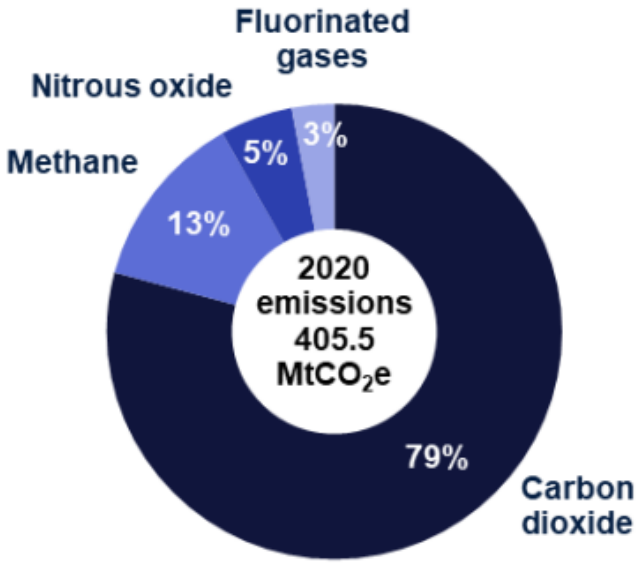


Figure 3.2.4 – Pie chart of UK greenhouse gas emissions in 2020 (World Health Organization, 2021)

Net territorial UK greenhouse gas emissions by sector, 2020 (%)

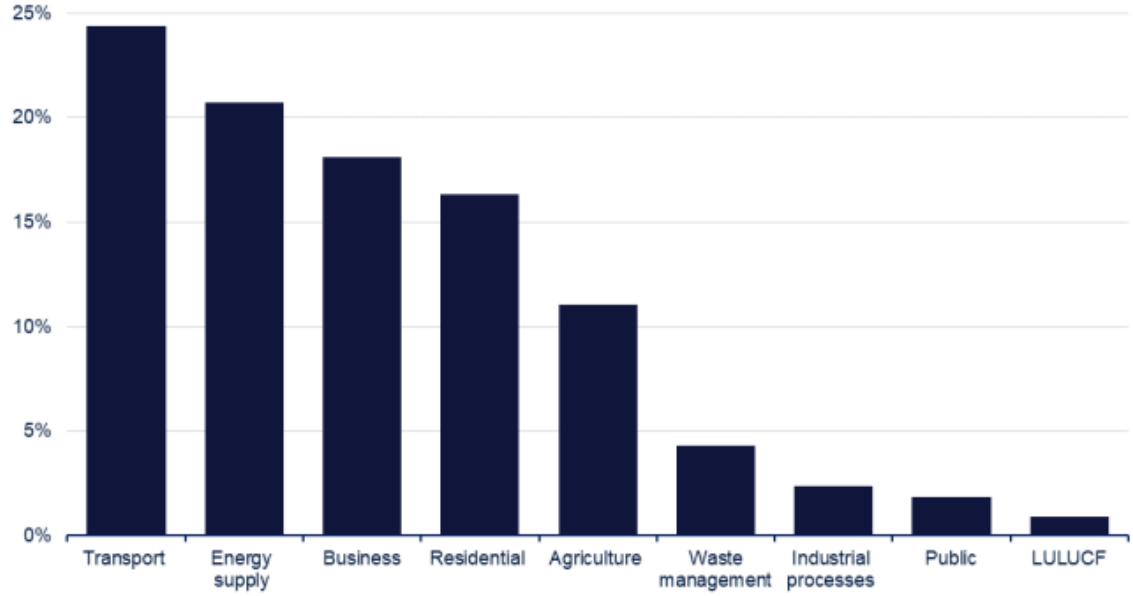


Figure 3.2.5 - Graph of UK greenhouse gas emissions by sector, 2020 (World Health Organization, 2021)

Figures 3.2.4 and 3.2.5 present the UK's GHG emissions by gas and sector in 2020. As can be seen, carbon dioxide accounts for over three-quarters of total GHG emissions, and energy supply is one of the primary sources of GHG emissions. One of the UK Government's Department for Business, Energy and Industrial Strategy aims is to ensure an 'affordable, clean, and secure energy supply' for the UK (The World Bank, 2021). LPG is a fuel able to contribute to this target, and potentially reduce the GHG emissions in the energy sector.

Table 3.2.10 presents LPG emissions output compared to diesel and petrol.

	Diesel	**Petrol**	**LPG**
Emissions	The four main pollutant emissions from diesel engines are carbon monoxide, hydrocarbons, particulate matter, and nitrogen oxides	Petrol engines typically use more fuel than diesel engines but produce fewer toxic emissions	Low particulate matter, NOx, and sulphur. Carbon footprint of LPG is 20% lower than heating oil and 50% lower than coal

Carbon dioxide (kg per litre of fuel)	2.48	2.18	1.55
Unburned hydrocarbons (kg per litre of fuel)	0.00026	0.0072	0.0012
Nitrogen oxides (kg per litre of fuel)	0.037	0.0066	0.00097

Table 3.2.10 - Emission output comparison when burning 1 litre of Diesel, Petrol and LPG fuel (UK Government, 2022)

As demonstrated in table 3.2.10, LPG fuel has lower harmful emissions than both petrol and diesel. One of the largest advantages of LPG engines is the low emissions output compared to petrol and diesel. LPG is a 'more ecological fuel' than its competitors, petrol, and diesel, in the fuel segment (Raslavicius, Kersys, Mockus, Kersiene, & Starevicius, 2014) as it produces less toxic combustion products. LPG is also a flexible fuel, able to satisfy remote and off-grid areas, requiring little infrastructure (WLPGA, 2018). LPG is an immediately available low carbon alternative, emitting 35% less CO2 than coal and 12% less than oil, also emitting almost no black carbon, which is 'arguably the second biggest contributor to global warming and perhaps the single biggest cause of arctic warming' (Liquid Gas Europe, 2022).

3.2.2.1.3 UK Political Factors

Globally, air pollution targets are critical for achieving 2030 Agenda for Sustainable Development. According to the WHO, 'air pollution is the largest single environmental risk to health' (World Health Organization , 2018), and over 90% of the air we breathe is polluted (World Health Organisation, 2018). Air quality relates to more than half of the SDG's and is also a focal discussion area in the UK's Move to Net Zero, opening a landscape for OakTec's low emission engines to compete and directly displace fossil fuels. There is a particular focus on decarbonisation in the industrial sector, which will

directly affect OakTec and the direction of the business. Such policies in the Net Zero Roadmap include continued shift away from fossil fuel-powered plants, major expansion of renewable and low carbon power generation, and all planning decisions to be compatible with UK climate targets (Climate Change Committee, 2019).

‘The transition to a net-zero economy is likely to be challenging and disruptive for many non-domestic businesses in off-grid areas. However, incentivising a switch to lower-carbon technologies such as LPG can reduce some of the barriers to transition’ (Liquid Gas UK, 2021).

On a larger scale, European targets will be important influences. They will impact the market, government legislation and business decisions, resulting in an expected surge in gas generator growth (Mordor Intelligence, 2021). The EU’s 2030 Climate Target Plan includes targets such as 27% improvement in energy efficiency and 40% cuts in greenhouse gas emissions [from 1990 levels] (European Comission, 2021). Over 90% of EU territory is rural and over half of the population live in rural areas. LPG is a versatile fuel able to reach these off-grid areas. Further, LPG ‘meets the four key objectives set by EU in guidelines for trans-European energy networks.’ (Tasic, Pogorevc, & Brajlih, 2011).

As noted in chapter two, SMEs may lack the market knowledge needed to enter the market. The above section has outlined the specific markets for the case study SME OakTec. On a more general level, it is important for SMEs to segment and research their own market segments in order to focus on their own target consumers.

4 Methodology

This chapter will present and discuss the research method, which involves how data is collected, the procedures used for analysing the data, and how the results will be presented, with the relevant justifications. First, the methods chosen to collect the data will be discussed, with introduction and discussion of the case study method and qualitative semi-structured interviews, which are the primary method of data collection. The second part of the chapter discusses how participants were identified, how the data will be collected, and any ethical concerns are raised and attended to. The final section will discuss how the data will be analysed and reported, including limitations of the research.

4.1 Case Study Research Method

For this project, the case study research method can be defined simply through (Merriam-Webster Dictionary, 2022)

‘An intensive analysis of an individual unit, stressing development factors in relation to environment’

Stake adds to this definition that when studying a case, it is important to ‘look for detail of interaction with its contexts’ (Stake, 1995), which is useful when studying the commercialization of a firm within the environment it operates. Case studies are exploratory, an in-depth investigation of a problem, conducted to gain a better understanding of the problem (Babbie, 1999). The justification of the use of this method can be explained through the words of Becker, in that ‘one can properly acquire knowledge of the phenomenon from intensive exploration of a single case’ (Becker, 1970). He adds further that this method ‘captures cases in their uniqueness’. It may be for this reason that this method is popular amongst sociologists and anthropologists, since rich data is gained, which can allow a comprehensive understanding of a subject. Scholars have likened this method to the narrative

approach, as the unique experiences captured are viewed within a cultural context (Clandinin & Connelly, 2004). The single case method also allows hypotheses to be formed and suggests implications for future research (Fidel, 1984).

Scientific research seeks generalizability, which is the extent to which data can explain phenomena outside the scope of the study. (Gomm, Hammersley, & Foster, 2000) states that the basic aim of a scientific experiment is to find generalizability, stating that 'there exists a uniformity of nature in time and space'. A common criticism of the case study method is that it lacks generalizability, due to the uniqueness of a single case being investigated. However, Stake puts forward that the case study research method can provide 'naturalistic generalizability' (Stake, 1995), which happens when 'the research resonates with the reader's personal engagement in life's affairs or vicarious, often tacit, experiences' (Smith B. , 2018). (Gerring, 2006) suggests that the insight sought from the research is the product of a good case study design. For this study, the SME OakTec will be used as the case study. The theoretical findings of the study for OakTec will be transferable to other SMEs who are looking to commercialize.

4.2 Qualitative Data

Due to the exploratory nature of the research project and the need for understanding in the case study method, qualitative research methods will be used as the primary method of data collection. Qualitative methods will allow for the concepts surrounding commercialization to be explored and investigating the context of the firm will allow the research problem to be explored in greater detail.

'The laboratory of the qualitative researcher is everyday life and cannot be contained in a test tube, started, stopped, manipulated, or washed down the sink' (Morse, 1994).

The quote from Morse helps to explain the real-life element of the research project. Businesses do not exist in an isolated environment, but within an extremely complex and intertwined social environment. There are multiple factors which influence activities daily, hence the need for a deeper understanding on a human level. Qualitative data aims to reach Verstehen, with a literal meaning 'to understand' in

German, which is why it is important to use methods which gather opinions and experiences, for example interviews and observations. (Morse, 1994) helps us to distinguish between scientific ‘knowledge’ and ‘understanding’ in the qualitative paradigm. Quantitative data, which is often described as the ‘numerical representation and manipulation of observations’ (Sukamolson, 2007) can only go so far in explaining phenomena, whilst examining people’s experiences in detail can explain why things are happening and patterns can be acquired (Hennink, Hutter, & Bailey, 2020) which may help to form hypotheses and encourage future predictions, prompting hints on where and when to look.

The main criticisms surrounding the qualitative approach is that the data lacks validity, generalisability and that it is too subjective, in that the significance of the data is subjective to the interpretation of the researcher (Bell, et al., 2018). However, as mentioned with the case study research methods, qualitative data provides insight into the research problem. This approach will be useful when studying OakTec within its network, as a deeper understanding of the business environment can help OakTec in making informed choices and give future direction for the business.

4.3 Semi-structured Interviews

Semi-structured interviews will be used as the primary method of data collection throughout this study, as this data method can result in reliable, in-depth data. The definition is as follows:

‘A semi-structured interview is a verbal interchange where one person, the interviewer, attempts to elicit information from another person by asking questions. Although the interviewer prepares a list of predetermined questions, semi-structured interviews unfold into a conversational manner offering participants the chance to explore issues they feel are important’ (Longhurst, 2003).

Semi-structured interviews are suited to research where there is enough objective knowledge surrounding a subject, but the subjective knowledge is lacking (Morse & Field, 1995). Studies that use semi-structured interviews produce sensitive, people-

oriented data. Interview questions are based around the prior knowledge of the research problem, which is gained through the literature review, market research, and spending time at OakTec. The open-ended question structure allows participants to tell their own stories and explain versions of events through their unique perspective (McIntosh & Morse, 2015). Gathering a range of opinions through the flexible response structure allows for a holistic overview of the research problem. Discussions during semi-structured interviews can also allow for topics to be raised in a 'safe space', and spark conversation which may usually go unnoticed (Valentine, 2005). The diverse range of opinions gathered through semi-structured interviews are subjective and provide unique insight on perception. This can be explained through the constructivist paradigm, which claims that truth is relative (Stake, 1995). This paradigm 'recognizes the importance of the subjective human creation of meaning but doesn't reject outright some notion of objectivity' (Baxter & Jack, 2008).

One advantage of semi-structured interviews is that the questions can be prepared ahead of time, which can allow the researcher to focus on data collection and the participant during the interview. When conducted well, semi-structured interviews result in reliable, comparative, qualitative data (Cohen & Crabtree, 2006). Criticisms surrounding semi-structured interviews include the need for interviewer sophistication. Adams states that interviewers must be 'smart, sensitive, poised, nimble, as well as knowledgeable about the relevant substantive issues' (Adams, 2015). Further, semi-structured interviews often generate a large volume of data to analyse which can be time-consuming. Another problem often associated with interviews is interviewer conscious or unconscious bias. In a social situation, participants may feel pressured to follow a cultural script explains that both interviewee and interviewer may subconsciously follow cultural scripts (Kaliber, 2019) and behave in a way they feel they should, answering questions based on what they feel may be expected of them, not how they truly feel (Diefenbach, 2009), this can be described as the Hawthorne effect (Adair, 1984). To avoid this bias, it is important to recognise potential biases in the interview and use the open-ended structure to delve beyond 'internalized norms' and to find out the true opinions of the participants (Diefenbach, 2009).

4.4 Participant Selection

Purposive sampling will be used to sample participants. Purposive sampling is a non-random sampling technique and can be defined as 'the deliberate choice of a participant due to the qualities the participant possesses' (Etikan, Musa, & Alkassim, 2016). Participants will be selected by expertise regarding research subject, and people who have experience within the firm. It is important to interview a diverse range of participants, to gain insider and outsider perceptions, creating a holistic view of the business and the pre-defined markets of interest, which will ultimately allow for deeper insight into the research problem. One limitation of this study is the low number of interview participants due to response rate. More participants could provide more detailed knowledge on the network, and what the network looks like for innovative products. The participants chosen for the interviews are listed in table 4.4.1 below, with the justification of why each participant was selected.

Wave One		
Participant	**Industry**	**Justification**
1	Marine Energy Industry	Access to critical, in-depth knowledge on the markets of interest
2	Welfare Cabin Hire	
3	Waste Management	

Wave Two		
Participant	**Job Role at OakTec**	**Justification**
4	CEO	Well-informed with phenomenon of interest interest (Cresswell & Plano Clark, 2011)
5	Project Manager	
6	Commercial Director	
7	Technician/ Chief Designer	

Table 4.4.1 - Interview Participants

4.5 Interview Guide

An interview guide ‘provides a clear set of instructions for interviewers and can provide reliable, comparable qualitative data’ (Cohen & Crabtree, 2006). As mentioned, to give a keen understanding of the topics and better formulate the interview questions, the semi-structured interviews are preceded by a review of literature surrounding SME’s, market segmentation, and time spent at OakTec. This review will enhance understanding on interactions between the network and identify the gaps that this study aims to address. This background will allow for question formations that focus on key topics relevant to the research aims and objectives. Questions in the interview guide will also be varied based on roles and expertise of participants. For research question one, potential customers will be interviewed with a set of questions. For research question two, three, and four, OakTec employees will be interviewed, with a set of interview questions tailored to each individual question.

The interview guide will begin with a general question such as ‘can you explain a little bit about your role’ to make the participants feel relaxed (Longhurst, 2003). During wave one, business partners will be contacted by email asking if they want to take part in the study. The reason for and benefits of the study will be explained through the email and, if the participant agrees to take part, an interview time and date will be set up via video link. All interviews will be face-to-face via video link and audio recorded. According to (McIntosh & Morse, 2015), face-to-face interviews optimize communication, and complex questions can be asked because ‘the interviewer can clarify confusion’.

The complete interview guide is listed in tables 4.5.1 and 4.5.2 below. The format is taken from (Zhou, Blazquez, McCormick, & Barnes, 2021).

Interview Guide – Wave One Participants		
Research Question	**Theme**	**Question**
(Linked to RQ 1)	Introductory question	Tell me about your role
RQ1	The existing market need	What are your energy needs and how are they currently being met? Do you think Net Zero will affect the industry, if so, how?
RQ1	Factors affecting power supply decision	Do you think there are any current or future problems in the market in relation to meeting energy needs? What factors are likely to be considered before making a power supply decision? What are your perceptions, if any, around clean gas technologies? What incentives are needed to switch to a low-emission technology? What is incentivising you to switch? What are potential roadblocks for innovative products/ new products entering the market? Is the industry willing to pay more for a low-emission product?
RQ1	Latent needs and opportunities	What kind of trends are emerging in the industry regarding meeting energy demand? What aspects/attributes would you like to see in new products? What kind of place do you think clean gas engines hold in your industry? What attributes would you like to see in new products? Is the industry willing to pay more for a low-emission product?

Table 4.5.1 - Wave one participant interview guide

Interview Guide – Wave Two Participants		
Research Question	**Theme**	**Question**
RQ2	Offerings	Could you please tell me each product and the benefit?
	Capabilities	What are OakTec's strongest capabilities as company? What have been the most useful/ important resources?
RQ3	Challenges	Do you have any challenges in reaching and engaging with customers? What have been the most influential internal and external challenges encountered by OakTec during the commercialization process?
	Solutions	How have you approached and navigated the challenges faced? How are you planning to attract the support of investors?
RQ 4	The ARA Model	Are there any forms of collaboration or external linkages which have been valued? What do you gain from these connections? What have been some of the key activities required during commercialization? How do you intend to communicate the value of your innovation to prospective customers?

Table 4.5.2 - Wave two participant interview guide

4.6 Data Analysis

To analyse the data, a mixture of deductive and inductive thematic analysis approaches will be used. This is a popular method of qualitative data analysis (Braun & Clarke, 2012) with a wide array of definitions, however for the purpose of this research, thematic analysis is defined as ‘a method for identifying, analysing, and interpreting patterns of meaning (“themes”) within qualitative data’ (Terry, Hayfield, Clarke, & Braun, 2017). After data collection, descriptive coding will first be used to identify relevant information, which is the ‘first step in identifying patterns in the data’ because similar data are grouped together (Bruan & Clarke, 2006). Codes are then clustered, and key themes emerge, as the clustered codes will help to map key patterns in the data. Key themes can be described as key analytic points (Clarke, Braun, & Hayfield, 2015), and relate to the research questions. The themes ca be seen in tables 4.5.1 and 4.5.2. Themes are reviewed against the data set to check for a good fit. Themes are defined, and the concept is explained through the theory as discussed in the literature review. This analysis follows Braun and Clarke ‘Six Phases of Thematic Analysis’ (Bruan & Clarke, 2006). Coding will be a mixture of deductive and inductive techniques. A set of codes based on the research framework and theories discussed in the literature review will first be set (deductive approach), however the codes will also be flexible and open to interpretation, depending on the data gained (inductive approach) (Terry, Hayfield, Clarke, & Braun, 2017).

For this research, a critical realist approach will be used. The data gained from the interviews will provide a ‘version of reality’ (Terry, Hayfield, Clarke, & Braun, 2017), which exists within a broader macro context. Data will be interpreted (Smith J. , 2003), and meanings will be sought. For example, when coding for research question one (the existing and latent needs in the pre-defined market segments), key themes can be interpreted and analysed, to suggest the necessary investments needed to address customer needs. For research question three (the challenges faced by the SME), part of the data analysis will aim to interpret the reasons for these challenges and identify how these challenges can be overcome. Further analysis techniques will include a SWOT analysis, which will outline company strengths, weaknesses, opportunities, and threats, to aid strategy formulation.

4.7 Ethical Considerations

Before conducting the semi-structured interviews, approval will be sought from Lancaster's Ethics Committee. All participants will be sent a consent form explaining the study and use of their data. Responses from the participants will remain anonymous. Participants to be made aware that they can retract their contributions up to two weeks after the interaction took place, and a copy of the transcript will be offered. Personal data will remain confidential, and any sections of transcript quoted in the text will remain anonymous (Longhurst, 2003).

5 Empirical Findings and Analysis

The following section analyses the empirical findings which have been uncovered throughout the research, primarily through the semi-structured interviews. Each section will evidence the findings, by using snapshots of the semi-structured interviews to uncover patterns in the data. The analysis will incorporate various theoretical constructs, which have been discussed in section two, whilst also within the context of the markets and industry, listed in section three. The data has been analysed and coded for each research question, and themes in the data emerged. These themes will be presented in thematic maps, followed by the analysis. The sub-themes, which are demonstrated on the maps, were coded during the participant interviews, as all participants frequently discussed similar topics within the themes. The themes are defined, and sub-themes explained in the following sections, with examples given from the data.

5.1 Research Question One

Shown in table 5.1.1 below are the relevant snapshots of the wave one participant responses to the interview questions for research question one.

Participant	Viewpoint expressed
1	• We installed a welfare unit on the pier at Hatston and Kirkwall which is where lots of cruise ships come in through the summer. That welfare unit is a hybrid battery solar hydrogen genset powered porta cabin, powering that means the crew can welcome the passengers off the cruise ships and go in there to warm up and have a cup of tea

2	• Normally a unit like ours would need about 11kva power, which can be achieved in two ways, cage 5.6kva and then we use an auxiliary LPG heating system which is another 6kva, part of it is generated via an engine and the rest is directly used, the direct use is for the space heating and the hot and cold water
3	• We have circumstances where we have a need for power and the only way to fulfil it is either an expensive grid location to a remote location where there might not even be one or a diesel generator, so those are two things where, but we do have a fuel which is a fuel gas which is landfill gas so it was to try and see if there is a way to try and utilise the landfill gas in a small generator

Table 5.1.1 - Snapshot one of wave one participant responses to interview questions for research question one

The first pattern that emerged from the data was the current market need of each participant to meet power demand. The primary need that emerged was the small-scale energy need in each respective market. The energy need that emerged for wave one participant is for remote areas largely off-grid, or where grid connection is too expensive. Examples given in the analysis from participants one and two included an energy need for cruise terminals on ferry ports and welfare cabins on construction sites, where a grid connection is difficult and there is a small-scale need to provide electricity in the cabins. Participant three expressed an interest in the biogas engines to remove methane from landfill sites, and use the electricity created to power the blowers (fans) on-site.

Participant one expressed an interest in OakTec's hydrogen generator, which is currently on trial on a project called the HIMET project, standing for the Hydrogen Integrated Maritime Energy Transition. The project focuses on two main areas, the first being the shoreside element and the infrastructure that ferries need on the port to come in and fuel, and the second being how the crew members use the port infrastructure and the energy needed there. The hydrogen genset has potential to provide the port with low carbon emission infrastructure for the ferries, the crew, and the passengers. The product is presented in figure 5.1.1. The photograph was taken at FutureWorx, which was an event showcasing innovation in the construction industry. This event was attended by the author.

Figure 5.1.1 - CAGE hydrogen genset, exhibited at Futureworx construction event.

Participant two's interest in OakTec was primarily for the LPG engine, with one currently on trial in a welfare cabin at a HS2 construction site. Their need for energy is to power welfare cabin units on construction sites. These welfare cabins are used for a variety of energy purposes, including providing electricity for workers, and to charge small applications such as charging tools.

Figure 5.1.2 - Photograph of LPG engine in welfare cabin at HS2

Participant three's need is for Oaktec's biogas engine. They expressed circumstances where they have a need for power, and the only way to fulfil this need is either through an expensive grid connection to a remote location or with a diesel generator. Their idea is to use fuel created by landfill gas and utilise it to power a small generator. Participant three discussed the size of the landfill sites where they work, explaining that their large size inhibits the ability to provide site wide power through one larger generator, meaning multiple small or 'nano generators', as described by participant three, are required to power various areas on the site. This need is currently met with a diesel generator. Figure 5.1.3 depicts the biogas generator and figure 5.1.4 shows the product with the customers.

Figure 5.1.3 - The CAGE6BM

Figure 5.1.4 - The CAGE6BM with end customers in the Kenyan market.

Table 5.1.2 below further shows the needs of the participants regarding meeting power demand.

Participant	Viewpoint expressed
1	• It's crucial that you can decarbonize the infrastructure that ferries need on port to come in • The public perception of business has changed, they want to see that businesses are actively looking to reduce their carbon footprint, they want to see that businesses have sustainability strategies, a lot of companies now are getting B Corp certified and that's an attractive thing for consumers to see that that companies care about sustainability • Net zero is certainly affecting the maritime industry, we've seen the International Maritime Organisation (IMO) come forth with ambitions to try and decarbonise shipping, a couple of years ago the UK government published a clean maritime plan and in that they set out goals and ambitions for the maritime industry. I think it's a priority area for the government
2	• We're part of the Modulaire group, we've got a statement to reduce our carbon to net zero by 2030 • We are changing the group's car fleet to electric, using different technology for HGV vehicles, and using solar hire units, and when it comes to planning investment, anything we plan to invest is also considered against Net Zero • If the finance institutions want to go green, everyone will follow. • There's a lot of people who, if there is a green option, will go with it because why wouldn't you?
3	• Methane is getting a lot more press attention from the impact it causes, the Environmental Agency and Defra are very much on top of this • Defra and the EA, certainly Defra and BEIS are looking at a way to incentive methane destruction on these sites in terms of a credit situation, so I see a potential, it's not been outlined yet maybe next couple of years they'll come up with a situation • We're trying to find a way be more sustainable and trying to find even small aspects we can do to make ourselves greener and if we can get rid of a diesel generator and utilise rather than just burning the gas which is what we do now

Table 5.1.2 - Snapshot two of wave one participant responses to interview questions for research question one

This responses in the table above also showed a clear theme of meeting power demand with a low emission solution. The participants discussed the varying levels of pressure on business to reduce carbon footprint, as participant one discussed the public pressure on the maritime industry. The participants expressed being part of a wider organization, which set targets for environmental improvement, for example the Modulaire Group. Other influencing actors brought up included governmental institutions and environmental groups.

Throughout the interviews the participants talked about the factors that affected their power supply decisions, as evidenced by the responses shown in table 5.1.3 below.

Participant	Viewpoint expressed
1	• One of the main challenges in innovation and decarbonisation is that the regulation hasn't yet been written for a lot of these things, so you've got a lot of standards for road transport and that's starting to come through in road decarbonisation but in the maritime sector the regulator and regulation is not really suited to innovation
2	• We must look at the cost of the CAGE engine against a standard engine and how much it would increase hire rate and would our client pay that cost, that's the driver all the time • Everybody considers the environment and the green option, it's in everyone's mind but us as a company always go down green path • Some want to change because we should change because the world needs us to change, others need an incentive on some projects • On some projects at the moment there is an incentive if you're doing construction projects, they're looking at how you're approaching that project from a practical method, what you're doing to reduce the carbon you emit and if you're using higher savings methods for your carbon output, they will add a % to the value of contract and give you money on price because you're saving carbon • While it might cost you more to hire the technology in the first place, the actual running cost is lower because solar and renewable energy which is free to use so the overall cost benefit is there, but you have to get on board and prove it
3	• There have been incentives, the ROCS renewable obligation certificates, they're a big deal in landfill gas, the majority are 20-year period that ended in 2027

Table 5.1.3 - Snapshot three of wave one participant responses to interview questions for research question one

Participant one talked about the challenges of regulation surrounding innovation, and how this may affect new products entering the industry. Participant two stated that the government enables discounted prices on construction schemes when carbon is saved. This currently doesn't affect the house building sector, but government bodies and authorities are forcing this through. Participant three talked about the role of Renewable Obligation Certificates [ROCs] within the waste management industry. They stated that ROCs are certificates issued to support renewable electricity projects, giving companies that export power to the grid a similar rate to a fossil fuel wholesale

power price. By exporting electricity from renewable sources [landfill is classed as renewable], credits are received for every megawatt hour. Others who do not take part in the ROCs must pay a green subsidy. The uptake of ROCs has been driven by Ofgem and the UK government, which has historically served as a great financial incentive for the waste management industry to produce renewable electricity 'go green'. As this period draws to a close, Ofgem and the UK government now seek an alternative incentive.

Furthermore, the participants also talked about innovation. Their responses are listed in table 5.1.4 below.

Participant	Viewpoint expressed
1	• We're always looking on the innovation side of things • I see discussion in industry media looking at the challenge with hydrogen and how if you leave it in gaseous form you would need a storage tank so that in itself is a challenge if you're then looking at ships which are going global shipping how would that work, people discuss cryogenic hydrogen, there are discussions around ammonia, and I don't know if the industry has converged yet on a fuel of choice • I think we've got to be open to testing the different fuels
2	• It's quite clear that out of covid everybody's looking for low emissions stroke no emissions renewable energy • We're looking for data from units to support use in hire, looking to use telemetry systems and report back and show the hire units what it's actually done in a period they've had it • People are quite keen to use LPG, the world's moving towards hydrogen, with the CAGE technology it's a matter of reprogramming to run on a different gas, which is a real advantage instead of buying whole new set, that engine will cope with the different gases that come onto the market, there's talk now of using ammonia as a fuel gaining ground in Europe, and the ability for their technology to overcome simple things like engine speed control
3	• Some want to go green for wrong reasons like publicly saying they look good, others do care – we want to become more sustainable and reduce emissions

Table 5.1.4 - Snapshot four of wave one participant responses to interview questions for research question one

The participants talked about the emerging trends in the industry regarding the notion of sustainability, and the differing reasons as to why businesses decide to ‘go green’. Various fuel options were talked about, specifically hydrogen for participants one and two, who stated that hydrogen was attracting a lot of attention within their industries.

5.2 Thematical Map of Research Question One

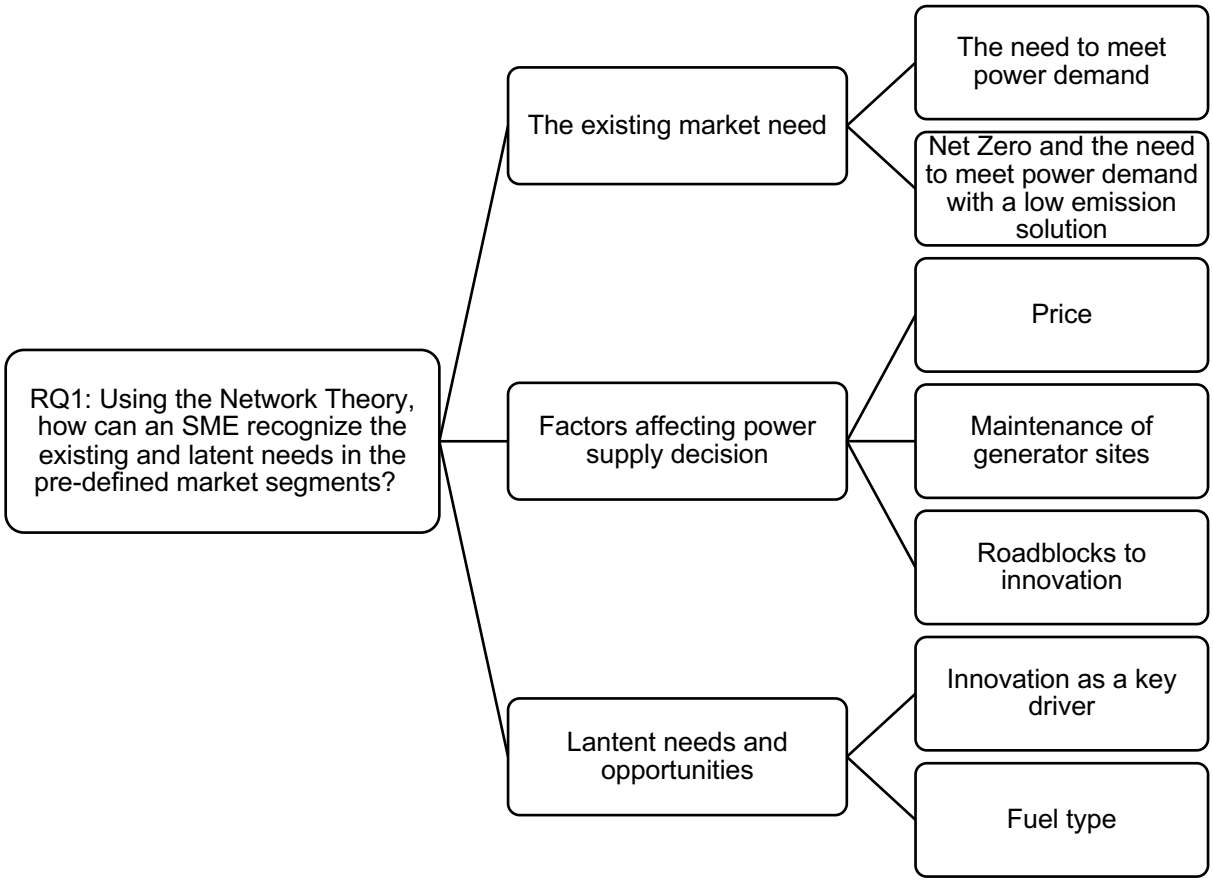


Figure 5.2.1 - Research Question one Thematic Map

5.2.1 Theme 1.1 - The existing market need

Theme definition: Understanding a customer's wants and needs is the first step in developing a product and service which can deliver those needs. Understanding this need can aim to satisfy the consumer's desire to get functional utility out of an offering thus creating value, through communication and delivery of value (Kotler, Burton, Deans, Brown, & Armstrong, 2015).

5.2.1.1 The need to meet power demand

During wave one, all participants expressed the need for small-scale electricity generation in their industries, thus the first sub-theme was formed. An example from the data includes participant two stating "normally a unit like ours would need about 11kva power'. Understanding the heterogeneity of needs of customers (Smith W. , 1956) allows the focal firm to segment the market and market their products and services effectively to reach the needs of their target population. As noted, marketing is an essential part of commercialization (Zadeh, Khalilzadeh, Mozafari, Vasei, & Ojaki, 2017). OakTec have incorporated the market from start to finish and have brought to market a focused product and service proposition, that aims to meet consumer requirements. These needs will be further discussed in the following sections.

5.2.1.2 Net Zero and the need to meet power demand with a low emission solution

A recognised existing need of all the participants was the need to meet the energy demand with a minimum negative environmental impact. Examples from the data

include participant one stating “It’s crucial that you can decarbonize the infrastructure that ferries need on port to come in”. According to the findings, this need to reduce carbon has been accelerated by the UK’s pledge to become Net Zero by 2050, as discussed in section 3. Where a diesel generator was once the primary solution of providing electricity to those in remote areas, diesel cannot meet this latent environmental need, due to its damaging qualities. This creates a huge gap in the market for OakTec to potentially infiltrate. Due to increased awareness on business, the transparency of the business supply chain has been emphasized, along with the external pressure on firms to reduce their carbon footprint. Each participant discussed their own industry targets and challenges relating to this goal. Participant one discussed the strategy of the International Maritime Organization to reduce GHGs, such ambitions include;

- ‘Carbon intensity of ships to decline through strengthening of the energy efficiency design requirements
- Carbon intensity of international shipping to decline, through a reduction of CO_2 emissions per transport work, as an average across international shipping, by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008
- GHG emissions from international shipping to peak and decline – to peak GHG emissions from international shipping as soon as possible and reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008’

Snapshots of the IMO GHG Strategy (UNFCC, 2018)

Participant two outlined their affiliation with the Modulaire Group, that has brought out a statement to reduce their carbon to net zero by 2030. The statement includes

- To source 100% Renewable Electricity for the Group where available
- To shift to circularity, and improve resource efficiency, water, waste, and energy

The UK government’s implementation of the UK’s Move to Net Zero, and the effect this has had on business, emphasizes the critical role of external organisations in facilitating the Energy Transition. The ambitions of the IMO and the Modulaire Group further support this statement.

5.2.2 **Theme 1.2 - Factors affecting power supply decision**

Theme definition: Any factor that will influence the purchase decision of the company. As with any business decision, there are factors to consider, and due to the innovative nature of OakTec's engine offerings, potential roadblocks to the route to market were discussed.

5.2.2.1 Price

Cost and power price were named as the most influential factors for all participants, perhaps beyond the need for a low emission solution, thus the formation of this sub-theme. All participants expressed a need to save cost on diesel, whilst participant two stated that "we must look at the cost…that's the driver all the time". The fuels used in OakTec generators are cheaper than diesel in the markets of interest, presenting a potential opportunity for cost savings. The participants also discussed the Red Diesel Replacement Scheme which was introduced in April 2022 by the UK Government, and the impact this is set to have on the industry in incentivising business to find an alternative fuel source. This will create a huge fiscal incentive for industry to find alternative fuel sources for the industrial machines and create an opportunity for OakTec to become price competitive with existing products on the market. Regarding the Sub-Saharan African market, OakTec's clean gas technology could contribute towards international targets by decreasing fuel prices, increasing the self-sufficiency of farmers, and improving health through improved air quality, whilst simultaneously disrupting the agricultural sector.

5.2.2.2 Maintenance of generators on-site

Generators are often used in remote sites where grid connection is not possible. Due to the lack of accessibility to these sites, the need that emerged was for minimum maintenance where possible. Participant three also discussed that fluctuations of gas levels on the sites create a gas curve over time. When this curve declines, more maintenance is needed on the generator. Whilst the gas curve may be a factor unique to participant three, the need for the generator to work with low levels of maintenance was a requirement for all participants.

5.2.2.3 Roadblocks to innovation

Whilst the government can often be a very positive actor in implementing positive change and facilitating the Energy Transition, governments can also stifle innovation, the analysis revealed. Through participant one, it emerged that the regulation surrounding new products may be a potential barrier to commercialization. Lack of understanding and confidence can often prevent new innovations entering the market. To combat this, participant one spoke of the importance of open communication throughout the acceptance process of new innovations into the market, stating “communication is important for increasing confidence amongst actors”. By working with the government and authorities, knowledge about the innovation is gained, and confidence is therefore increased, which means the new innovation can be accepted into the market.

5.2.3 Theme 1.3 – Latent Needs and Opportunities

Theme definition: The emerging needs in the industries, these needs may not be met yet due to lack of information about the subject area, or associated products and services may not yet be available.

5.2.3.1 Innovation as a Key Driver

Analysis of the findings revealed a fundamental drive in each industry to go greener, creating this sub-theme. The participants discussed the incentives to reduce GHG emissions in the industry, which can be split into extrinsic and intrinsic motivations to find innovations that facilitate industry targets. The extrinsic motivations surround the financial incentives mentioned in section 3, the desire to be regarded highly in public perception, and keeping a good relationship with local authorities and environmental agencies. The participants spoke mainly about the intrinsic motivation, which is a personal desire to push the boundaries of innovation. To give an example, participant three said “we want to become more sustainable and reduce emissions. “The analysis revealed the drive of the participants to be at the forefront of new technologies and to use the best available technology to reduce their emissions. The size of the firm was also highlighted in analysis, as larger firms have more capacity to test new technologies, therefore may be prepared to take the risk and trial new technologies, whereas for the smaller firms, reasons for change may be very much economic.

5.2.3.2 Fuel Type

The discussion revealed a critical point for all three industries interviewed, which was deciding the optimum fuel for providing energy, which provided the setting for the final

sub-theme. Participant one's interest in OakTec is for the generator that uses hydrogen, which is used for the welfare cabins at cruise terminals. They said "That welfare unit is a hybrid battery solar hydrogen genset powered porta cabin". There appeared to be a substantial interest in hydrogen as a fuel, despite concerns over its storage. Participant two's interest is in the generator offerings which use LPG and support a 3.5kW solar array on a roof that feeds through a hybrid power system into a battery bank. When this level of power is not enough for the client, the system kicks the generator in to produce more electricity and OakTec's generator is used as the support generator. Participant three's interest remains with the biogas generator, as the landfill can provide a source of biogas. They said "we want to try and see if there is a way to try and utilise the landfill gas in a small generator". One of the most important conclusions to make regarding fuel choice is that there has not been an optimum fuel solution for many new innovations, and there is no singular fuel choice that will satisfy each power requirement scenario. Factors which may need to be considered include fluctuating prices, location, and fuel efficiencies.

5.3 Research Question 2

This section splits the interview responses into two primary sections, which show Oaktec's engine offerings and their capabilities as a firm, evidenced through the responses of wave two participants.

5.3.1 Offerings

Oaktec have 3 main offerings, which are based on the type of fuel that the engines use, these being Biogas, LPG and Hydrogen. Tables 5.3.1, 5.3.2 and 5.3.3 below give details on these offerings.

Concept: Biogas generator – CAGE6BM

Proof of Concept	Productization	Trial
Assuming a clean gas source, gas engines' oil change periods can be more than double compared to diesel thus saving cost, environmental waste, and time	CAGE6BM A light duty biogas 4kw engine for small scale farmers in developing countries	Completed biogas trials of 5 gensets in Africa during 2021 on remote farms using 50/50 methane/CO2 fuel mixes have encountered no reliability problems and customers are delighted with performance and reliability First commercial sale of 20 6kW gensets to Sistema Bio in May

Table 5.3.1 – Oaktec's Biogas Generator Offerings

Concept: LPG offerings – CAGE6PG and CAGE25PG

Proof of Concept	Productization	Trial
Standard petrol and diesel engines can be converted at low cost to run on a range of low carbon fuels such as LPG, biogas, and hydrogen	Reduced carbon emissions to deliver corporate decarbonisation targets Lower local emissions of particulates and via CAGE's unique 'cool combustion' technology using an ultra-lean air fuel ratio, lower NOx and CO emissions	OakTec have strong relationships with global LPG market leader SHV Energy and their UK business Calor, who are supporting OakTec growth in the UK construction sector. LPG engines on trial with HS2 contractors Costain CSJV, and EKFB over 18 months on hybrid welfare units, typically sing CAGE engine to augment solar derived power. HS2 calculates 75-95% saving in CO_2 compared with diesel equivalents

Table 5.3.2 - Oaktec's LPG fuel offerings

Concept: Hydrogen and hybrid

Proof of Concept	Productization	Trial
Using precise combustion, CAGE hydrogen engines can attain over 40% thermal conversion efficiency, compared to circa 30% for diesel engines High efficiency at low capacities mean that the hydrogen engine is well adapted to hybrid power solutions in combinations with solar	CAGE Zero Hybrid gas engine (o use any LPG/ hydrogen ratio) that will allow an early switch to LPG from red diesel and a phased move to 100% hydrogen as associated infrastructure and security of hydrogen supply develops	Technology being trialled as part of a hydrogen generator with solar and battery storage in Orkney, through EMEC as part of the HIMET project 2022

Table 5.3.3 - Oaktec's Hydrogen and Hybrid fuel options

5.3.2 Capabilities

The following section discusses OakTec's firm capabilities using evidence from the semi-structured interviews. Table 5.3.4 shows snapshots of responses from the participants.

Participant	Viewpoint expressed
4	• The engineers host vast engineering expertise • Our capabilities lie within our research and development, the rate at which things are done, carrying out tasks effectively • We have a mindset of always looking into the future, sometimes looking too far into the future, the worlds not ready for what we're looking at but eventually the world catches up • Networking, the doors are open everywhere
6	• Our strengths lie within the engineering minds, you can give them almost any engineering problem and they will probably solve it, we're very knowledgeable about the technology we provide • The collective innovative mind • We're good at networking and seeing connections, things that could be symbiotic where other people don't see
7	• Our ability to find creative solutions at low cost to problems, particularly engine control problems and engine calibration problems which traditionally take a lot of people a lot of time and money to fix • *Manager* is an absolute strength, they have a very optimistic outlook, and a real drive to keep things going

Table 5.3.4 - Snapshot one of wave two participant responses to interview questions for research question two

When asked about the strengths of the firm, all participants evidenced their technological abilities, through their ability to find solutions to technical problems at low cost, The participants also talked about a passion for research and development, which has been a main driver of the firm to innovate, as technical challenges are enjoyed. The later responses also show a pattern of strong human resources, regarding leadership and the ability to network and form connections in order to progress the firm towards its goals.

5.4 Thematical Map of Research Question 2

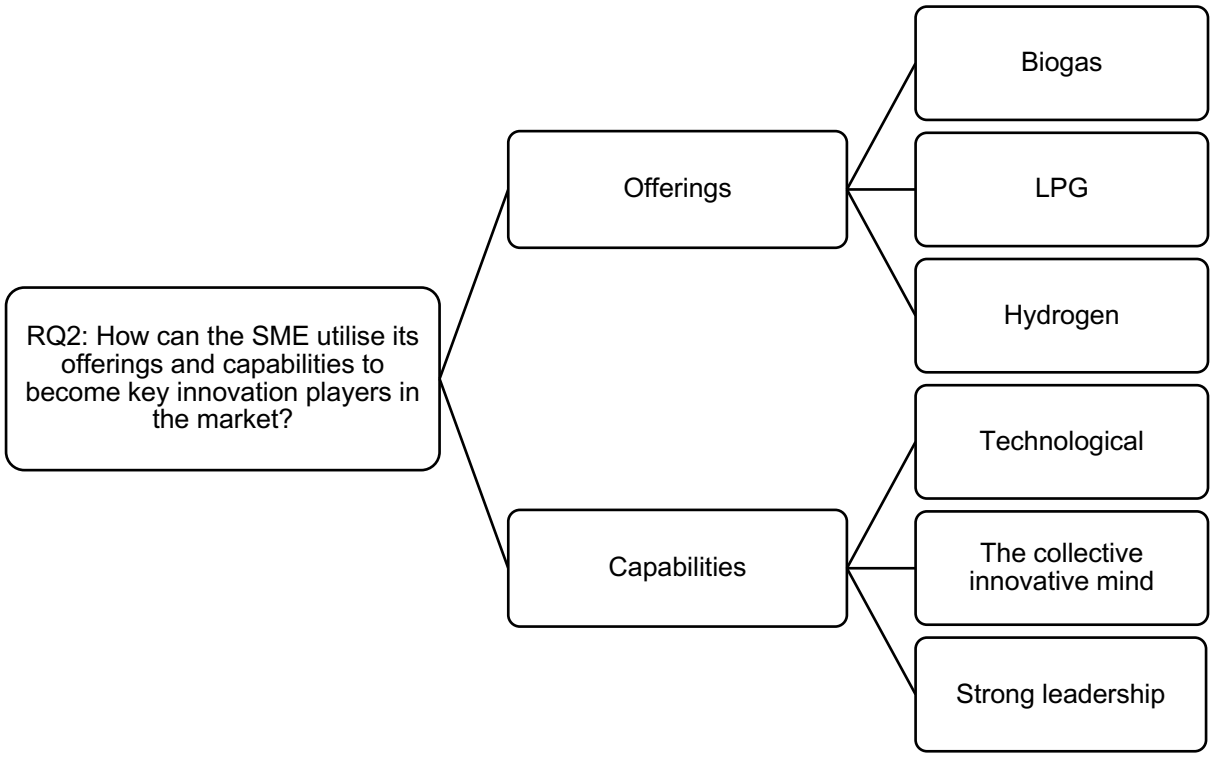


Figure 5.3.1 - Thematic Map for Research Question Two

As previously stated, two areas of focus emerged from the responses, which can be separated into two themes: OakTec's offerings and the organizational capabilities. OakTec's offerings can be split into 3 sub-themes: Biogas, LPG, and hydrogen. These sub-themes are based on the product offerings. The themes that emerged for organizational capabilities were the company's technological capability and the collective innovative mind, which can be described through Teece's Technological Commercialization Theory of dynamic capabilities.

5.4.1 Offerings

The main offerings that have been discussed in the thesis are the biogas and the LPG offerings. Hydrogen has also been touched upon in chapter four and discussed during

the semi-structured interviews. The biogas offerings will primarily impact lower income economies, such as Sub-Saharan Africa and India, which were discussed in chapter four. These markets offer suitable climates and agricultural productivity to provide a reliable source of fuel. OakTec's offerings could potentially solve issues of waste management and environmental degradation OakTec have already entered the Sub-Saharan African market through the biogas trials, which were carried out in Kenya in 2021. As the data in chapter three suggests, India also presents mass opportunity for the firm, and Sistema Bio provide a route-to-market. The needs in the Sub-Saharan African and Indian market also present an opportunity for OakTec and partners, as their technologies present viable modern energy access for those in hard-to-reach areas. Their innovative biogas technology may contribute towards the circular economy model by using feedstock for the anaerobic digestion process, which includes agricultural waste, manure, municipal waste, plant material, sewage, green waste, and food waste. There is also a small-scale opportunity in the waste management industry, as the findings revealed, where the biogas generator could potentially be used on landfill sites.

The LPG offerings will primarily target the small-scale power generation needs of the UK construction industry. Their offerings have been on trial with HS2 contractors, and OakTec also have gained strong relationships with LPG supplier Calor through their network. As chapter four discusses, the UK's construction industry is undergoing huge changes towards a decarbonised sector. OakTec aim to address these carbon challenges by offering a 75-95% saving in CO_2, compared to the diesel equivalent, whilst also offering a low noise solution on sites which are predominantly in urban areas. The firm could also solve this problem for other companies in the industry, who experience similar problems and are seeking a low emission, low noise level energy solution. OakTec's hydrogen genset is the latest product in development. Chapter three also touched upon OakTec's latest hydrogen genset product in development, and the findings further explored the hydrogen space. The analysis revealed that hydrogen as a fuel has generated a lot of interest in the maritime industry, and OakTec's technology has proved viable during the trial in Orkney. The high efficiencies at low capacities also create an opportunity for the engine to adapt to hybrid power solutions with solar.

5.4.2 Capabilities

The following section discusses OakTec's firm capabilities by analysing the findings of the semi-structured interviews. Figure 5.4.2 is an adaption of Teece's schema of dynamic capabilities, the firm's business model, and strategy, and gives a simple understanding of the interconnected nature of dynamic capabilities and how this can be viewed during the formation of strategy.

Theme definition: The firm's ability to design and develop new process, product and upgrade knowledge and skills about the physical environment in unique way, and transforming the knowledge into instructions and designs for efficient creation of desired performance (Wang, Lo, Zhang, & Xue, 2006).

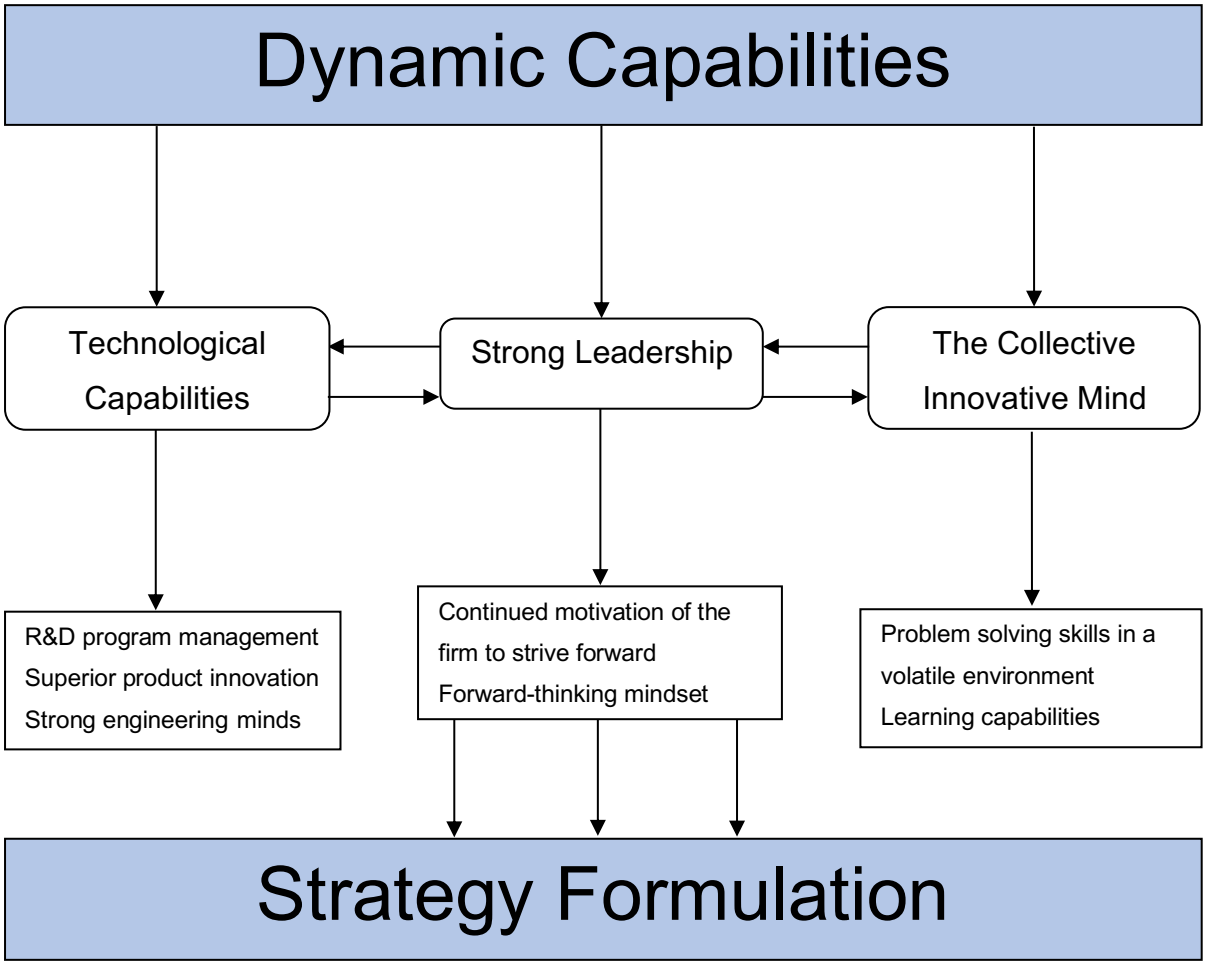


Figure 5.4.2 - The interconnected nature of dynamic capabilities, adapted from (Teece D. , 2018)

As noted, acknowledgement of a firm's capabilities can be a major step for the firm in devising a business strategy (Teece D. , 2018). The capabilities identified from the interviews can be split into two sub-themes: core competencies and dynamic capabilities. OakTec's core competencies surround the everyday processes of the firm, such as 'admin and basic governance', which allow the defined set of activities to be carried out effectively (Teece D. , 2018). It was expressed that the core competencies referred to the daily activities of the firm, such as daily communications.

OakTec's dynamic capabilities can be viewed through the lens of Teece's Technological Capabilities Theory. They are the idiosyncratic capabilities, which are difficult for a rival firm to imitate. The ability to create an innovative product of quality creates the potential for an exceptional competitive advantage in the market. Whilst the firm's learning capabilities and daily processes are integral to the function of the firm, the interviews revealed that OakTec's core dynamic capability as a firm lies within their technological capabilities, and the knowledge surrounding their product offerings. To give an example from the data, participant four stated that "our capabilities lie within our research and development". These capabilities stem from the strong engineering minds of the employees, who together, host vast engineering expertise. The employees provide the firm with an exceptional team of in-house expertise, creating a dynamic capability which can be described as inimitable, and thus provides the firm with a foundation for a sustained competitive advantage. Another example from the data which demonstrates the firm's dynamic capabilities includes participant six stating, "our strengths lie within the engineering minds".

5.4.2.1 Strong Leadership and The Collective Innovative Mind

Theme definition: Strong leadership is an intangible dynamic capability which can be described as the ability to encourage, challenge, and inspire employees to produce their best work. Strong leadership has been listed as an important aspect of the commercialization process, as employees feel motivated and inspired to produce their best work. This leadership translates into a collective ability to find solutions at low

cost, and find connections in the business environment, seeking an effective way through towards a common goal.

The ‘collective innovative mind’ described by participant five, was a concept explored throughout the analysis which describes the ability of the firm to find creative solutions at low cost, to problems such as engine control and engine calibration, which traditionally take multiple people a lot of time and money to fix. This ability is essential during commercialization, as small firms often find limited finance and resource as a major barrier to success. Not only does the collective mind allow the firm to use their technical expertise to solve engineering problems, but it emerged that the firm has also used this capability to solve problems in the business environment. This harvests a creative, forward-thinking culture of the firm, which is always looking towards the future. Evidence from the data includes the statement from participant six, “we’re good at networking and seeing connections, things that could be symbiotic where other people don’t see”. This statement can be related to Teece’s framework of dynamic capabilities, in which one aspect can be described as the ability to identify the potential opportunities in the business environment (Teece, D. J., 2007).

The collective innovative mind can be described as a dynamic capability which can be linked to organizational learning. Learning has been described as essential throughout all stages of commercialization. The ability to reflect upon one’s own experiences and transfer knowledge gained quickly and efficiently is a dynamic capability that can prove extremely useful during commercialization. The analysis revealed an ability of the employees to ‘find creative solutions under low cost’. It can be suggested that this ability is the result of a commercialising environment, where finances in SME’s are often limited. Whilst limited finance and resource may initially be viewed as a disadvantage, overcoming adverse circumstances can strengthen a firm’s ability to cope with future uncertain environments. Such skills include systematic problem solving and using past patterns to make informed business choices based on past experiences. A commercialising environment is one of great uncertainty, depending how this uncertainty is viewed will depend on the ability of the firm to learn and transfer knowledge towards different problems encountered. Successful learning can result in the firm being able to refigure its capabilities to seek out opportunity, respond to the external environment, and gaining of confidence to make decisions under uncertainty and build new strategic assets (Teece, Pisano , & Shuen, 1997).

5.5 Research Question 3

Table 5.5.1 below shows the participants responses to questions asked relating to research question 3.

Participant	Viewpoint expressed
4	• The business model, growing the structure, putting systems in place • If we're going to maximise our potential, we're going to need a lot of money to do it • We've got loads of ideas, the doors are open everywhere, it's having the time and resources to go and hollow it up
5	• This is where the most fundamental changes in business must take place, such as the strategy, business processes, business culture, mindset, which stripe on your commercial flag do you identify as, if you like • You can't set off on a journey unless you know the destination • We're good at shoving the rock to the top of the hill, but we get it to the top of the hill and then we push it round, we're not so good at pushing it down the other side • It's your business plan, it's your pitch, it's the story you tell, we tell a good story, and in contrast to many businesses in this area of clean tech, ours is backed up by substance in the sense that we have working technology • Rather than starting from the bottom and trying to approach contractors or hire companies, we've tried to get in from the top and went to HS2, by getting in at that you create a pull, by going in at the top if you convince the top, you tell people below they have to do it, to some extent the biogas is the same approach, rather than sell to farmers, we've gone in with the business that does the whole thing • You've got to pick your horse; you can't ride two horses because you'll do neither well
6	• The main issue as a small business is trying to decide which opportunities to follow because there aren't enough of us, and we don't have enough money • Our strongest pitching point is our products and the need for them, we've got so much interest
7	• One of our biggest challenges is understanding what our products are worth, what is the price that somebody is prepared to pay • Time is a challenge, ours, and the customers • We have gained the ability to create with limited resource • Having too many good ideas and not knowing which ones to focus on • Our ability to find creative solutions at low cost

Table 5.5.1 - Snapshot one of wave two participant responses to interview questions for research question three

The participants spoke of the challenges they have faced during the commercialization process. Participant six compared the process of commercialization to the act of

“pushing a rock up a hill”, whereby the firm succeeds at completing the technical challenges and creating a market-ready product but reach difficulty when faced with what to do after. The main challenges mentioned can be acknowledged as internal and external. Internal challenges surrounded financial resources, which affect every aspect of the business, from manufacturing budget to the marketing activities. Time was also mentioned as challenge, as the SME lacks time to carry out activities, due to their size as a firm. Lack of strategic direction was also discussed, and how the firm makes decisions on which opportunities in the market to seize.

5.6 Thematic Map of Research Question Three

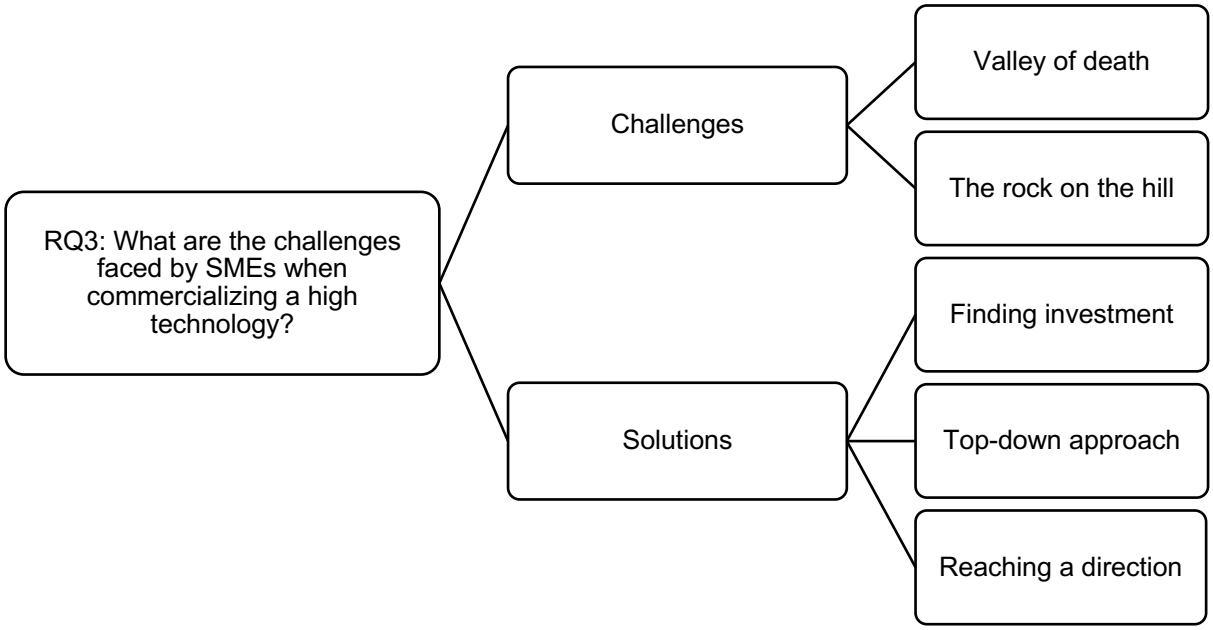


Figure 5.6.1 - Thematic Map of Research Question three

SME’s face heightened challenges when making the decision to enter a new product or service into the market. Research question three delves into the specific challenges faced by OakTec and gives insight into some of the solutions to those challenges, and the options available to them.

5.6.1 Theme 3.1 - Challenges of Commercialization

Theme Definition: The obstacles faced by the SME during the entire process of commercialization from invention to market. These obstacles can be due to external conditions, such as a dynamically changing business environment, and increasing intensity of competition, or internal conditions, such as lack of finances. These challenges are enhanced when the product is a high technology, due to technological complexities and acceptance into the market.

5.6.1.1 Valley of Death

The first theme identified from findings in section 5.3 is the Valley of Death. The Valley of Death can be described as the time frame between completing the technical tasks and commercialising the finished product. This period is characterized by the participants as a time of limited financial resource, and a lack of time to meet deadlines. It is a critical timeframe of a firm's life and is called the Valley of Death because it is within this period that over 70% of start-up firms fail (Embroker, 2022). This period encompasses a range of internal and external challenges to the business, listed in figure 5.6.2.

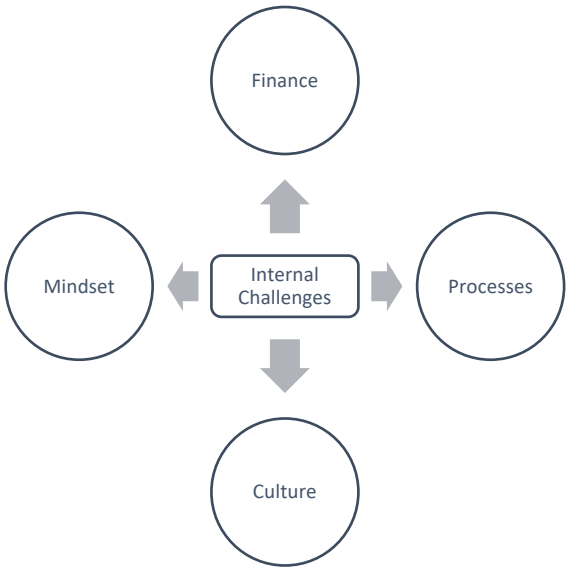


Figure 5.6.2 - Internal Challenges

Whilst presenting challenges, lack of financial resource has also created an organizational capability. The use of systems for the daily activities of the firm was listed as a present challenge, from supply to parts procurement. Supply problems appear to stem externally, from Brexit, which has created longer lead times and increased the price of parts. One example given was the subcontractors of the panels for the generators, who are struggling to get the parts themselves, which creates a knock-on effect. External supply problems such as the subcontracting of parts are described as unavoidable. Internal systems were also described as a challenge, specifically recording the parts used during the building of the generators, and the parts procurement system. Due to the innovative nature of the generators, the building process often involved the trial and error of multiple parts to find the optimum solution, and recording the parts used to form a fully comprehensive list has been a challenge.

5.6.1.2 The Rock on the Hill

This sub-theme relates to the internal challenges of the firm, namely the decision of strategy and which direction the firm should take. It discusses the engineering ability of the firm to reach its technical goals, compared to lack of direction once the product is market ready. The theme is titled ‘the rock on the hill’ after an analysis of participant six’s response, who compared the process of commercialization to the act of pushing a rock up a hill, whereby the firm succeeds at completing the technical challenges, but reach difficulty when faced with what to do after. Another example given from the data is from participant four, who said “the doors are open everywhere “, meaning that the firm has many options to choose from, which was a further contribution towards this sub-theme title. The analysis revealed that the overarching internal challenge that faces the firm is choosing the direction that the business wants to go in. This relates to the lack of direction of the firm, and having lots of opportunity in the business environment, but not knowing which one to seize.

5.6.2 Theme 3.2 - Solutions

Theme definition: The key activities required to overcome the challenges faced throughout the commercialization process. These activities have been developed into three distinct themes which are finding investment, accessing the market through a top-down approach, and reaching an agreement on a direction for the future.

5.6.2.1 Finding Investment

Seeking investment was listed as a key activity by all the participants, hence the creation of this sub-theme. It is also a common solution to the lack of finances faced by many SME's during commercialization. A critical part of attracting investment involves outlining a distinct business plan and strategy for the business, to be pitched to investors. Factors of the pitch which were mentioned by the participants included laying out the journey that the firm has been on, describing how they think it will grow, and showing how the specified amount of money will help the firm achieve its targets. An example from the data can be given by participant five, who said "it's your business plan, it's your pitch, it's the story you tell, we tell a good story".

5.6.2.2 Top-down Approach

Accessing the market was a challenge listed by the firm and its employees. To approach this problem, a top-down approach has been used. The rationale is given in the data through participant five, who said "Rather than starting from the bottom and trying to approach contractors or hire companies, we've tried to get in from the top and went to HS2, by getting in at that you create a pull ". A top-down approach involves identifying the right actors to provide a platform where a firm can sell their product

offerings. For OakTec, HS2 has provided a platform in the construction industry to utilise their generators on HS2's construction sites. Sistema Bio, the Mexican based biodigester company, have also provided OakTec with a platform to sell their biogas generators, and a means to commercialise internationally. Sistema Bio provide a critical link to the hard-to-reach areas, listed in section three, whilst also facilitating payment with their financial model which provides a means of financing.

5.6.2.3 Reaching a Direction

One of OakTec's primary challenges throughout commercialization has been lack of direction and strategy. The participants were clear in describing their ability in engineering, and the subsequent options made available to the firm in the market, however choosing which routes to explore has been a notable challenge. An example from the data is from participant five, who said "You've got to pick your horse; you can't ride two horses because you'll do neither well ". This extract depicts the importance of choosing one direction. The decision on which direction to take is the decision of strategy at the firm level. The analysis revealed the aims and goals of the business, based on firm capabilities and present opportunities in the market, which can be developed into a firm strategy.

5.7 Research Question 4

The following section will outline OakTec's network, which has been shown in figure 5.7.1 below. Figure 5.7.1 illustrates OakTec's network through the ARA model, which depicts the interconnected relationships between OakTec's actors, resources, and activities.

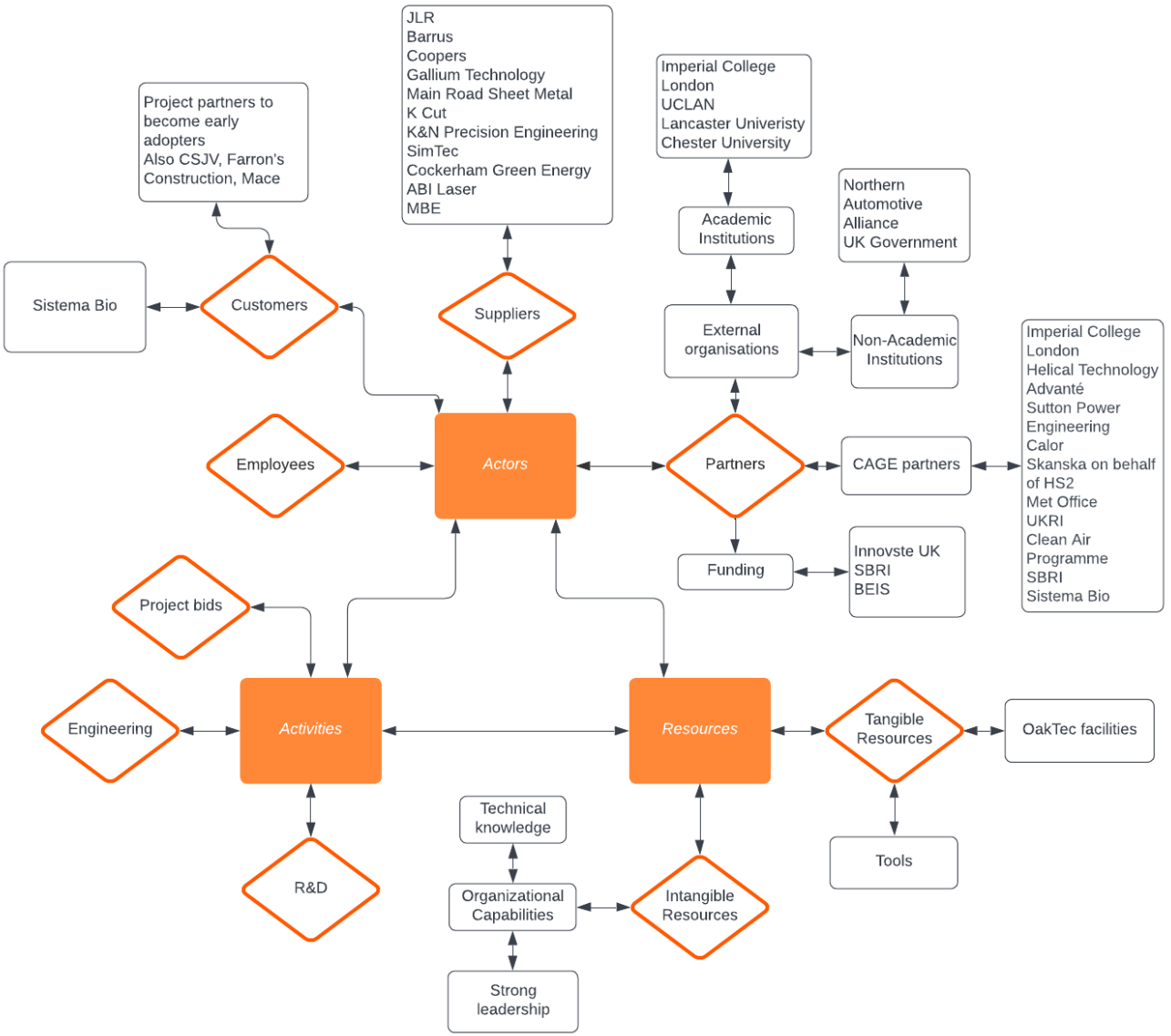


Figure 5.7.1 - Oaktec's Network through the ARA model

The findings revealed that OakTec functions within a network of actors, resources, and activities. It is important to note that the diagram is not exhaustive but listed with the most valuable exchanges for the firm during its commercialization.

Table 5.7.1 below aggregates the key actors in OakTec's network and depicts their value to the firm, through extracts of the semi-structured interviews.

Actor	Connection to OakTec	Value
HS2	Project partner	Helped the firm to 'understand how the construction industry works, giving us access to the construction companies'
Sistema Bio	Project partner and customer	They are 'a key link we've got They have taught us about 'the world of renewable energy in developing economies'
Innovate UK	Funding support	We wouldn't exist today without Innovate UK. They have been incremental in financially supporting the firm
Calor	Project partner and fuel supplier	Calor are a key link we have, supplying the fuel for our projects for free
Northern Automotive Alliance	Engineering Affiliation group	They run a lot of really useful programmes they've had like a group that have got together every so often and they can all talk about the problems they have with their business and how they've overcome them, and people can ask each other for certain pieces of advice on how you tackle certain issues, so I think that's been quite useful
Sutton Power	Generator parts supplier	Sutton taught us everything we know about generators
Advante	Project partner	Advante brought the idea of solar hybrid welfare cabins
EMEC	Project partner	They hosted the hydrogen project

Table 5.7.1 - Key Actors in Oaktec's Network

Each actor listed in the table has aided OakTec in the commercialization process. The participants spoke of the importance of networking and talked mainly about the collaborations which have formed project partnerships, and how they have contributed value to OakTec and its network, either through their share of knowledge or resources. Another crucial actor who has aided the firm financially are Innovate UK. Innovate UK are a government organisation who are part of the UK Research and Innovation Department. According to participant six, their funding has been crucial in allowing OakTec to create, test, and showcase their engines.

5.8 Thematic Map of Research Question 4

The analysis of the interviews revealed that OakTec's network has been incredibly valuable, providing critical connections and opportunity throughout the commercialization process. The themes that emerged are the knowledge exchange and the access to markets and resources. The following section will explore OakTec's network using the Network Theory, and the ARA model.

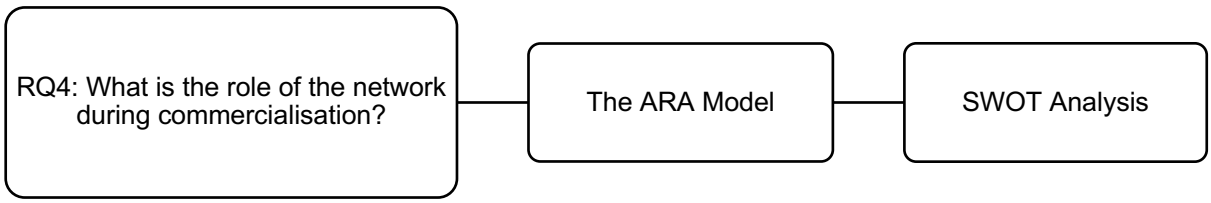


Figure 5.8.1 - Thematic Map of Research Question Four

5.8.1 The ARA Model within the Network

Theme definition: The interconnected relationships of the firm which is categorised by actors, resources, and activities. It is within this network that the firm gains value from the knowledge and resource exchanges, promoting the long-term growth and health of the firm.

The actors involved in OakTec's commercialization process have provided the firm with extremely valuable connections. They include the partner firms, who are involved in the project's collaborations and trials, suppliers, and external organizations who influence the firm's activities. The dual-way exchanges provide the firm with different forms of value, building inter-organizational relationships, whilst also giving the firm tools and resources to navigate commercialization, such as the tools to increase problem solving skills. The term 'cooperation' is not often used when discussing competitive markets, however OakTec's collaboration through its actors have brought great value to the firm.

The analysis revealed the vital role of the projects and collaborations, namely the HS2 project, the biodigester trial with Sistema Bio in Kenya, and the HIMET hydrogen project with EMEC. These projects have provided OakTec with a vital opportunity to test and showcase their products, giving them a platform through which they can market their innovations. The trials also provide the firm with an opportunity to share any lessons learnt, sharing potential frustrations, things that went well and highlighting areas for improvement, to lower first mover risk. Ensuring the knowledge exchange within the network and extending beyond to the industry and market means that each project continues to improve, as each actor in the project discovers the creases and snags in terms of wider scale roll out on a commercial level. As new innovation faces increased uncertainty in the market, innovative programmes and trials can increase adoption rates by increasing user confidence, Lower first mover risk, faster acceleration to market. The Northern Automotive Alliance is another actor who have been of great non-monetary value to OakTec. Participant six said "the group runs a lot of really useful programmes" which has allowed the firm to learn. Whilst providing a

platform for OakTec to trial and showcase their products and service, the project partners have also exchanged knowledge on their respective industries, teaching the SME valuable market intelligence. An example of a tangible resource gained through the network includes LPG gas provided by Calor, and generator panels provided by Sutton Power. Financially, Innovate UK is an actor who have provided OakTec with a funding resource for the projects throughout the years, which has given the firm a platform and means to design and create their innovations. Their importance is stressed through participant six, who said “we wouldn’t exist today without Innovate UK”

OakTec have undergone vigorous stages throughout their process from innovation to a market-ready product. These processes can be described as activities. The daily activities mentioned by the firm include communications, which are all integral to the day-to-day workings of the firm. Whilst all activities are integral to the daily function and progression of the firm during commercialization, some activities that lead to more significant business events or ‘milestones’ were described by the participants. At present, OakTec carry out most activities listed above, however as the firm progresses through commercialization, there may become more option to outsource activities to save time and capital.

5.9 SWOT Analysis

The table below analyses the data collected from the semi-structured interviews into categories of strengths, weaknesses, opportunities, and threats to the business.

It has been uncovered that much of OakTec's value is created through its inimitable dynamic capabilities, primarily the technological superiority and the collective innovative mind, giving the firm an ability to integrate, build, and reconfigure capabilities to enhance decision making and respond to the external environment. OakTec also thrive in their ability to network and create new connections which is important, to further their platform and widen their reach. For example, participant four said "our strength is networking". The formation and collaboration with project partners raise awareness of their product and service offerings in the market. Supreme technical ability and strong networking skills has given the firm a tremendous ability to cope in an uncertain commercialising environment, which has resulted in the firm's first commercial sale of the biogas generators.

Strengths	**Weaknesses**
• Dynamic capabilities of the firm, principally the technological expertise which has translated into efficient, quality product • Collective innovative mind • Strong leadership creating strong network links • Creative problem solving • Legislative drivers, Regulation favouring low emission innovations • Project partners enabling international market entry	• Lack of capital • Lack of employees to carry out all business activities
Opportunities	**Threats**
• Increased commercial sale through project partner Sistema Bio in developing markets • First commercial sale of LPG and hydrogen hybrid offerings in the UK Construction industry	• Lack of time • Lack of strategic direction • Slow lead times on parts due to disrupted supply chain

Table 5.9.1 - SWOT Analysis

The main weaknesses of the firm which were uncovered during the interview were lack of resources and business direction. This is synonymous with the challenges faced by many SMEs during commercialization. If not addressed, weaknesses can lead to firm threats. For example, lack of human resource can result in a lack of time to complete all necessary activities, which will ultimately lead to missed order times. Lack of strategic direction can result in a firm missing an opportunity or entering the market late and missing out on a first mover advantage. To be a pioneer, it is important for OakTec to formulate a firm strategy.

6 Conclusions and Implications

This section will first cover the recommendations to be put forward to OakTec, based on the findings and analysis of the semi-structured interviews. The section will focus on the optimum strategic priorities and protocols, whilst discussing the role of the network in the route-to-markets into the relevant market segments which were discussed in section 3.2.

6.1 Business strategy and development

After analysis of all the data gained, it is recommended that OakTec adopt an international business strategy. An international business strategy is a strategy where all business functions, including management and operations, are centralized in the home country. The firm imports and exports goods internationally but do not have offices in any other country. All business investment is made in the home country, and the firm maintains autonomy over their business decisions. This allows business decisions to be streamlined, so that operations are carried out effectively and timely.

Figure 6.1.1 - OakTec and CAGE Technologies brand image

Whilst OakTec have a clear view of global trading under one brand image, it is recommended that OakTec and CAGE Technologies Limited adopt two separate paths, shown in figure 6.1.1. The analysis revealed that the firm's strength lies within its ability and passion to research and develop new technologies. By splitting the two

entities, OakTec can maintain its blue-skies R&D function, whilst CAGE Technologies Limited adopts the commercial side of the business, which generates revenue through sales.

6.2 Route to Market

OakTec's strategy is to utilise grant funding to continue to demonstrate the clean gas technologies and convert trial partners to become early adopters and first commercial customers, as has been the case with Sistema Bio becoming the first commercial customers for OakTec's biogas generators. Of the three current product offerings, it is believed that OakTec's nearest term opportunity lies with Sistema Bio and the biogas generators. Sistema Bio has ambitious expansion plans for its anaerobic digester firm in several developing economies, including operations in Sub-Saharan Africa and India. Entering seemingly unattractive markets with a low GDP may serve as strategic importance for the future, as being a first mover in the market can gain competitive advantage. For the LPG and hydrogen offerings, OakTec's market of focus remains in the firm's country of origin, aiming to serve customers in the UK Construction industry, by replacing diesel generators to support the UK's Move to Net Zero. OakTec's engagement in this industry include Costain, Mace, and Farrrans, along with project partner HS2. Figure 6.2.1 depicts sales projections for each product, sourced from OakTec.

Customer	Timing	Period Revenue	Comment
1 Biogas product			
1a Sistema Bio	2022	£140k	Following successful trial of 5 units in Kenya, first order received for **20** 6kW gensets. Supply by Q3.
1b (i) Sistema Bio	2022 -2023	£2,000k	Verbal commitment, subject to positive feedback from first customers, for **500** genset units of cost- reduced version of machine supplied above. Order expected Q4.
1b (ii) Sistema Bio and similar customers	2024 onwards	£6,500k	Estimated **13,000** units of modified engines to support AD fuelled gensets across Africa, South and SE Asia, Central and South America. Global rollout from Sistema Bio, as well as opening sales to other customers (conversation to send test unit to Vietnamese customer).
1c UK & Europe AD and Landfill applications	2022 onwards	£2,000k	CTL approached by multiple UK operators and is now in discussions with 12 prospects including SUEZ/Veolia, FINNbiogas, Telemark Technologies and Landfill Systems. High value low volume application bespoke solutions. c.**200** units.
2 Pure H_2 product			
2b (i) Hydrogen early adopters UK	2022-2023	£165k	Proof of concept gensets based on 6kW Orkney HIMET units. Interest to buy **10 or more units** following enquiries from Myerscough College, HS2 and UK Port Authority and others.
2c (ii) Hydrogen early adopters UK	2023-2024	£2,400k	Higher capacity proof of concept hydrogen-only genset. 11-15kW. HS2 example- requirement on their suppliers to improve air quality and reduce harmful impact. Potential to apply to site buildings, welfare, cranes, generators and over longer term site vehicles. **120 units** out to 2027 sales will move to CTL's hybrid engines.
3 Hybrid LPG/H_2			
3b Jaguar Land Rover, Coopers, and other engine OEM's	2024 - 2026	£13,000k	Licence CAGE engine control technology, volumes growing to **2-300,000 units per annum**. To supply technology at scale, this will be delivered through combination of physical product, but moving to licence model. CTL has MOU with EP Barrus that targets supply of **12000** 6-15kW gas engines to displace small diesel engines.
4 Pure LPG			
4b (i) Existing contractors now engaged with CAGE	2022 - 2023	£900k	CTL working with Costain, Mace and Farrans on the Red Diesel Replacement project, part UK Government funded but contractors also committing resources. Opportunity to supply pre-certified 11-15kW engines for construction industry. **500 units** estimated prior to rollout of CAGE's hybrid engine.
4b (ii) Other UK infrastructure projects	2023 - 2026	£2,100k	Interest expressed from Network Rail, National Highways, DEFRA, Ports, Forestry and others to secure an interim alternative to diesel ahead of the availability of a hybrid engine availability. Potential to supply clean power for site buildings, welfare, cranes and generators with a certified 11-15kW LPG solution. Other applications such as site vehicles over longer term. **2500 units** estimated by CTL's partner currently operating in this market.

Figure 6.2.1 - Expected sales growth of the biogas, LPG, and hydrogen offerings from the year 2022 onwards

Financial Projections

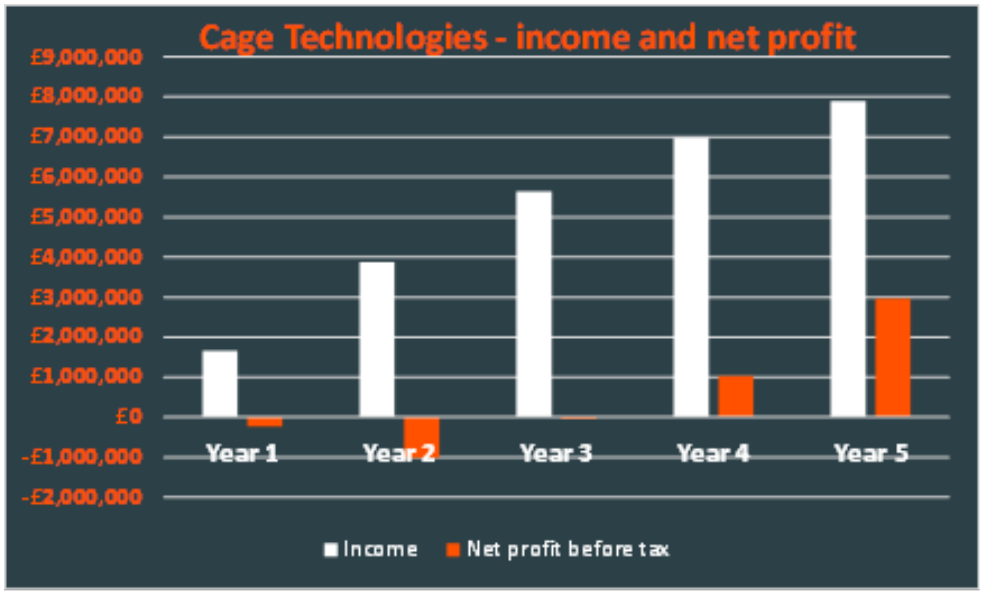


Figure 6.2.2 - Oaktec Financial Projections (Oaktec)

Figure 6.2.1 outlines the expected sales growth of the biogas, LPG, and hydrogen offerings from the year 2022 onwards, with the resulting financial projections, depicted in figure 6.2.2. The analysis revealed that, as an SME, OakTec have lacked time to gain knowledge of potential overseas markets. A common challenge of commercialization in SME's is market acceptance, adoption, and diffusion, along with accessing market knowledge, especially when the product is a high technology. Through key actors, depicted in figure 5.7.1, there is evidence of a cooperative strategy in the sales projections for each of the clean gas technologies, as the project partnerships and collaborations provide OakTec with a route-to-market, with an aim to eventually become OakTec's first customers and early adopters. Project partners help to deliver valuable market intelligence, which OakTec may have difficulty accessing as an SME, due to lack of specialism and resources. Project partners also provide value to OakTec through enhanced brand recognition and reduce first-mover risk. Market level deployment of a new innovation often comes with elevated risk, and regulation from government and the market can often stifle innovation, as the analysis revealed. Working with collaboration creates high uncertainty avoidance and gives consumers confidence through the credentials of the partner organisation.

Operational Plan

Phase 1 from 2022

- Low volume inhouse manufacture of engine conversions within existing HQ facilities – planned capacity 2 units per day with possibility to increase to 4 units per day (1,000 units per annum).
- A small amount of equipment investment is planned to facilitate these volumes.
- Beyond this we would seek to outsource the build operation – no firm route for this committed yet.
- Very low volume build on gensets also within existing facilities – potential capacity 2 per week. (100 units per annum)
- Beyond this Gensets for CTL supply would be built by Sutton Power ltd.
- Additionally there is an opportunity to source fully built gensets for some applications and add CTL engine technology.
  This operation would be outsourced.

Phase 2 (from 2023)

- In-house configuration of conversion kits for proprietary engines – planned capacity 10 per day, with potential to increase to 20 per day (5,000 units per annum).
- These conversion kits will be engineered to suit specific engines used by key customers, funding for this is included in the business plan.
- A small amount of equipment investment is planned to facilitate these volumes.
- Beyond this we would seek to outsource the build operation.
- Procurement and material planning for this phase would be conducted by the existing team, with the addition of a Purchasing and Logistics Manager during this phase.
- To support the build operations, the workshop headcount will grow from 1 to 4/5.

Phase 3 (from 2024)

- Application of CAGE technical solution to engine OEM's under licence (individual customer project volumes >10,000).
- Significant bespoke engineering to suit specific engines - funding for this is included in the business plan.
- Engineering resource doubles through the period to deliver this.
- Legal services become key to ensuring appropriate IP protection and contractual framework – this cost is included in the business plan.

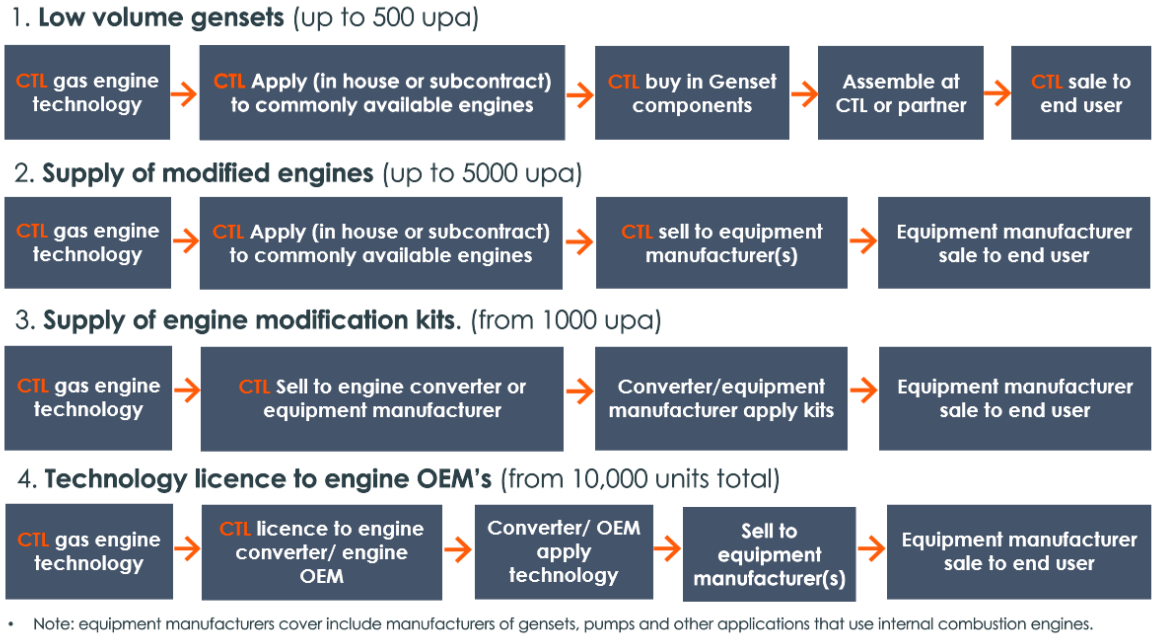


Figure 6.2.3 - Oaktec's proposed business models

OakTec's operational plan describes the steps OakTec will be taking in the next 2-4 years, split into three phases. During phase one, OakTec will focus on building a low volume of products in-house. During phase two, the building operation activities will become outsourced, and a Purchasing and Logistics manager will be sought. Figure 6.2.3 depicts the proposed business models which will support OakTec in each phase of the commercialization process, as the firm focuses on scaling up the volume of gensets. During this period, OakTec's network will gain new actors and resources, which will aim to aid future increase in units of sale, by providing increased manufacturing capabilities which will increase unit capacity, whilst simultaneously aiming to transform the power sector, by working with NGO's, developmental actors, governmental organisations, and private sector actors, all of which stride toward a common goal – reducing our dependence on fossil fuels whilst simultaneously providing affordable, clean energy.

Source of Competitive Advantage

OakTec's network have provided the firm with a sustained foundation for competitive advantage through a differentiation leadership approach. This is a clear strategy of

differentiating one's product in the market by providing the customer with a unique selling point and charging slightly higher prices in order to provide the value presented through the marketing plan. The customer value proposition (CVP) can be suggested below.

> Customer Value Proposition: For operators of gensets, construction equipment, and agricultural equipment that currently use internal combustion engines to attain their net zero carbon ambitions via a well-defined path at minimal cost, disruption, and risk.

The CVP articulates the key benefits of the firm's product offerings, outlining who the customers are, the problems that the customers face, and how OakTec intend on solving problem, whilst also providing a clear picture of where the value is added. Throughout the research it has been made clear that one of the key drivers of the market is the desire for clean energy. The CVP is successful in defining the potential users of the products, and the environmental benefits of the net zero emissions. Through the CVP, OakTec can position itself as a highly innovative, technology centred SME, with the capacity to compete in the market against large incumbents.

6.3 Concluding remarks

The semi-structured interview analysis from wave one participants revealed that the main drivers for the potential customers are cost and the need to reduce carbon. OakTec have produced commercially viable, market-ready offerings. Through the collaborations, such as Sistema Bio, HS2, and EMEC, OakTec have been given a platform to showcase significant emissions reductions through their innovations, which has created a significant market opportunity. The collaborations with project partners through the network have the potential to facilitate accelerated adoption though targeted customers, whilst also strengthening the knowledge exchange within OakTec's network.

The analysis from wave two participants uncovered a strong organisational dynamic capability to innovate. It may be beneficial for OakTec and Cage Technologies Limited to separate entities, to maintain the valuable R&D function, whilst also creating a commercial element to the business, where revenue can be generated. Through a differentiation leadership approach, OakTec can separate their product from current offerings on the market. OakTec should now prioritise seeking investment, to scale-up the business, both in terms of human and physical resources, with an end goal of increasing their commercial sales and achieving financial targets. If executed correctly, OakTec will successfully commercialise their small power generation engine offerings and participate in the green revolution to end the dominance of diesel generators.

7 Limitations and directions for further research

This report has focused on the commercialization of the SME, the challenges and opportunities faced by an SME, in the market. Gaps in the literature involved understanding how SME's can recognise and exploit the opportunities available to them, and the network can facilitate commercialization of high technologies for the SME. The study's strengths and limitations are presented in the following section.

The study allowed purposive sampling to be used, meaning participants were chosen based on their knowledge of their field, meaning rich data could be gained for analysis. The transcripts were recorded onto a secure word document to ensure audio was written accuracy throughout the transcription to ensure accurate data analysis. The format of the interview allowed for explanation and depth of interview answers, which allowed participants to explain any points that were made. After analysis of the results, the study can add the following contributions to the existing literature. The study recognised how the SME can use their network as a core strategic priority. The study also focused on the specific challenges of the SME during commercialisation and opportunities made available through the network, which translates to increased value for the firm, depicted in the CVP. The most notable challenges of commercialisation for the SME when commercialising a high technology are financial, this is in line with the existing literature. It was also found that acceptance of the technology was a potential challenge. In order to combat this, the results revealed that the SME works closely with actors in the network to educate them on the benefits of the technology.

The network aids the SME in recognising the existing and latent needs in the market through communication with market players. The network increases opportunities for the SME to commercialise through exchanges with actors, activities, and resources. These exchanges increase the SME's knowledge on the industry and the commercialisation process, they have provided critical funds for the SME during commercialisation, and the network of actors has ultimately led to OakTec's first commercial sale. This demonstrates the enhanced learning capabilities of the SME in the network. One solution that may be added to the literature is the top-down approach that the SME has taken in order to reach the market and its customers. This can be recognised as a core strategic priority.

There were several limitations to the study, the first being that the wave one participants are hard-to-access, due to their positions in industry. This created a small sample size, which is a limitation of the study as more participants would have resulted in more data to analyse. The industries represented in the semi-structured interviews were the waste management industry, the construction industry space, and the maritime energy space, however failed to represent the biogas space in developing countries, a large potential market for OakTec. A lack of representation in this market was due to lack of response rate. Secondly, findings can't be exactly replicated in all situations. According to (Yin, 2009) this can become a future opportunity, as the findings may instead reveal new considerations that may hold relevance in other situations. One final limitation worth noting is the time frame of this study, which does not allow for a longitudinal study.

A mixed methods approach (Denscombe, 2014) defined as analysing primary and secondary data, to assess market opportunities may be useful in assessing future market opportunities beyond those made present in OakTec's network. Future research may also include a detailed analysis of further markets for OakTec and CAGE Technologies Limited, specifically the hydrogen space, which has been touched upon in this research.

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