How are absorptive and desorptive capacities developed in the UK energy supply sector? The role of transition intermediaries

by

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Copyright Statement

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

To Viviana

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Abstract

The 2050 net zero goal committed by the UK Government represents a great challenge for the energy supply industry. This sector has been dominated by incumbent firms traditionally interested in maintaining business as usual and with little capabilities to lead the technological leap necessary to decarbonise operations. For such reasons, radical innovation can be found in socio-technical niches. A sheltered space, shielded from incumbents' influence, where innovation actors have the freedom to learn how a new technology works in a process full of uncertainties.

To meet the net zero goal, the UK energy supply industry must find a way to increase the sluggish adoption of innovation in incumbents, alongside reducing the high failure rate of niches. This thesis points out that the fundamental driver of change may be transition intermediaries, which can support the enhancement of capabilities in both niches and incumbents to respectively diffuse and adopt new technologies.

This thesis examines how this triad of actors can propel a socio-technical transition in the UK energy supply sector. Methodologically, this investigation proposes a new conceptual framework to analyse the development of absorptive capacity in incumbent firms and desorptive capacity in socio-technical niches through the influence of transition intermediary functions. Following this approach, this thesis makes an important contribution by inserting the Resource-based View of the Firm theory into the transition literature.

The study identified that transition intermediaries provide critical resources for strengthening capabilities for diffusing and adopting technology innovation. The results contribute to explaining how intermediary functions push actors to deviate from incremental trajectories. The findings are valuable to the transition literature because they explain how different actors collaborate to produce technological innovation, replacing the Schumpeterian notion of creative destruction. For practitioners, the significance lies in the impact that the intermediary functions have on innovation management at both levels of adoption (incumbents) and diffusion (niches) of new technologies during the turbulent time of a socio-technical transition.

Appended conference presentations

Gonzalez, H., Hannon, M. and Tapinos, E. (2021). *The generation of strategic capabilities at the UK Energy Revolution.* R&D Management Conference, PhD Colloquium, July 2021, University of Strathclyde, Glasgow, UK

Gonzalez, H., Hannon, M., Tapinos, E. and MacKenzie, N. (2020). *Strategy for circulating innovation: Incumbents, intermediaries and niches at the UK Low-Carbon Energy Revolution.* The 11th International Sustainability Transition Conference, August 2020, AIT Austrian Institute of Technology, Vienna, Austria

Gonzalez, H. and Hannon, M. (2019). *Accelerating the energy transition in Scotland via the new alliance of Davids and Goliaths*. SPRU PhD Forum, May 2019, University of Sussex, Brighton, UK

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List of Acronyms and Abbreviations

BBC British Broadcasting Corporation

CCC Climate Change Committee

CO_2 Carbon Dioxide

CVEI Consumers, Vehicle and Energy Integration

DBEIS Department for Business, Energy and Industrial Strategy

DECC Department of Energy and Climate Change

DfT Department for Transport

DMIW Digital Manufacturing Innovation Hub

EDF Electricité de France (French Electricity)

EIC Energy Innovation Centre

EMEC European Marine Energy Centre

ES Catapult Centre of Energy System

ETI Energy Technologies Institute

EV Electric Vehicle

GHG Greenhouse Gas

HMRC His Majesty Revenue and Customs

HVMC High Value Manufacturing Catapult Centre

IEA International Energy Agency

IPR Intellectual Property Right

KTN Knowledge Transfer Network

LNCF Low Carbon Networks Fund

M&A Merger and Acquisition

MISP Michelin Scotland Innovation Parc

MLP Multi-level Perspective

NDA Non-disclosure Agreement

OECD Organisation for Economic Cooperation and Development

OEUK Offshore Energy UK

OFGEM Office of Gas and Electricity Markets

OGA Oil and Gas Authority

OLEV Office for Low Emission Vehicles

ONS Office for National Statistics

ORE Catapult Centre in Offshore Renewable Energy

PNDC Power Networks Demonstration Centre

RBV Resource-based View of the Firm

R&D Research and Development

RWE Rheinisch-Westfälisches Elektrizitätswerk (Rhenish-Westphalian Power Station)

SE Scottish Enterprise

SP Scottish Power

SSE Scottish and Southern Energy

SVT Standard Variable Tariff

TIS Technology Innovation System

UKIPO UK Intellectual Property Office

UKPGA UK Public General Acts

1 Introduction

This thesis investigates the development of capabilities for the diffusion and adoption of low-carbon technology innovation in the United Kingdom (UK) energy supply sector[1].

Today, the UK faces great pressure to transform its energy supply sector, particularly to reduce carbon emissions. At the heart of this industry are utility companies, which for decades have provided power under stable conditions thanks to the extended use of fossil fuels. Despite the efforts to decarbonise the generation of energy, utility companies still produce almost half of the electricity from gas, while more than three-quarters of the total heating demand from end users is supplied with gas (DBEIS, 2020).

Recently, these companies have faced significant concerns about the security of energy supply (Benton et al., 2022) and, at the same time, the pressure to find alternative and affordable technologies to become less dependent on fossil fuels (DBEIS, 2021a). This last target has been a recurrent goal of the UK Government aiming to address climate change by promoting a more sustainable society. The UK was the first major economy to set a net zero target for cutting greenhouse gas emissions by 2050 (DBEIS, 2019). The combination of these factors has pressured the UK energy supply sector to radically modify the carbon base on which it operates.

According to the IEA (2020), the introduction of technological innovation is essential for achieving this goal. In the energy supply industry, technology innovation is defined as the set of devices and processes related to the extraction, processing and use of energy, including energy security, energy poverty, air and water pollution and global climate change (Gallagher et al., 2012). For example, new technologies to widely electrify end-use sectors, such as advanced batteries; carbon storage systems that can capture CO_2 emissions from large power generation; hydrogen and related fuels that can decarbonise heating; and bioenergy whose lower carbon emissions can be easily absorbed by the atmosphere. Technological innovation is generally costly and risky by

[1] This sector is referred to producing and transmitting electricity as well as transporting gas mainly for heating purposes, and selling both to the final customer (ONS, 2022a).

nature (Dodgson et al., 2008), with few utility companies willing to get involved in its development (Geels and Turnheim, 2022).

For this reason, technology innovation tends to be produced by non-incumbent actors who are less compromised with the dominant industrial structures. They nurture low-carbon technologies in incubation rooms or "socio-technical niches", protected spaces where radical novelties emerge (Geels and Schot, 2007). There, academic projects, start-up firms, experimental ventures and field trials can demonstrate the functionality of a new technology. Thus, socio-technical niches are expected to promote low-carbon alternatives that can be later adopted by large utility companies helping to achieve the net zero transition. However, the diffusion of new technologies in the energy supply sector is extremely difficult due to the interconnection of technological pieces within the power system; and additionally, the strong interrelatedness between energy with the economic system, with most economic processes depending on the current energy system (Negro et al., 2012). Hence, any integration of innovation into the energy supply system will require a great coordinated effort of incumbent and niche actors in two main areas. Firstly, the decarbonisation of the current energy supply system based on fossil fuels. Secondly, on minimising the risks of affecting other components of the economy during this transition.

The literature has reflected on the intricate relationship between socio-technical niches and incumbent firms (Bergek et al., 2013; Berggren et al., 2015; Kivimaa and Kern, 2016), proposing transition intermediaries as the key catalysts to approach positions and facilitate the change towards sustainable systems (Kivimaa et al., 2019a). These are defined as middle organisations actively pursuing sustainable goals through the generation of networks that can lead to deep reconfiguration of industrial sectors (Caloffi et al., 2023).

This thesis assumes that net zero transition can be progressively induced through the collaboration between this triad of actors. Precisely through the efforts of transition intermediaries that can enhance capabilities for diffusing and adopting technology innovation in actors that receive their assistance. Thus, incumbent firms can develop absorptive capacity, namely the firm's ability to recognise, assimilate, transform and exploit external knowledge to commercial ends (Zahra and George, 2002). Meanwhile, socio-technical niches can cultivate desorptive capacity as the organisational faculty to identify opportunities for externally exploiting new technologies and transferring these to other network actors (Lichtenthaler and Lichtenthaler, 2010).

Consequently, this research focuses on analysing how transition intermediaries support the development of absorptive capacity in utility companies and desorptive capacity in socio-technical niches in the UK energy supply sector. By strengthening this relationship, new technologies can be transferred from one small, niche organisation that owns specific and complex technological knowledge to another larger, incumbent firm for commercial ends (Bozeman, 2000).

The previous set of ideas suggests that the presence of transition intermediaries plays a critical role in enhancing capabilities in both socio-technical niches and incumbent firms. These capabilities can help to establish stronger links of collaboration for promoting the development of technology innovation and thus meet sustainable goals, such as net zero in the UK. Taking these elements as the critical concepts to be investigated by this thesis, the Introduction presents the overarching research question as follows:

> ***How do incumbent firms and socio-technical niches develop technology innovation management capabilities?***

To address that question, this thesis will employ the UK energy supply sector as the specific empirical context through which the investigation will be conducted. To explore the role that transition intermediaries have in enhancing capabilities propelling absorptive and desorptive capacities, the overarching research question is disaggregated into two research questions as follows:

> ***A. How do transition intermediaries support the development of absorptive capacity in utility incumbent firms of the UK energy supply sector?***

Here the thesis seeks to identify the functions that transition intermediaries deploy to develop capabilities related to absorptive capacity (Zahra and George, 2002) in energy supply incumbent firms.

B. How do transition intermediaries assist the cultivation of desorptive capacity in socio-technical niches of the UK energy supply sector?

The aim is to similarly analyse the functions that transition intermediaries employ to influence the development of capabilities related to desorptive capacity (Lichtenthaler and Lichtenthaler, 2010) in socio-technical niches of the UK energy supply sector.

To address the research questions, this thesis creates a novel conceptual framework to qualitatively examine the functions that transition intermediaries implement to enhance capabilities to absorb and desorb green technologies in the UK energy supply sector.

The next sections of this Introduction Chapter outline the investigation's empirical and theoretical background, which has been organised in the following way. Section 1.1 explains the need for the energy transition in the UK, from three key dimensions: economic, energy security, and sustainability. Additionally, it discusses the current efforts made by the energy supply industry to achieve the transition and the future scenarios involving a high degree of technology development to decarbonise utilities' operations. Section 1.2 presents the theories that explain the multi-dimensional processes in economics, political, institutional and socio-cultural areas, influencing the transition in the UK energy supply sector. This consists of a combination of technical and social aspects that the research community has named socio-technical transition. Section 1.3 introduces the research gap that consists of the lack of understanding about how the triad of actors (incumbent firms, socio-technical niches and transition intermediaries) can develop technology innovation in the UK energy supply sector. Finally, Section 1.4 describes the general structure of this thesis.

1.1 The need for the energy transition in the UK

This section covers the need for a transition in the UK energy supply sector, based on three key areas: economics, energy security and sustainability. These combined make a strong argument to move forward with a radical transformation of the energy supply system, which is the main topic in this section.

1.1.1 The economic point of view supporting the energy transition

Through the second half of the 20th Century, the UK experienced a considerable decline in heavy industry and the country was transitioning to a services-oriented economy (Turner, 1995). During that period, the discovery and later exploitation of the North Sea's oil and gas have become a major part of the national economy since the 1970s (Shepherd, 2015). However, the total oil and gas production has declined in the last decade, combined with a fall in the international price of such hydrocarbons (HMRC, 2022). As Figure 1.1 shows below, the oil and gas companies have responded to these challenges by reducing the expenditure on the North Sea operations. By the end of 2021, the production was less than 50% of the level seen in the peak year of 2014. The North Sea oil and gas production has become a severe concern for the UK Government, due to the implications for power security and the risk of becoming an energy net importer country (UK Parliament, 2023a). Moreover, the oil and gas industry is a major contributor to the UK economy, with an estimated £12.8 billion in taxes for 2022/23 and supporting 214,000 jobs (OEUK, 2022). Immediate measures were proposed. As part of the UK Chancellor's Budget in 2015, the government introduced a new investment allowance and reduced the headline rates of tax to incentivise investments in this beleaguered sector (HM Treasury, 2015).

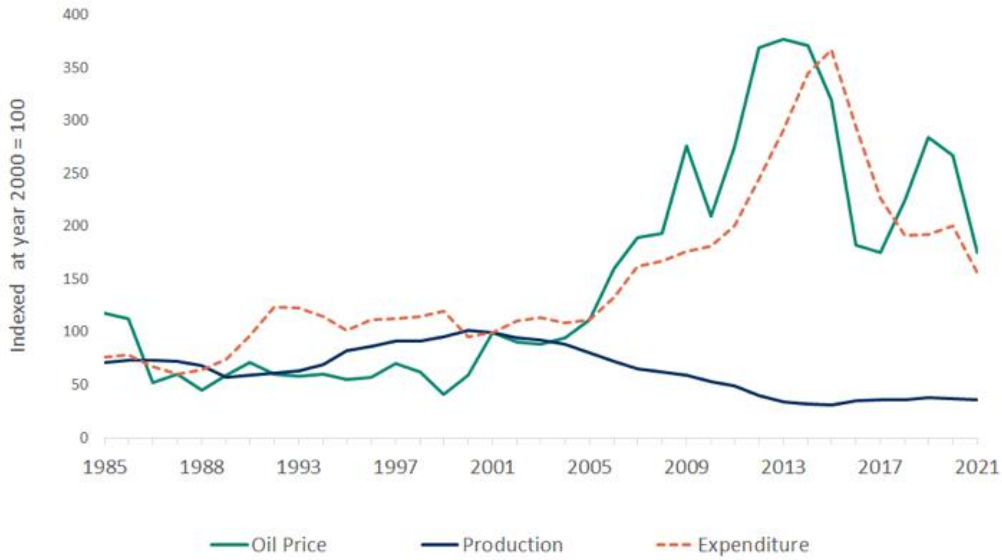

Figure 1.1 Oil & gas production, operating expenditure and Sterling oil price in British territory 1985-2021
Source: HMRC (2022)

Despite efforts to boost the industry, the oil fields in the North Sea are in a steady decline. As shown in the next Figure 1.2, oil and gas production in British waters peaked in 1999 and then declined almost 8% every year until 2014. Despite a slight increase since then, the level of production in 2017 was still around a third of the top recorded in 1999. Natural gas has encountered a similar drop since the highest production in 2002; in 2017, the outcome was around 20 million tonnes of oil equivalent (Mtoe), which was less than half compared to the highest level 15 years ago.

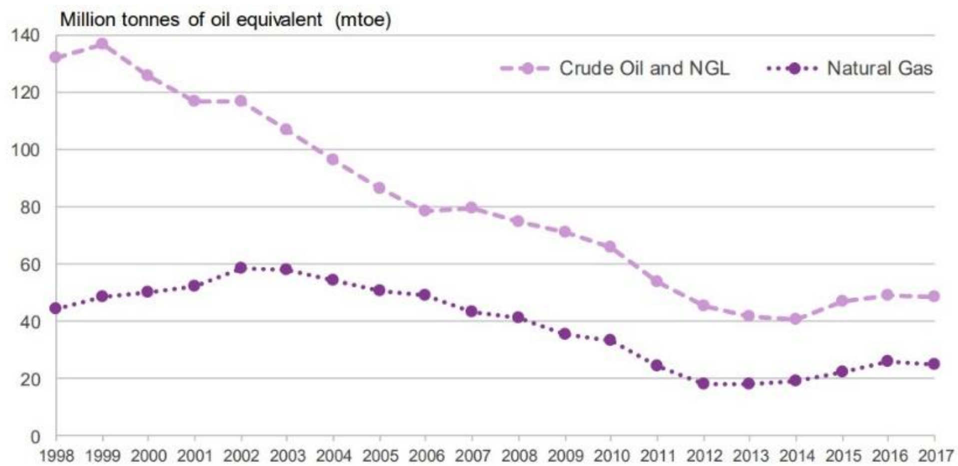

Figure 1.2 Oil and gas annual production volumes in British adjacent waters
Source: Scottish Government (2021)

The OEUK report (2022) expects that oil and gas reserves can be extended beyond 2050, with estimated remaining reserves of up to 15 billion barrels. Nevertheless, different forecasts have calculated 5.7 billion barrels for probable reserves, which could sustain production for another 20 years (OGA, 2016). According to these trends, the next couple of decades will be critical for the UK to complete the transition to clean sources of energy. Otherwise, the country is at risk of becoming energy dependent. Importantly, not being capable of taking advantage of the opportunities that a future green economy will bring in terms of developing technologies and engineered solutions (CCC, 2020).

1.1.2 The security point of view supporting the energy transition

In the last couple of years, the international price of oil and gas has increased the cost of energy to a record level in decades. In September 2022, the wholesale price of gas grown by 404% in the past 12 months (Ofgem, n.d.[a]). This has had two main ripple effects in the UK energy supply industry. First, with almost 85% of British households heated by gas boilers, the average cost of heating has increased more than 10 times in the last year (Ofgem, n.d.[a]). Second, gas is responsible for 38% of the electricity generation in the UK (DBEIS, 2022a). This means that the price of producing electricity has increased the average bill of a typical household from around

£1,000 at the end of 2019 to more than £2,500 by October 2022 (UK Parliament, 2023b). Overall, the energy price cap[2] has steadily increased from the beginning of the Covid-19 outbreak in 2020, and this tendency has augmented even further after the Russian invasion of Ukraine in 2022[3]. Figure 1.3 shows the gap between the price cap and the cheapest tariff between 2012 and 2023 of around 28 million householders on standard variable tariffs (SVT) controlled by the price cap. This graph exhibits a price cap increase of 54% in April 2022, which continued with another rise of 80% in October 2022 (UK Parliament, 2023b).

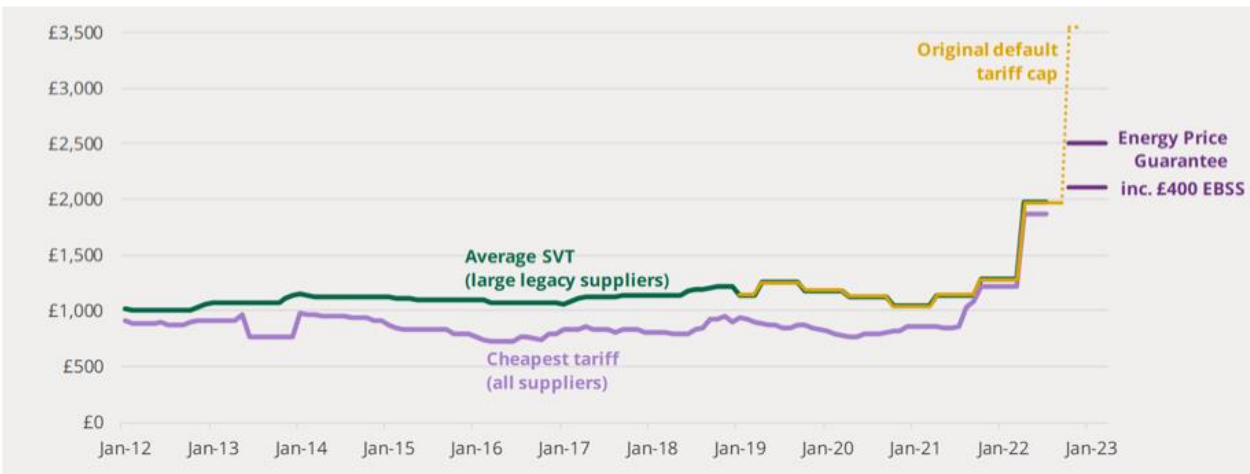

Figure 1.3 Average energy bill (electricity and gas) in a British household
Source: UK Parliament (2023b)

These international events have exposed the vulnerability of the UK energy supply system and presented a strong argument in favour of reducing dependency on fossil fuels. Some voices have proposed that this geopolitical context turns urgent the transition to net zero in the UK, including a zero-carbon power sector by the next decade (Froggatt, 2022). This is one of the biggest

[2] The energy price cap is a backstop protection from the government for people to pay a regulated price of energy, limiting how much suppliers can charge the customer per unit of gas and electricity. The energy price is calculated based on the underlying costs of producing and supplying energy to the end consumer (Ofgem, 2020).
[3] Russia is the second largest producer of natural gas in the world, according to IEA (2021). This has brought tremendous destabilisation in the international market of gas and consequently impacted the price of electricity in the UK and the whole of Europe (Zakeri et al., 2022).

challenges that the UK energy supply sector has ever faced, with different stakeholders asking for a stronger public commitment to accelerate total decarbonisation (CCC, 2020).

1.1.3 The environmental point of view supporting the energy transition

The increase in greenhouse gas (GHG) emissions, as the result of burning fossil fuels, presents a huge threat to human welfare. To prevent it, the UK needs "to start cutting emissions now" (CCC, 2008: p. xiii). DBEIS (2018) has pointed out that CO_2 is the main GHG emitter, accounting for 81% of the total emissions in the UK and estimated the annual net emissions of CO_2 in 366.9 million tonnes in 2017. The report has stated that oil and gas combined are responsible for 333.9 million tonnes of GHG, which accounts for 91% of the total GHG emissions. This indicates that CO_2 emissions have caused a variation of 2.1% in the external temperature for that year alone in the UK. The Committee on Climate Change, the independent public body advising the UK Government and Parliament on tackling for climate change, established six sectors as the main issuers of GHG emissions in the UK: power supply, industry, building and transport, with non-CO_2 GHG gases in agriculture and waste (CCC, 2008). The details of GHG emissions per sector are shown in Figure 1.4.

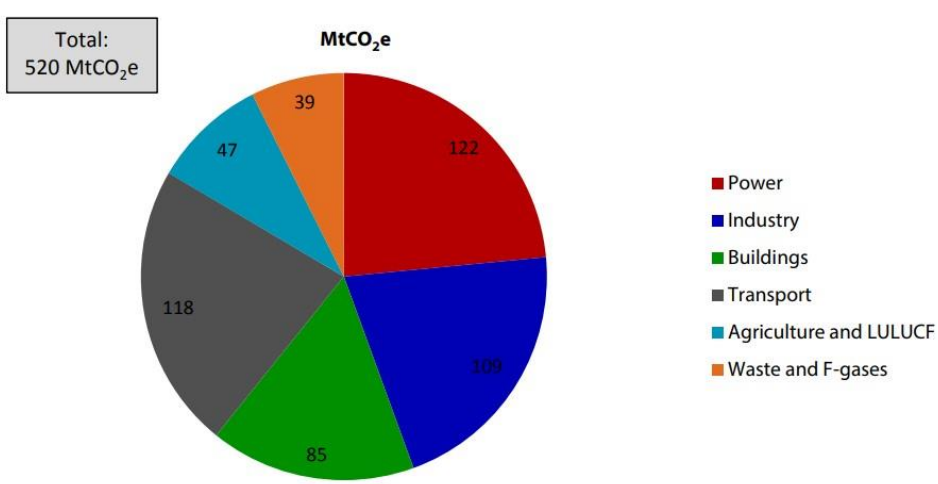

Figure 1.4 *GHG emissions by sectors in the UK*
Source: CCC (2015)

Electricity and heating generation contribute to the larger proportion of total GHG emissions in the UK, due to the predominant use of fossil fuels. The proportion of electricity generation coming from fossil fuels was 42.6% in 2021 (DBEIS, 2022b); and the use of gas in heating generation was 70% (Ofgem, 2016). To mitigate this environmental damage, the UK energy supply sector is under great pressure to reduce GHG emissions by promoting the phase-out of carbon sources. In this scenario, the overall energy demand would switch from fossil fuels to mainly electricity, driven by the demand for new appliances in transport and heating (HM Government, 2020). Consequently, “the level of electricity consumption in 2050 could be up to 135% above the level in 2014” (CCC, 2015: p. 8). This represents a great challenge for the UK energy supply sector that can be addressed by integrating new technologies (CCC, 2022a).

1.1.4 General sustainability overlook of the UK energy supply sector

The current outlook makes it imperative to proceed with a radical transformation of the energy supply sector. In response to these challenges, the UK Government has decided to initiate a transition towards a low-carbon emission economy and consequently became the first major economy to legislate GHG reduction targets (DBEIS, 2019). Following the 2009 Climate Change Act, the UK targeted a net zero reduction in CO_2 emissions, compared to the baseline of 1990 (UKPGA, 2008). The deadline for this goal is 2050. The 2009 Climate Change Act also established an institutional framework for setting intermediate carbon budgets and holding the UK Government accountable for achieving the net zero target. The CCC, part of this institutional setting, consisting of experts in climate science, technology and economics, recommends monitoring the net zero progress through carbon budgets. These budgets consist so far of six periods (2008-12, 2013-17, 2018-22, 2023-27, 2028-32, and 2033-2037), which will be progressively covered with new budgets every four years until reach net zero by 2050. The CCC proposed the Sixth Carbon Budget in December 2020 comprising a limit of 965 $MtCO_2e$ for the period 2033-2037, implying a 78% reduction from 1990 to 2035, as Figure 1.5 presents.

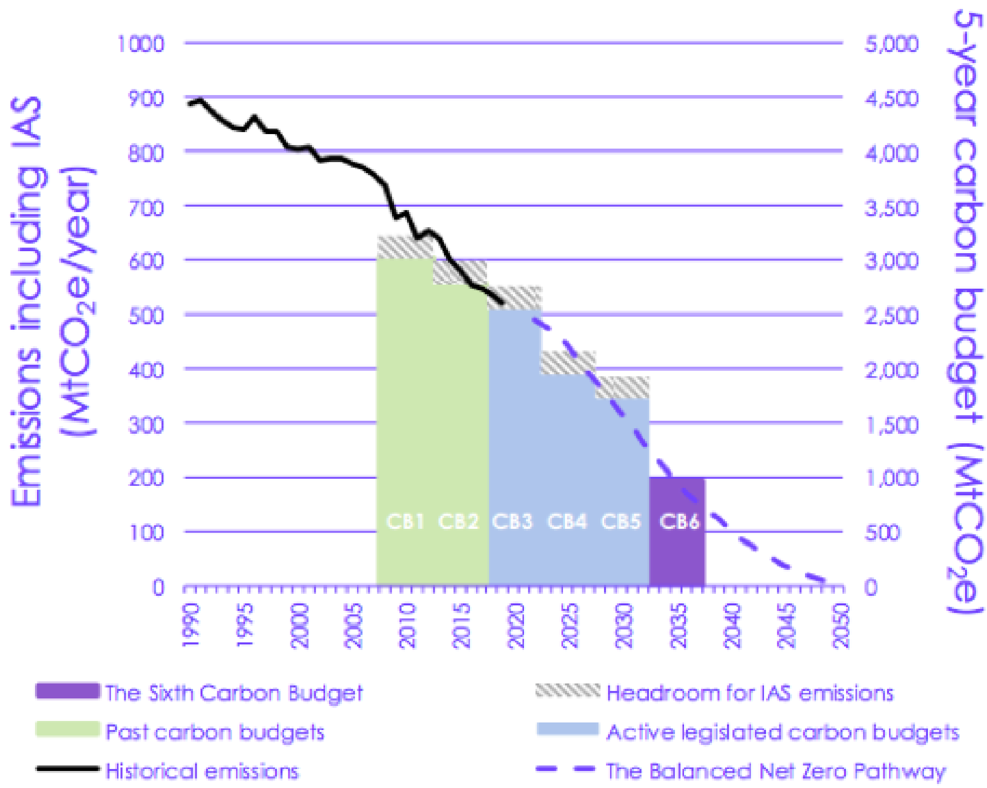

Figure 1.5 The recommended sixth carbon budget for the UK 2050 net zero target
Source: CCC (2020)

Such a transformation puts the incumbent firms of the UK energy supply sector under great pressure to transform their business operations. As previous data has shown, these greatly rely on fossil fuel sources to generate energy and later distribute it to the final consumers. Consequently, incumbent firms continuing with business as usual is simply not an option for the long-term purpose of reaching a sustainable energy supply system (Pereira et al., 2022).

This challenge has been a relevant topic of discussion to proceed with the net zero transition (Kattirtzi et al., 2021). The energy supply sector is dominated by six utility companies: EDF, E.ON, RWE, Scottish Power, Centrica, and SSE. The so-called “Big Six” have a market share of around 73% by 2018 (Kattirtzi et al., 2021). A position of leadership obtained thanks to cross-ownership and vertical integration into other areas of the energy supply sector (Ekin, 2011).

Incumbent firms have made little progress in decarbonising the energy supply system. Despite the growing share of renewables to produce power, the supply sector still relies on natural gas as the principal source of energy generation. Figure 1.6 shows that offshore wind is the main renewable source of energy generation from the Big Six companies, but to a lesser extent in comparison to gas.

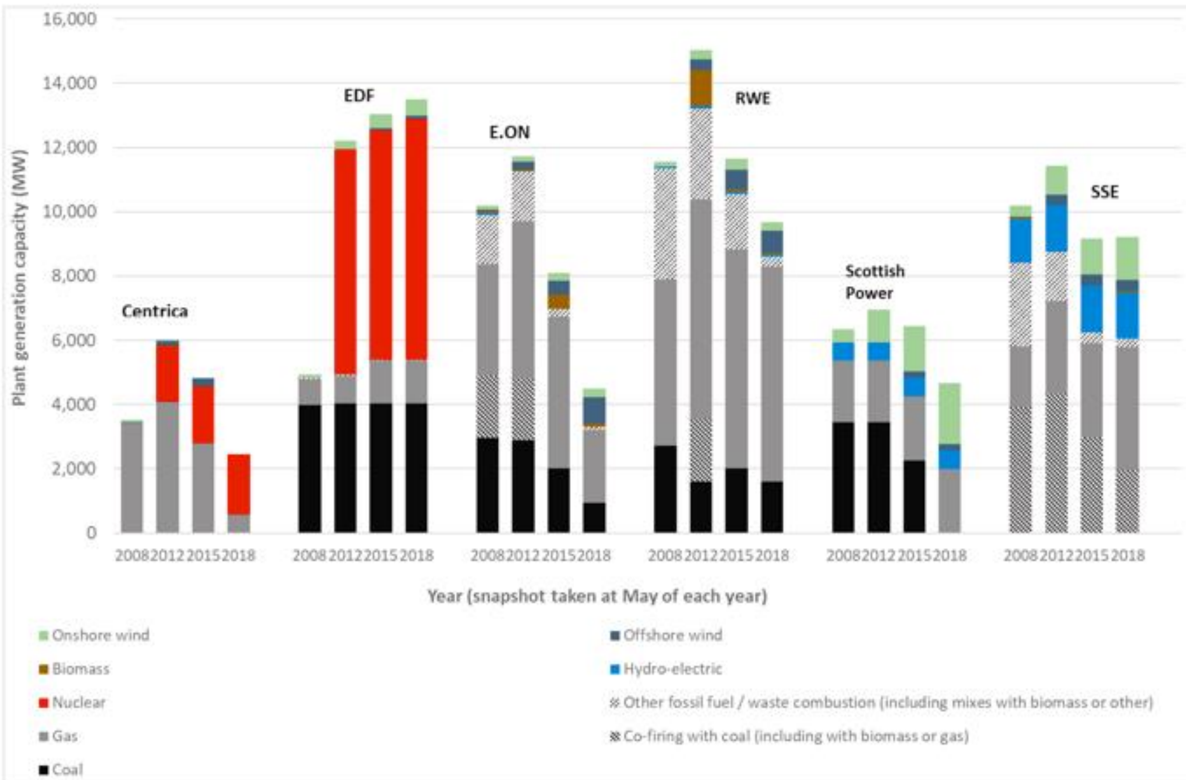

Figure 1.6 UK Total power installed generation capacity owned/part-owned
Source: Kattirtzi et al. (2021)

To remedy these circumstances, the development of new technologies by incumbent firms via corporate R&D is considered a critical element that can move forward the intensity of the net zero transition (Polzin, 2017). However, the private investment in internal R&D from the Big Six has remained low. Table 1.1 exhibits that the annual investment in R&D from the total revenue of the Big Six is 0.1% on average. This represents an estimated sum of £110.9 million per year, according to the last annual reports of those companies. A figure that does not significantly contribute to the total budget for energy R&D in the UK of £1,200 million in 2021 (IEA, 2022), in which most of the investment comes from public funds.

Table 1.1 Estimated annual investment in R&D from total revenue by Big Six firms

Company	*Total investment in R&D*	*Total Revenue*	*Percentage of R&D investment from total revenue*
Scottish Power	£4.4 million	£5,349 million	0.08%
SSE	£12 millions	£8,616 millions	0.14%
EDF	£17 million	£13,700 million	0.12%
E.ON	£58.5 million (EU total)	£115,700 million (EU total)	0.05%
Centrica	N/A	£23,741 million	N/A
RWE	£19 million (EU total)	£21,600 million (EU total)	0.09%
	Total £ 110.9 million		**Average 0.1%**

Source: Based on Corporate Reports from SP (2021), SSE (2022), EDF (2022), E.ON (2022), Centrica (2022), RWE (2021)[4]

Similarly, the tax credit claims on R&D from the electricity, gas, steam and air conditioning sectors, which include the utility industry, have one of the lowest levels among the whole UK industry, as the following Figure 1.7 presents. During the fiscal period of 2020-21, the utility sector declared a total expenditure of £195 million on this item.

[4] In the cases of E.ON and RWE was not possible to find the specific figures for the UK market. Their corporate reports only publish numbers in the European market.

Figure 1.7 Number of R&D tax credit claims by industry sector (fiscal year 2020-21)
Source: ONS (2022b)

We can compare these numbers with the fines imposed on utility firms for failed goals on energy efficiency, smart metering deadlines, and mismanagement in customer service. In 2021, the total payment of fines in the whole sector totalised £191 million in that year (Ofgem, n.d.[b]). This annual sum represents more than the total R&D budget of the Big Six firms of £110.9 million; and is slightly behind the tax credit claims of £195 million. In consequence, there is growing pressure for the Big Six to increase its clean technology commitment to develop low-carbon infrastructure that can replace its current carbon dependency and move towards the net zero goal.

The target to reduce GHG emissions is certainly ambitious, and it is expected that new technologies for such purpose will be introduced in the UK energy supply sector (Hannon and Skea, 2014). The generation, diffusion and adoption of net zero technologies in this industry requires coordinated efforts between government, industry and consumers to overcome the failures and market barriers that translating R&D results for producing new technologies represent (Foxon et al., 2005). The scale of this change is unheard of, affecting not only the incumbent utility firms but also reconfiguring current patterns and scale of economies that will affect most of the social, industrial and commercial activities in the UK (Bridge et al., 2013).

1.1.5 How the transition in the energy supply sector could take place in the UK?

Based on technical and economic modelling, the UK will transition towards future scenarios in which fossil fuels' consumption would shift to electricity, generated from low-carbon sources (Foxon, 2013). This electrification scenario is shared by other analyses (Barton et al., 2018; Chilvers et al., 2017), forecasting the transition to low-carbon electricity with high levels of renewable generation (National Grid, 2017). This requires significant levels of investment in energy innovation (Winskel et al., 2014). Although such an approach has progressed in the last couple of years in the UK (Hammond and Pearson, 2013), it is assumed that further electrification will be harder to achieve given that it will deeply affect the current energy supply system. Electrification would mean that consumption is going to be concentrated in a couple of renewable sources, making it difficult to manage peak demands and having the risk of saturating the system (Quiggin and Buswell, 2016).

The CCC (2015) has recognised such possibilities and suggested the need to focus the low-carbon electricity in certain areas (households, transport and power supply) and proposing extra efforts on developing technologies in electrification for heating and transport, plus the implementation of carbon capture and storage technologies in heavy industries. Recent arguments have placed hydrogen as a credible option to complement low-carbon electricity (CCC, 2020). Particularly, to replace natural gas in places where electrification is not feasible or prohibitively expensive. Other ingredients of the future energy supply system will potentially include a growing role in data analysis on the intelligent management of demand and supply (Milchram et al., 2018). However, incumbent firms are ill-equipped to deliver this decarbonisation agenda due to their technological, operational and strategic lock-ins that make it difficult for them to adopt such innovations (Erlinghagen and Markard, 2012; Richter, 2013; Verbong and Geels, 2010).

In summary, the combination of technological options demands that different actors –such as utility firms, the public sector, innovation producers and end-users– share a common vision of the low-carbon future. It is a difficult task where multiple stakeholders present different priorities for the future energy supply system (Foxon and Pearson, 2014). The CCC (2022b) has warned about the challenges of the energy transition in the current cost of living crisis in the UK, derived from Brexit and the war in Ukraine, suggesting to joint position on the critical topics of energy security, climate change and new infrastructure in delivering a net zero future. This underlines the need to develop collaborative frameworks where a variety of actors can contribute to the technological upgrade of the UK energy supply system.

1.2 Socio-technical transition to sustainability

The previous section 1.1 described the empirical context and the associated challenges in which the energy transition will take place in the UK. This framing put the incumbent firms in the UK energy supply sector under pressure to modify their business and operational practices based on fossil fuels. This section now presents relevant theories making the case that incumbent firms must innovate and that connecting them better with niche actors via transition intermediaries is a critical next step. Accordingly, different theories will be used by this thesis to explain the multi-dimensional processes to link these three actors and achieve sustainability goals in the UK energy supply sector.

A wide range of studies has shown that any transition of today's energy supply system to a future of lower GHG emissions is not only a technical matter (Skea and Nishioka, 2008). The transition literature argues that the modification of the energy supply system also depends on societal aspects, related to the behaviour, values, norms and strategies of different individual and institutional actors, who in combination with technological elements will promote a sustainable future (Foxon et al., 2010). The research community has named the conjunction of technical and social aspects that leads to this fundamental shift as “socio-technical transitions” (Markard et al., 2012). This concept assigns equal importance to both elements of technology and social practices in driving forward the sustainability transition.

Geels (2002) has explained that technology development is possible in association with human agency, social structures and organisations. This inter-relationship tends to blend over time, facilitating the use of artefacts and subsequently generating routines in individuals as well as organisations. When these practices gain robustness, it can be said that we are in the presence of a "socio-technical regime" (Geels, 2005a). This term describes the interdependence of material and social structures, such as policies, culture, technologies and markets, which co-evolve into a stable configuration that subsequently enables the fulfilment of a certain societal function, like energy provision (Fuenfschilling and Truffer, 2014). The socio-technical regime imposes a logic and direction for improving routines through incremental change creating rigid pathways for technological development (Markard et al., 2012). Often, this produces unsustainable regimes because of the main technological function brings negative effects (Geels, 2004). For example, the energy supply system operated by incumbent firms and based on fossil fuels that generate carbon emissions with serious impact on the natural environment and human life.

New entrant firms, academic R&D and entrepreneurs have recognised these problems and developed technical alternatives in niches that compete with the dominant design from regimes (Geels, 2006). In this conceptualisation, socio-technical transition consists of a shift from one configuration to another, involving the substitution of technology as well as the modification of social elements. However, new technologies have extreme difficulty in being diffused and adopted because of the mismatch with the established socio-institutional regime (Geels, 2004). This has led to identifying socio-technical dimensions of the regime as inert or directly resistant to external change, such as incumbent firms (Geels, 2014).

To date, much of the research exploring the engines mobilising the socio-technical transition has been focused on the technological change that emerges from green innovations, paying less attention to incumbent actors who protect the stability of the socio-technical regime (Turnheim and Sovacool, 2020). On the contrary, it is equally important to consider the role of incumbent firms from existing regimes and the use of power to facilitate, deter or stop change coming from socio-technical niches (Steen and Weaver, 2017). Therefore, this research aims to develop an alternative approach proposing that socio-technical transitions are in part a consequence of incumbent firms and socio-technical niches interaction. Specifically, with their ability to collaborate for diffusing and adopting technological innovation. Following this argument, the next sub-section 1.2.1 will introduce the idea of collaboration between incumbent firms and socio-technical niches as a driver of the socio-technical transition in the UK energy supply sector.

1.2.1 The potential collaboration between incumbent firms and socio-technical niches

Incumbent firms are defined as large commercial organisations which have achieved a significant share of the market and have operated their business model for a long period, frequently using an outdated set of technologies (Lowes et al., 2017). They have set the material conditions for technology to operate and establish routines enabling the continuous functionality of the socio-technical regime. In both processes, incumbent firms demand intensive labour, becoming an attractive pole for professionals to develop their careers. In addition, incumbents represent an interesting offer with moderate risk for private investment. Furthermore, incumbent companies encompass networks to forge a relationship with supporters of their agenda, which enables the mobilisation of resources when it is required (van Wijk et al., 2013). Consequently, incumbent firms are important actors in conferring stability to socio-technical regimes, whose role provides them with power.

Transition scholars have traditionally portrayed energy supply incumbents as resistant to change to maintain the legitimacy of their current business practices (Turnheim and Sovacool, 2020). Nevertheless, this perception has been gradually changing and reflecting on incumbents' role during the transition as a broad phenomenon that is not strictly attached to a unique response of resistance (Bergek et al., 2013; Berggren et al., 2015; van Mossel et al., 2018). A possible way forward for incumbents to navigate the socio-technical transition is by pursuing sustainable opportunities for the adoption of new knowledge produced outside of the firm (Hockerts and Wustenhagen, 2010).

Precisely, the development of radical innovation can be found in socio-technical niches, defined as a protective space shielded from dominant designs wherein new technologies can be nurtured (Smith and Raven, 2012). Niches are composed of actors, such as new entrant firms, academic

R&D and entrepreneurs, seeking to develop sustainable solutions that would solve persistent problems where incumbent firms have been inefficient (Geels, 2019).

Socio-technical niches have their own difficulties in the scale-up of technology innovation, usually failing in this journey (Nanda and Rhodes-Kropf, 2013). The diffusion of new technologies in the energy supply sector is extremely difficult due to the interconnection of pieces in the system and affecting any of these elements can have unpredictable effects (Negro et al., 2012). A challenge for which socio-technical niches seem deficiently prepared. As it was discussed earlier in this sub-section, the configuration of a new technology needs time and resources for learning the best alignment of socio elements that will favour the emergence of the technology's function (Raven, 2005). Therefore, socio-technical niches require extensive help to arrive at this stage, in which the technology innovation will be ready for market adoption. Such support could be provided by incumbent firms who would be interested in accessing new technologies for the aims of the energy transition. Nevertheless, this relationship has important difficulties. Incumbent firms are burdened with core rigidities derived from the legacy of old technologies (Bergek et al., 2013). Whilst niches lack the capabilities and resources to scale the new technology for market adoption, generating uncertainties for the investment in innovation (Negro et al., 2012).

Both approaches make it difficult to build the links between these two actors. Hence, considering the potential but intricate relationship between incumbent firms and socio-technical niches, the next sub-section 1.2.2 will briefly describe the role of transition intermediaries as a key to approach positions and speed up the change towards sustainable systems (Kivimaa et al., 2019a).

1.2.2 The role of transition intermediaries congregating incumbent firms and socio-technical niches

As was presented in the previous sub-section 1.2.1, the intended exchange of technology innovation between incumbent firms and socio-technical niches faces many obstacles. This process is generally slow for reasons laying on the systemic nature of innovation, in which the new technology requests adaptation to the existing configuration and demands to mobilise a large number of resources (Negro et al., 2012). Due to the urgency of a sustainability transition, public and private initiatives have developed policies and entities that will progressively replace the regime's practices with alternative technologies emerging from niches (Kivimaa and Kern, 2016). As a part of such initiatives, transition intermediaries are created. These are defined as a group middle bodies that positively influences transition processes by linking actors and activities in order to create momentum for systemic change by disrupting dominant configurations (Kivimaa et al., 2019a). A wide variety of organisations can be considered as transition intermediaries, including innovation agency funders, technology transfer offices, public policy task forces, project developers, consultancies and demonstration centres (Kivimaa et al., 2020).

Transition intermediaries play a critical role by offering a bridge for the exchange of information and knowledge in the innovation process through an impartial position without normative interest (Klerkx and Leeuwis, 2009). Consequently, transition intermediaries can congregate incumbent firms and socio-technical niches thanks to their neutral position in the innovation process, in which they facilitate a high level of specialised knowledge and influence decisions by linking science, industry, markets and society (Cabanelas et al., 2013).

In technology transfer, the coordination of actors is even more laborious, in which separate pieces of technical knowledge are moving in a process involving different participants and capabilities at each stage (Bessant and Rush, 2000). Under these circumstances, the role of transition intermediaries focuses on performing activities that one or more actors could not adequately cover. As a result of such a heterogenous role, the literature (Klerkx and Leeuwis, 2009; Markard and Truffer, 2008) has positioned intermediaries within the technology innovation system, defined as a network of actors interacting in a determined industrial space involved in the promotion of technology innovation (Hekkert et al., 2007).

In the context of socio-technical transitions, intermediaries negotiate the integration of niches' technology innovation within incumbent firms' domains, helping to transform the regimes into sustainable configurations (Berkhout, 2002). Moreover, transition intermediaries serve as an instrument proposing the change of the regime's rules enabling innovation adoption (Edler and Yeow, 2016). For such reasons, transition intermediaries take a strategic position to nurture and protect socio-technical niches from the regime's influence (Bush et al., 2017; Schot and Geels, 2008; Smith and Raven, 2012) and simultaneously facilitate the innovation to scale by eroding the resistant position of incumbent firms (Kivimaa and Kern, 2016; Matschoss and Heiskanen, 2018).

Contributing to defining this dual role of intermediaries is an emerging challenge for the transition literature (Kanda et al., 2019). This can be addressed by developing new frameworks that will explore the diversity of transition intermediaries by performing functions (Howells, 2006; Kilelu et al., 2011; Kivimaa and Kern, 2016; Lukkarinen et al., 2018; Sovacool et al., 2020; van Lente et al., 2003). According to the assumptions formulated by this thesis, transition intermediary functions can promote capabilities in actors of the technology innovation system learning how to diffuse and adopt new technologies for sustainable goals in the energy supply sector. The next sub-section 1.2.3 will explore this approach by presenting transition intermediaries as builders of organisational capabilities in socio-technical niches and incumbent firms.

1.2.3 Transition intermediaries as capability builders

This sub-section will present transition intermediaries as fundamental actors of the technology innovation process, playing a significant role in developing capabilities in socio-technical niches to diffuse radical innovations as well as in incumbent firms to adopt these. Capabilities are the collaborative processes that can be deployed by individual or group competencies in any specific activity of the organisation (Amit and Schoemaker, 1993). These are important because they can manage the development of new resources, such as technology innovation (Barney et al., 2001), improving the sustainable position of firms and, in some cases, the whole industry.

As it was previously discussed, this thesis assumes that incumbent firms and socio-technical niches lack the capabilities to manage the technology transfer process in the UK energy supply sector. These organisational inefficiencies may be supplied by transition intermediaries, which can disseminate specific information that generates capabilities promoting the diffusion and adoption of new technologies (van Lente et al., 2003). This intermediation mechanism fills managerial gaps that provide articulation for detecting needs, selecting options, adopting support, proceeding with training and improving project management towards the development of innovation management capabilities (Bessant and Rush, 1995).

For instance, most incumbent utility firms in the UK energy supply sector have made scarce R&D investments, as Table 1.1 and Figure 1.7 have already shown, focusing instead on strengthening their operational capabilities to keep the network running, which are locked-in to established technological trajectories (Bolton and Foxon, 2015). Their strategies have focussed on cost competition and energy flexibility in response to fuel price fluctuation (Pearson and Watson, 2012). In the absence of product differentiation, competition in the energy supply sector occurs on costs, resulting in less incentive to innovate and as a possible consequence a decrease in their capabilities for long-term technology projects (Geels and Turnheim, 2022).

Transition intermediaries can detect these gaps where incumbent firms require assistance for innovating and encourage the development of specific capabilities (Spithoven et al., 2010). Particularly, supporting the creation of absorptive capacity, defined as the organisational skill to recognise the value of new and external knowledge, to then assimilate and apply it for commercial ends (Cohen and Levinthal, 1990). This theory is based on the firm's preference for borrowing and interpreting external technologies rather than internally creating these, responding to fast-changing environments (Camison and Fores, 2010).

A similar approach to developing capabilities can be suggested in socio-technical niches. These have been portrayed as inventor organisations that perform inefficiently the commercial activity (Schot and Geels, 2008). Therefore, they lack capabilities for diffusing technology innovation into the market. This is considered a necessary managerial competence for scaling the invention (Kemp et al., 1998). In this case, socio-technical niches are engaged with the outbound process of diffusing innovation, seeking external partners that are suited to commercialise their technology by implementing an open innovation strategy (Chesbrough, 2006). Likewise, such capabilities can be enhanced by the intervention of transition intermediaries that support in socio-technical niches the cultivation of desorptive capacity, defined as the organisational mechanism to outwardly exploit internal knowledge in technology transfer activities (Lichthentaler and Lichthentaler, 2010).

On this point, it is important to establish the definitions of capacity and capability, as two different concepts in this research. Capacity is the quantitative measure that allows the organisation to hold, receive or accommodate resources (Vincent, 2008). Whist capability is a collaborative process that can be deployed by either individual or organisational skills applied to a specific activity of the firm (Amit and Schoemaker, 1993).

Going back to the development of absorptive and desorptive capacity. This research aims to investigate how both are enhanced in large and small organisations of the UK energy supply sector by the intervention of transition intermediaries. Based on this theoretical construction, it can be said that transition intermediaries can approach positions of distant actors (i.e., niches and incumbents) by developing their respective capabilities to diffuse and adopt technology innovation. This might facilitate the socio-technical transition in the UK energy supply sector.

Nevertheless, the transition literature has overlooked the interlinkages between the producer and adopter of the technology innovation with the assistance of intermediaries during socio-technical transitions (Matschoss and Heiskanen, 2018). On the other hand, the management literature has partially explored the development of capabilities to handle the diffusion and adoption of new technologies in an industry difficult to transform, such as the energy supply sector (Bell, 2012). This thesis contributes to such a discussion by investigating the interactions between this triad of actors in the UK energy supply sector. The following Section 1.3 will finally outline the research gap on that topic and how this thesis will seek to address it.

1.3 The research gaps this thesis targets

This thesis argues that there is a pressing need to investigate: (i) the factors responsible for enabling or inhibiting socio-technical niches and incumbent firms to establish collaborative links for exchanging technology innovation; (ii) the core functions of transition intermediaries to connect both actors during a socio-technical transition; (iii) how the deployment of these intermediation functions enhance capabilities at both levels of actors; and, finally (iv) by taking the case of the UK energy supply sector, this thesis explores how that triad relationship can move forward this industry towards the 2050 net zero goal. These four topics present gaps in the literature that can be unpacked in the following terms.

i. Despite the range of studies highlighting the role that collaboration between different actors plays in technology innovation processes, this phenomenon has been less explored by the transition literature (Kohler et al., 2019). The reason may be the predominant analysis based on the technology substitution process as a battle between emerging innovations that challenge incumbent technology (Bergek and Jacobsson, 2003; Geels, 2002; Markard et al., 2012). This follows the classical Schumpeterian narrative of "creative destruction"[5] where technology substitution happens through the competition between an emergent and a dominant technology. This assumption is under important limitations in the energy supply industry, due to the strong interconnection of elements interviewing in the power system. In addition, most of economic activities depend on the efficiency of the energy system. Therefore, radical technology requires greater changes in critical parts of the energy and economic systems. This implies a great risk, with stakeholders expecting a strong validation of innovation, which not necessarily happens through the typical market competition, to proceed with the technology substitution in the energy supply sector. The scale of this transformation demands a collaborative effort beyond anything we have witnessed so far (Negro et al., 2012). Nevertheless, the socio-technical transition literature (Kohler et al., 2019) has had difficulties exploring collaborative options due to the unintentional bias for technological novelty, manifested in their conceptual frames (e.g., Strategic Niche Management, Technology Innovation System, Multi-level Perspective). These frameworks have applied bottom-up approaches to technology innovation, emerging from niches and inevitability clashing with ineffective

[5] According to Schumpeter (1934), the creative destruction paradigm consists of the idea that innovation may bring profits and social progress, but it also creates structural change that usually affects actors incapable of modifying business practices. Therefore, creative destruction makes possible a surge of new entrants, with eventual devastating effects on existing firms and industries. This reorganisation of economic structure is also associated with profound social consequences (Dodgson et al., 2008).

and passive incumbents (Turnheim and Sovacool, 2020). This view can be considered insufficient for addressing the urgency of transitions in fundamental sectors of society that can be difficult to modify, such as the energy supply.

ii. On the contrary, this thesis argues that to address these deficiencies in the literature, it is necessary to develop new frameworks that can investigate the dynamics of collaboration between socio-technical niches and incumbent firms with the support of transition intermediaries. Different transition approaches have positioned intermediaries as enablers for innovation producers to learn the best way to scale new technology for sustainable purposes (Raven et al., 2008). In this regard, transition intermediaries have been presented as organisations that favour socio-technical niches (Bush et al., 2017), and erode the position of resistant incumbents (Matschoss and Heiskanen, 2018). While other scholars have proposed that transition intermediaries are tied to the established regime and the interest of incumbent firms (Sovacool et al., 2020). Consequently, there are few studies examining the cross-boundary functions of transition intermediaries for linking both actors. Consequently, investigating how transition intermediaries facilitate the collaboration between incumbent and niche actors will offer us the opportunity to understand how technological innovation emerges beyond the creative destruction paradigm. By obtaining these insights, a clearer understanding of transition intermediaries could be presented at the end of this research.

iii. In particular, a representation of incumbent-niche links facilitated throughout specific functions of transition intermediaries will afford us to collate the capabilities that socio-technical niches and incumbent firms should have to collaboratively develop technology innovation. To mobilise these research objectives, this thesis suggests that additional theories can be brought to supply the deficiencies of transition frameworks. The Resource-Based View of the Firm (RBV) has been a theoretical approach ignored within the transition literature. RBV explains that the competitive advantage is sustained by valuable, rare, inimitable and non-substitutable resources (Barney, 1991). In order to create or obtain these resources, like new technologies, the organisation requires capabilities (Amit and Schoemaker, 1993). These can foster the management of complex resources through a process of learning and experimentation that enables innovation to flourish (Easterby-Smith and Prieto, 2008). Scholars have suggested that transition intermediaries support the enhancement of new capabilities for diffusing and adopting innovation in organisations that receive their assistance during the technology transfer process (Spithoven et al., 2010). In particular, it has been indicated that the receiver (i.e., incumbent firm) should develop absorptive capacity (Zahra and George, 2002). Meanwhile, the sender (i.e., socio-technical niche) should cultivate desorptive capacity (Lichtenthaler and Lichtenthaler, 2010). In this regard, the literature is not precise about how different actors cultivate capabilities for diffusing and adopting technology innovation from a holistic perspective. Possibly by the intervention of neutral organisations like transition intermediaries.

iv. In the energy supply sector, the introduction of technology innovation is under important limitations. The development of costly infrastructure over decades has produced strong practices associated with the efficient deployment of energy supply (Seto et al., 2016). This creates a lock-in effect in which the systemic interactions among technologies and institutions make it difficult to crown out alternatives (Unruh, 2000). For this reason, transition actors have severe problems diffusing and adopting new technologies into the energy supply system because of the strong practices associated with the dominant design (Geels, 2014). In the context of the UK energy supply sector, capabilities tend to become rigid because of such orientation to efficiency. This leaves little space for testing new ideas that can contribute to decarbonising operations and thus it represents a serious setback to achieving the 2050 net zero goal. This issue calls for an integrated view of the transition's actors, where they interplay roles in a coordinated mode to bring green innovation without disrupting the efficiency of the energy supply. To progress on these ideas, this research proposes the view that organisational capabilities can be enhanced by external influence. In this case, transition intermediaries can lead to consistent management of novel technologies contributing to achieving this sustainable goal. Therefore, the investigation of how technology innovation is developed by the triad relationship of incumbents, niches and intermediaries can bring an alternative route for the substitution of unsustainable practices during socio-technical transitions.

Through an in-depth investigation of the relationship between socio-technical niches and incumbent firms with the support of transition intermediaries, this thesis seeks to make important contributions to the transition and innovation management literature in the following aspects:

- The core functions of transition intermediaries supporting the development of managerial innovation capabilities to incumbents and niches, during socio-technical transitions. To examine this broad topic, this thesis will employ the empirical case of the UK energy supply sector.
- The plural role of incumbent firms in socio-technical transitions, which has been usually portrayed as slow and even resisting transition efforts.
- The collaborative approach of niches in socio-technical transitions, working towards demonstrating their technology innovation through coordination with apparent business rivals as incumbent firms.
- Integrating absorptive and desorptive capacity under a collaborative proposition of technology transfer between different actors to achieve transition goals.
- Understand the development of capabilities that make it possible to unfold absorptive and desorptive capacities for technology transfer activities, using as empirical context the UK energy supply sector.

An examination of the above would help to achieve the general objective of this study. This consists of exploring the form in which capabilities for managing technology innovation are developed. This overall research goal is well aligned with the research questions presented on pages 3 and 4.

1.4 Thesis structure

Chapter 1 has presented the main background of this research. The following Chapter 2 will provide a review of the relevant literature about socio-technical change. This consists of three main theories this study will employ: Technology Innovation System (TIS), Multi-level Perspective (MLP), and Resource-Based View (RBV). The review has a twofold purpose. First, it will highlight the lack of attention that scholars have paid to the role of collaboration between different actors in promoting technological innovation during socio-technical transitions. Second, it will offer the theoretical elements to feed the conceptual framework to be presented in Chapter 3, which this research will employ to address the research questions.

Chapter 4 will introduce the method this research will use to apply the conceptual framework. The method departs from a social constructionism assumption that utilises a qualitative approach based on abductive reasoning as the main procedure for theoretical development.

Chapter 5 will present the findings from the empirical investigation. Aiming to answer Research Question A, the thesis will explore the development of capabilities in absorptive capacity by utility incumbent firms with the assistance of transition intermediaries. The investigation will apply the conceptual framework developed in Chapter 3, exploring the intermediary functions that have contributed to developing capabilities for integrating new technologies in incumbent firms.

Chapter 6 will turn the attention to examining the cultivation of capabilities in desorptive capacity by socio-technical niches with the support of transition intermediaries. Likewise, this part of the research will use the conceptual framework from Chapter 3 to study the influence of intermediary functions for enhancing capabilities to outwardly exploit new technologies produced by niches. The findings in this chapter will help to answer Research Question B.

Chapter 7 will draw upon the research's findings and discuss these with the literature to present the main contributions this thesis attempts to make to the three main bodies of literature where it aims to position: absorptive capacity in incumbent firms, desorptive capacity in socio-technical niches, and the role of transition intermediaries linking both.

Finally, Chapter 8 will offer the conclusions of this research, addressing the research questions, assessing the contributions, presenting the broad implications for practice and policy, and future research considerations.

2 Literature Review

The purpose of this chapter is to provide a critical review of the different theories found in the literature explaining the key concepts to be analysed by this research. Particularly, it focuses on the socio-technical nature of innovation and the collaborative roles of actors to diffuse and adopt new technologies for sustainable goals.

This chapter will provide important insights into the behaviours of actors during socio-technical transitions and their complementarity resources in the development of technological innovation. This will be outlined by three main theories: Technology Innovation System (TIS), Multi-level Perspective (MLP), and Resource-Based View of the Firm (RBV). These constitute the main components to feed the conceptual framework in Chapter 3, which this investigation will employ to address the research questions.

The present chapter is structured in the following way. It begins with Section 2.1 defining the concept of innovation, which serves as a base to explain the generation and application of new knowledge into technology innovation. This long and non-linear process is deeply affected by social factors, which convert the development of technology innovation into a complex intertwined between material elements, end-users, policymakers, societal groups, suppliers, research communities and finance (Rip and Kemp, 1998).

This combination of multiple aspects has great relevance when key industrial sectors (e.g., energy, transport, food) pursue fundamental technological change addressing persistent sustainability issues (e.g., carbon emissions). The literature has named these profound configurations as “socio-technical transitions” (Geels, 2002). This topic will be covered in Section 2.2. In turn, this broad topic will serve to introduce two of the theoretical frameworks to be applied in this research.

First, it will discuss the Technology Innovation System (Bergek et al., 2008; Hekkert et al., 2007), which explains the nature of socio-technological change through the conformation of a dynamic network of agents. Importantly, the drivers in the Technological Innovation System can be enhanced by the intervention of transition intermediary functions (Kivimaa et al., 2019a).

Second, it will review the Multi-level Perspective (Geels, 2002). This framework explains how and why industrial sectors are transformed, providing insights to understand the difficulty of moving from one socio-technical configuration to another. Moreover, the Multi-level Perspective will serve to outline the behaviour of incumbent firms, socio-technical niches and intermediaries during transitions. According to the literature review, this thesis assumes that incumbents and niches can build a relationship with the support of intermediaries to achieve sustainable goals.

Section 2.3 will further explore this notion using the Resource-Based View of the Firm (Barney, 1991). This theory will provide important elements for reviewing the complementary relationship between absorptive capacity (Zahra and George, 2002) developed by incumbent firms and desorptive capacity (Lichtenthaler and Lichtenthaler, 2010) by socio-technical niches. This section will discuss the different dimensions that both conceptualisations present, in order to assign capabilities for diffusing and adopting technology innovation.

2.1 Conceptualising Innovation

This section reviews the concept of innovation as the basic term to explain how new ideas are converted into a business's products, services, processes or methods. As this research investigates how the UK supply energy industry promote innovation to become environmentally and economically sustainable, it is necessary to briefly explain the form in which innovation can be produced, diffused and adopted. It also reviews the social aspects that innovation confronts to finally arrive at the market, informing how these risks can be reduced through collaboration between multiple actors.

The concept of innovation was coined by Schumpeter (1934) in his effort to explain how economic growth is achieved. Essentially, Schumpeter saw innovation as the new combination of existing resources (1942). Since then, the literature on innovation has grown exponentially moving from an emphasis on the results of innovation to exploring the complexity of the process (Pavitt, 2006). In such a regard, Dodgson et al. (2014) have described innovation as inherently uncertain. Therefore, learning from failed experiences (or *wrong* combinations) generates important knowledge that can be useful for understanding how to achieve the right amalgamation of resources and produce an effective innovation (Acs et al., 2013). Nohria and Gulati (1996) have argued that a firm needs a certain level of resources and capabilities to proceed with this challenge by detecting new opportunities and creating different outputs to exploit them. According to Pavitt (2006), the firm requires two different sets of competencies to become an innovative organisation. These are the exploration skill of identifying business opportunities, and the exploitation faculty of developing a new or improved solution (inventions) to take advantage of the identified opportunity.

An important aspect of the process of innovation development is that participants must recognise the degree of novelty that the innovation presents to the overall market. Tidd et al. (2001) have differentiated between radical innovations, described as the advancement in knowledge and consequent development of new products and processes, and incremental innovation, which is the ongoing improvement of product, process and service. Radical innovation is characterised as a fundamental change in the activities of not only business organisations but affecting society as well; whereas the term incremental is commonly used to define innovations with a lesser degree of novelty (Norman and Verganti, 2012). Both types of innovation propose different challenges for managers (Dodgson et al., 2014), which this thesis aims to explore. Incremental innovation mainly applies to daily operations and seeks to improve performance through low risk. Organisations that focus entirely on incremental innovation are exposed to radical innovation. Therefore, the portfolio of innovation should seek to balance the company on diversifying new businesses by building upon and developing radical innovation beyond existing capabilities (Dodgson et al., 2014). This research will explore how this balance can be achieved in collaboration between large and small innovative organisations.

Taking these concepts into consideration, this thesis defines innovation as the process by which new products, services and industrial proceedings are conceived for commercial application, covering the non-linear procedure from invention to (un)successful market launch. This research argues that such a definition provides a useful starting point for exploring how organisational capabilities are developed to complete this journey. The next sub-section 2.1.1 will define the concept of technology innovation, which is the core element this thesis aims to investigate on how is diffused and adopted by deploying organisational capabilities.

2.1.1 Technology Innovation

Technology innovation is an extended concept of innovation that focuses on the process of developing technical aspects of a new product, service or industrial process (Dodgson et al., 2014). More precisely, technology innovation consists of the technological traits manifested through the invention of new devices, processes, techniques or even systems (Dodgson et al., 2008). To explore further this conceptualisation, it is important to first define the term "technology". Arthur (2010) has considered it as a branch of knowledge that is applied and executable to a practical purpose, whose creation and diffusion generate economic and social value. This idea underlines that technology is executed through a device or a complex process produced by engineering knowledge that performs a task for satisfying a human need.

To achieve the execution of such a task, technology development is based on the application of scientific knowledge that evolves into practice (Arthur, 2010). Therefore, technology has a close connection with basic research as the supplier of scientific theories explaining natural phenomena, which later might provide a foundation for a practical application in the rise of science-based technologies (Freeman, 1974). The Frascati Manual (OECD, 2015) has encompassed this link in the single term of research and development (R&D) and divided it into three types of activities: basic research, applied research and experimental development. Neither of these provides economic value *per se*. They must be followed by the process of converting the invention into innovation to reach such a reward (Becker and Whisler, 1967). Pavitt (2006) has described this linkage and considered it in the additional interaction that innovation has with the end user. The stages of technology innovation are summarised in the following Table 2.1.

Table 2.1 Innovation process (from R&D to the market)

Innovation Stage	*Description*
Basic Research	Experimental or theoretical work undertaken to generate new knowledge of a phenomenon, without any application or use in view.
Applied Research	An original investigation undertaken to acquire new knowledge, directed towards a specific, practical objective.
Experimental Development	Systematic work, drawing on knowledge obtained from research for producing additional knowledge, which is oriented to create new products or processes, or to improve existing products or processes.
Translation of knowledge into working artefacts	The specialisation of transfer knowledge production, including subsystems and components, expressed in demonstrative prototype near industrial reproduction.
Responding to and influencing market demand	Involves the continuous process of matching artefacts with users' requirements in terms of usability and commercial aspects. This stage presents information that the commercialisation agents can use to improve the technology and hence influence the user's decision.

Source: Based on OECD (2015) and Pavitt (2006)

Under the previous group of ideas, technology innovation was initially considered a linear process, in which R&D provides the basis for technology development and later commercialisation. However, this notion has evolved into constant feedbacks between each phase of the overall process. This approach presents greater flexibility to meet the challenges that technological innovation has in terms of uncertainty according to the unpredictable social, economic and industrial conditions in which is rooted (Dodgson et al., 2008). Therefore, technological innovation can take steps forward and back until it reaches the market (Skea et al., 2019), as Figure 2.1 shows.

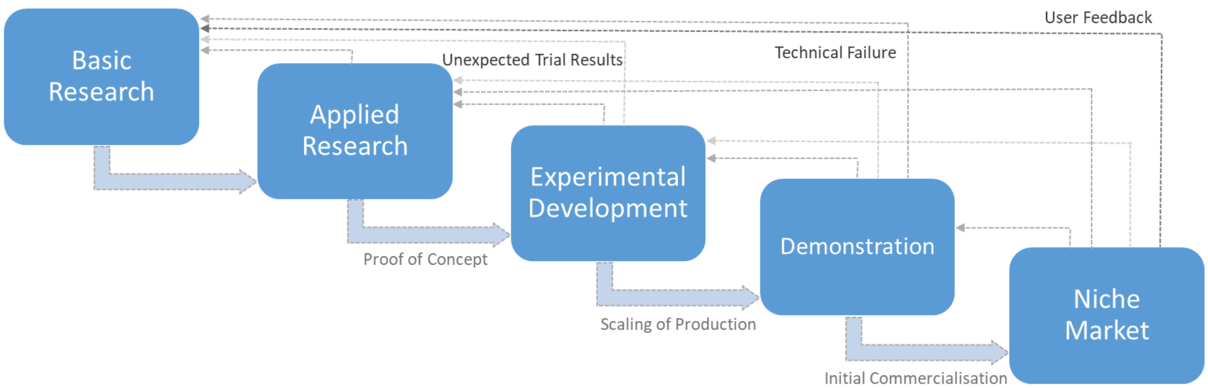

Figure 2.1 Non-linear innovation process
Source: Based on Skea et al. (2019)

Skea et al. (2019) have stated that this non-linear process aims to propose new products or services to the market in the final stages. Nonetheless, reaching that point requires a constant iteration of information among different actors over many years, even decades. Thus, technological innovation has a great challenge in shortening these phases and arriving sooner at the market, consequently bringing improvement in social and human conditions. An important barrier that most forms of innovation, including technological, face in getting rapidly to the market is social aspects. Tidd et al. (2001) have considered innovation as a broader process fundamentally influenced by the social context. In such a regard, the literature has equally considered the technical as well as the social aspects to understand how technological innovation can be produced. The next sub-section 2.1.2 will discuss the relevance of social aspects in the development of technology innovation.

2.1.2 Social aspects of technology innovation

The technology innovation literature has largely discussed the iterative processes described in Figure 2.1. Arriving at the conclusion that organisations embarking on technological development deeply interact with social, economic, institutional and political factors, such as user preferences, legislation and industrial practices (Fagerberg et al., 2013). This idea indicates that technological innovation involves multiple levels in which social actors and material elements are intertwined, in a disorganised relationship built through improvisation and experimentation that does not occur in a linear explanation (Garud et al., 2013). According to Rip and Kemp (1998), such experiments can lead to learning in which the new technology becomes a configuration that works with social factors. In the first instance, this presents artefacts but also includes the human skills to install and operate devices, division of labour and cultural norms in which the technology must be handled to perform productively. Rip and Kemp (1998) illustrated this idea through the configuration achieved by automobile technology: "*The motorcar is not an isolated artefact, but the label for part of our socio-technical landscape, made up of steel and plastic, concrete (the roads), law (traffic rules), and culture (the value of meaning of personal mobility*" (p. 335).

Based on this idea, society creates institutions and regulations to mould the interaction between technology and social aspects (Nelson and Nelson, 2002). These are influenced by end-users, policymakers, societal groups, suppliers, research communities and financial systems that stabilise the technology configuration. Consequently, rules and institutional structures have a profound impact on the way that technologies are developed and later used. For this reason, new technologies face a disarrangement with the established rules and institutions making difficult the emergence of radical innovation (Freeman and Perez, 1988). The literature has suggested that the development of new technologies that are not aligned with the existing rules requires the creation and strengthening of new types of institutions (Tidd et al., 2001).

The configuration of technology development with social aspects has great importance when entire industrial sectors pursue major transformations addressing sustainability problems. The literature has referred to this blended process as "socio-technical transition", which consists of a change from one configuration to another, involving the substitution of technology as well as modification in institutional rules, industrial practices and user behaviour (Geels, 2002). Therefore, changes in one of these aspects trigger adjustments in other elements due to the linkage between technical and social components. This is a key discussion in the net zero transformation of the energy supply sector (Miller et al., 2013).

Section 2.2 will introduce the conceptualisation of socio-technical transitions through different strands of literature. Moreover, this section will use relevant transition frameworks (e.g., TIS and

MLP) to explain how the behaviour of incumbent and niche actors can collaboratively generate technology innovation with the support of transition intermediaries.

2.2 Socio-Technical Transitions

This section will review the concept of socio-technical transition and discuss through this body of literature the ways by which entire economic sectors move from one configuration state to another. Geels (2004) has defined the term socio-technical transition as the need for transformation in systems that provide a critical function to society (e.g., energy, transport, food, housing). These are affected by persistent environmental problems that require changes. In the first instance, such issues are addressed by integrating new technologies. However, as sub-section 2.1.2 has explained, the technology innovation process is deeply affected by the social aspects in which it is rooted. Consequently, the study of transitions involves societal components around consumer practices, cultural meanings, markets and infrastructure to adopt the technology innovation (Elzen et al., 2004).

This thesis will use both elements to describe the manner in which transition actors can generate technology innovation through collaboration. To proceed in the critical review of the transition literature, the following sub-section 2.2.1 will cover the main theoretical approaches to understanding socio-technical transformations. To then justify the selection of the relevant transition frameworks to be used by this research (i.e., TIS and MLP).

2.2.1 Different theories explaining socio-technical transitions

Most of the theoretical approaches to describe socio-technical transitions come from the field of innovation studies, including evolutionary economics, innovation systems and the sociology of science and technology. It represents a hybrid field that integrates different but complementary bodies of literature. This approach has the advantage of drawing analytical attention to both social and technical aspects, by describing the role of actors involved in technology innovation (Kohler et al., 2019). A key notion that this research aims to further investigate. In particular, the links of collaboration that transition actors configure to produce new technologies in the UK energy supply sector.

The present sub-section will introduce socio-technical transitions by reviewing the theoretical approaches applied to understand the complex process of substituting established technologies. According to Markard et al. (2012), the foundational frameworks in socio-technical transitions are essentially four: Transition Management, Strategic Niche Management, Technological Innovation System, and Multi-level Perspective. It is worth noticing the increasing number of complementary approaches in the field that converge in these four main theories. It is not the purpose of this review to examine each of these theories and provide an articulated analysis of the whole body of literature. It will rather concentrate on describing the four most recognisable theories. Later, it will consider the two most appropriate (i.e., MLP and TIS) to focus on understanding how actors collaborate in the generation and integration of technology innovation for a socio-technical transition.

Transition Management is a policy-guided framework that combines concepts from complexity science and governance studies (Rotmans et al., 2001; Loorbach, 2010). It has proposed a prescriptive framework suggesting that policymakers can design a transition through sequential steps. Transition Management has contributed to governance studies but leaving aside other important topics, such as geography scales, justice and ethics (Kohler et al., 2019). More importantly, it has been recognised that transitions cannot be managed from a top-down perspective, rather it needs to consider the plurality of actors and the complexity of managing several stakeholders (Voss and Bornemann, 2011). As this theory has limitations for drawing on the relationship between actors, it was excluded from the main topic of analysis in this research.

Strategic Niche Management suggests that radical innovations are only possible in protected spaces, shielded from the incumbents' selection (Rip and Kemp, 1998). Thus, technological innovation is often generated by niches that take the risk encountered in producing it. To overcome such challenges, multiple experiments must be conducted to enable the technology trajectory (Geels and Raven, 2006). Strategic Niche Management has been considered a relevant contribution to explaining the origins of innovation. However, it is less extended in illuminating how a new technology grows in influence confronting a dominant design. Consequently, Strategic Niche Management offers an inconclusive framework to explore the relationship between emerging technologies with incumbent actors.

Technology Innovation System (TIS), elaborated by Bergek et al. (2008) and Hekkert et al. (2007), explains that technology development comprises the interaction of actors and institutions through networks. These elements are interrelated forming the structure of a system which in turn deploy functions to enable the emergence of technology innovations (Jacobsson and Bergek, 2004). The main critique made to TIS is the lack of clarity about the tensions between incumbents and niches generating instability in the existing system (Kohler et al., 2019). Nonetheless, TIS is a feasible framework for studying the role of intermediaries in creating networks between innovation actors (Lukkarinen et al., 2018). Recently, the literature has called to further investigate how the TIS functions are supported by the intervention of intermediaries (Kanda et al., 2019). This shows that TIS is a relevant framework to explore how socio-technical transitions unfold through a perspective of systemic functions that are reinforced through the action of intermediaries. Therefore, TIS is the starting point to discuss how intermediaries employ functions that enhance the socio-technical dynamics of different actors and generate a network for sustainability purposes. This framework will be covered in detail in the following sub-section 2.2.2.

Finally, the Multi-level Perspective (MLP), proposed by Geels (2002), offers a theoretical framework that explains transitions as the interplay of three different levels (niches, regimes and landscape). Radical innovation is produced in niches that exploit windows of opportunities generated through the societal pressure occurring in the landscape, calling for modifying the outdated practices of the regime (Geels, 2002). MLP explains that a transition happens between the links of a dominant regime and socio-technical niches, creating conflicts between stability and the promise of a sustainable but uncertain technological change. The MLP has been criticised for assuming that innovation surges from niches to destabilise the regime, which in turn usually resists transformational change (Berkhout et al., 2004). To overcome this bottom-up bias, Geels and Schot (2007) proposed different transition pathways in MLP, which acknowledge that change can be originated from regime or landscape levels. Additionally, MLP has been questioned for the lack of agency of actors who seemingly are led by historical events to deal with transformations (Smith et al., 2005). To solve part of this problem, Geels (2011) suggests that MLP can be theoretically enriched by mobilising insights from auxiliary theories. This thesis aims to contribute towards such a direction by combining aspects of TIS (i.e., intermediary functions) to study how MLP actors (i.e., niches and incumbents) interact.

Barring these criticisms, MLP has proven to be a rich theoretical framework including different elements, such as power at different levels (Avelino and Rotmans, 2009), the role of intermediaries in aligning niches and regimes (Ehnert et al., 2020), and even giving space to the direct collaboration between incumbents and niches (Geels et al., 2016). MLP offers the opportunity to make contributions on the interaction of a plurality of actors facing transitions. Further research can elaborate on how they collaborate to find the best alternative for promoting sustainability by considering equally technological and societal factors (Berggren et al., 2015; Penna and Geels, 2015; Turnheim and Sovacool, 2020). The debate around MLP makes a call to investigate the interrelationship between actors positioned at different levels, who can provide each other with resources and capabilities to accelerate urgent transitions (Turnheim and Geels, 2019). Therefore, MLP is the second theoretical framework selected by this thesis to investigate how collaboration among actors take place during a socio-technical transition.

Having justified the choice of two transition frameworks, the next sub-sections will critically review these. The next sub-section 2.2.2 will explore TIS; to then describe MLP in sub-section 2.2.3.

2.2.2 Technological innovation system (TIS)

The TIS framework focuses on a specific technology sector and its associated knowledge field (Hekkert and Negro, 2009). TIS describes a network of actors interacting in a determined industrial area under an institutional infrastructure involved in the generation, diffusion and utilisation of technology (Hekkert et al., 2007). To explore this phenomenon, TIS recognises that innovation is the result of continued interaction of activities, with research, learning and market formation all mutually reinforcing each other. TIS rejects the linear model of innovation and instead emphasises a system perspective of interrelated factors as a build-up process pushing for sustainable innovation (Suurs and Hekkert, 2012). Consequently, TIS takes social aspects into consideration to explore how technological innovation emerges. According to TIS, the social and technical factors are composed of four structural entities, as Table 2.2 details.

Table 2.2 The structural entities of TIS

Dimension	***Definition***
Actors	Individuals, private and public organisations responsible for developing, diffusing and adopting technological innovation. These are educational institutions (e.g., universities), industry and market agents (e.g., suppliers, firms and customers), public agencies (e.g., regulators and government bodies) and supporting organisations (e.g., venture capitalists).
Institutions	Sets of norms, beliefs, rules and laws that shape the behaviour of actors. These include formal (e.g., laws and regulations) and informal institutions (e.g., routines and expectations).
Networks	Non-structured or structured relations that connect actors and shape their relationships. This consists of scientific, industrial and government actors, or a combination of these (e.g., industrial associations and research groups).
Technology and infrastructure	Artefacts, including coded and tacit knowledge, embedded in institutional or individual practices associated with technology. They conform to an infrastructure that fosters technological innovation. It can include test facilities, associated technologies and operational/transmission networks.

Source: Based on Bergek et al.(2008) and Hellsmark and Jacobsson (2009)

Presenting these structural dimensions helps to recognise the dynamics of TIS processes and their capacity to foster technology innovation. Hekkert et al. (2007) have labelled such processes as functions, which contribute to the goal of generating, diffusing and adopting technological innovations. These functions are emergent properties of the interplay between social actors, rules and institutions (Markard and Truffer, 2008). Each TIS function might have a positive effect on reducing the uncertainty of the technology innovation process (Hekkert and Negro, 2009). Therefore, these functions constitute an intermediate level between the components of a TIS and its performance in which any changes in one function can lead to modifications in other functions (Jacobsson and Bergek, 2004). Table 2.3 summarises TIS functions.

Table 2.3 TIS functions

Function	***Description***
Knowledge Development	The mechanisms of learning of the technology innovation process, generated through systematic activities searching for new knowledge. The most recognisable is R&D.
Knowledge Exchange	The networks of actors can circulate and transfer information that goes beyond technical knowledge and facilitates learning. This information influences the decisions of government bodies, industrial players and R&D.
Entrepreneurial Experimentation	Entrepreneurs assess the potential of new technologies and convert these into commercial experiments. These trials create tacit knowledge and reduce uncertainties associated with the new technology.
Guidance of the Search	Pressures that motivate actors to enter a technology field and afterwards guide the activities they undertake, such as policy targets.
Resource Mobilisation	Provision of financial, human and physical resources which are key to the technology innovation process. For example, R&D grants or public subsidies to develop and test specific knowledge.

Market Formation	Mechanisms that generate niche markets. As recent technology is inefficient, it requires protected spaces for operational and market learning.
Legitimation	The action of providing legitimacy to a new technology by enhancing its fitness with dominant designs, infrastructures and societal aspects. TIS actors seek to mould dominant patterns through new technology schemes.

Source: Based on Bergek et al. (2008); Hekkert et al. (2007); Hekkert and Negro (2009); Jacobsson and Bergek (2011)

Suurs (2009) proposes that TIS functions can reinforce each other over time through a process of cumulative causation. This has been labelled as "motors of innovation", which are formed by patterns of interaction between TIS functions (Suurs and Hekkert, 2012). These papers have empirically explored this concept to later categorised observed patterns for explaining how the TIS growth and decline. The concept of motors of innovation resonates well with the need to map the dynamics of TIS functions. Surprisingly, further elaboration on motors of innovation has not been pursued by the TIS literature, except for Walrave and Raven (2016). Therefore, this presents an opportunity to investigate the broad policy of intermediation supporting the motors of innovation and explore how intermediaries propel underlying mechanisms that drive actors to innovate (Kohler et al., 2020).

In summary, TIS functions are relevant for this research because they help to examine the performance of the technology innovation system and detect failures that can be addressed through public policy and/or corporate strategy to improve innovation performance (Markard and Truffer, 2008). These ideas support the core topic of this thesis, which consists of understanding the intervention of transition intermediaries that promote technological development to address sustainable goals. To further explore that process, this thesis acknowledges the importance of intermediaries and their influences in shaping TIS (Kanda et al., 2019). In this regard, the literature has proposed that intermediaries can reinforce the technology innovation system by deploying functions that promote the socio-technical transition. For this reason, the term "transition intermediaries" will be used by this thesis to name middle organisations actively pursuing the goals of deep reconfiguration of industrial sectors. The following sub-section 2.2.2.1 will explore the role of intermediaries in socio-technical transitions through the lens of TIS literature.

2.2.2.1 Transition Intermediaries in TIS

As the previous sub-section 2.2.2 has explained, the TIS framework has been regarded as rooted in the transition literature by implementing a process focus to study the dynamics of innovation networks and understand how actors can develop new technologies for sustainability purposes (Markard et al., 2015). A fundamental actor that constructs such networks are the intermediaries, capable of supporting the TIS functions and strengthening the relationship between distant participants of the network (Sovacool et al., 2020). Particularly, linking the niche producer of new technology with the incumbent industrial adopter (Matschoss and Heiskanen, 2018).

A vast range of research has established the importance of intermediaries in innovation processes and their role in reconfiguring socio-technical systems. The analytical work of Caloffi et al. (2023) has systematised these approaches and proposed a typology of intermediaries. The authors suggest that middle organisations assume different formats according to the kind of innovation system they are part of. The types of intermediaries are summarised in the following Table 2.4:

Table 2.4 Intermediary typology

Intermediary type	***Description***
Innovation system intermediary	Support innovation by addressing system failures that enable the exchange of knowledge (e.g., science and technology parks, providers of advisory services).
Open innovation intermediaries	Facilitate open innovation processes by scouting ideas and connecting them with organisations and people (e.g., innovation centres and crowdsourcing platforms).

Transition intermediaries	Promote transitions through the creation of networks for translating early R&D into applied projects tackling sustainability goals (e.g., dedicated bodies promoting sustainable changes in industrial systems).
Technology Business incubators	Incubate the birth of start-up firms in high-tech sectors or emerging industries (e.g., university and corporate incubators).
Knowledge Intensive Business Services	Offer consultancy in knowledge-intensive business processes in other companies (e.g., law and accountancy firms, management, computer and engineering, advertising agencies, and R&D support).

Source: Based on Caloffi et al. (2023)

This typology notices the evolution of intermediaries from being middle organisations that operate in the space between other actors to promote innovation activities (Howells, 2006). This supports to describe how intermediaries take different roles in the course of an iterative innovation process (Klerkx and Leeuwis, 2009). In this regard, the surge of sustainable challenges pushes intermediaries to adopt long-term approaches to address environmental issues under the context of deep transitions (Gliedt et al., 2018). This perspective consists of the multidimensional shift that key industrial sectors, such as energy, transport and housing to name a few, must take towards a sustainable configuration. Nonetheless, these processes require decades to shape up due to the natural risk of integrating new technologies into a fundamental industry, which involves profound technological, institutional, consumer and cultural changes (Schot and Kanger, 2018). Middle organisations committed to accelerating these transformations have been referred to as “transition Intermediaries”. These are defined as middle agents that connect groups of actors involved in transition processes, overcoming systemic failures of sustainable technological development by creating collaborations that generate momentum for socio-technical change (Kivimaa et al., 2019a). Examples of transition intermediaries include innovation agency funders, technology transfer offices, public policy task forces, project developers, consultancies and demonstration centres (Kivimaa et al., 2020). Kivimaa et al. (2019a) elaborated a specific taxonomy of transition intermediaries that respond to different contexts of deep transformations, categorised into the following five types:

- Systemic intermediaries operating across all transition actors (particularly niches and incumbents), delivering an agenda to achieve changes in the whole system.
- Regime-based intermediaries linked to institutional arrangements but with a specific task to promote transitions.
- Niche intermediaries experimenting with innovations that aim to scale up for modifying prevailing practices.
- Process intermediaries promoting a change process perspective without an explicit agenda and rather supporting priorities set by other actors.
- User intermediaries transferring new technologies to users and assessing how they respond to such alternatives.

Based on these definitions, this thesis situates the view on transition intermediaries within the systemic description. This type of intermediary operates on a system level opening up spaces for new technologies to be diffused, articulating and aligning multiple actors in the whole system (van Lente et al., 2003). By performing this mission, transition intermediaries obtain the trust of actors to facilitate new technologies due to a clear position of neutrality compared to either niche or incumbent oriented intermediaries (Kivimaa et al., 2019a). Moreover, transition intermediaries operating at a system level are important in disrupting unsustainable configurations with a clearer transition agenda compared to process intermediaries (Kivimaa, 2014). To achieve this goal, Kanda et al. (2020) argue that transition intermediaries undertake different activities in-between different contexts (e.g., interacting between niche and regime actors). Such an idea is relevant for this thesis because it provides the basis to investigate how intermediaries assume normative positions in which they promote new technologies with a sustainable purpose among different levels of actors.

In summary, the systemic option within the five taxonomies of transition intermediaries is preferable due to the acceleration phase in which the UK net zero energy transition currently stands (Kivimaa et al., 2019b). Thus, this thesis will analyse how transition intermediaries align perspectives through network creation, with the purpose of engaging promising niches with stable incumbent firms by deploying intermediation functions. The next sub-section 2.2.2.2 will cover the transition intermediary functions and present a list of these connected with the TIS literature.

2.2.2.2 Transition intermediary functions

The previous sub-section 2.2.2.1 addressed the diversity of middle organisations arriving at the specific type of transition intermediaries that promote profound socio-technical modifications. These have been characterised as facilitators of purposeful innovation, engaged in system-building activities and capable of shaping the entities with whom they collaborate (Caloffi et al., 2023). By taking this role, transition intermediaries deploy functions focused on articulating options and demand, aligning actors and fostering learning processes (Kivimaa et al., 2019a). The function perspective has gained relevance in the study of intermediaries (Howells, 2006; Kilelu et al., 2011; Polzin et al., 2016; Stewart and Hyysalo, 2008), nevertheless it has been less explored in the TIS literature (Lukkarinen et al., 2018). This theoretical challenge calls for conceptual advancements linking the different intermediary formats with the TIS functions (Kanda et al., 2019).

It is important to note that the function approach is one lens to analyse the intermediation roles. As Caloffi et al. (2023) have suggested, the conceptualisation of intermediaries can take different positions according to the theoretical frameworks in which they are outlined. In the case of transition intermediaries, the literature is composed of a heterogeneous group of middle organisations that covers from bridging bodies that facilitate learning (Klerkx and Leeuwis, 2008 and 2009) to become the main channel of diffusion for new technologies (Hyysalo et al., 2013; Hyysalo et al., 2018). In this range of options, the literature has considered that the intermediary function approach is sufficiently deep to explore the middle activities that contribute to achieving the complexity and diversity of sustainable goals (Kivimaa et al., 2019a).

In this regard, the review of intermediation literature has identified critical aspects explaining the functions of transition intermediaries. Initially, intermediary functions were elaborated following a systemic perspective, based on the interplay of actors. According to this standpoint, Howells (2006) positioned intermediaries within a systemic view in which they facilitate the exchange of resources by system participants for producing innovation outputs. To address the complexity of the innovation process, intermediaries assume functions acting as bridges to connect the phases of technology development. Klerkx and Leeuwis (2008) further developed the intermediary functions within the systemic stance by investigating the challenges that the innovation process has in specific industrial sectors. Kilelu et al. (2011) expanded this work by proposing a set of functions focused on connecting the different actors of the agriculture innovation system. This stream of research is significant because explores the intermediary functions as bridges that establish networks helping to mediate the innovation process, as the TIS framework has taught us. Importantly, this strand of the literature has been connected with the broad issue of sustainability (Kanda et al., 2019; Lukkarinen et al., 2018). These ideas depart from van Lente et al. (2003) who suggested that intermediation functions should not only facilitate the flow of knowledge for innovation purposes but also engage actors in deep transitions.

The work of Kivimaa (2014) took this systemic approach of intermediary functions as a baseline to connect it with the TIS framework. Consequently, the intermediation literature started to focus on the different actors that interplay in the complex scenario of socio-technical transitions following the TIS approach. In specific, by paying attention to incumbent actors who apparently resist profound transformations whilst niche actors are in favour. Following this argument, Kivimaa and Kern (2016) proposed that transition intermediary functions develop a mixed approach to support innovation in niches while at the same time destabilising incumbents. Such a combined view of intermediary functions facilitates the socio-technical transition.

Consequently, the latest studies on transition intermediaries have acknowledged a broader relationship between niche and incumbent actors during transitions, opening the way to propose novel articulations of such an interaction through the TIS approach. Recent studies have investigated the construction of intermediary functions to foster this link. In this sense, Lukkarinen et al. (2018) identified intermediary functions, using a TIS perspective, as drivers that align different actors towards sustainability goals. Similarly, Kanda et al. (2019) took a TIS approach to analyse how intermediation functions articulate a common vision by which actors recognise opportunities and establish networks to address the socio-technical reconfiguration. Sovacool et al. (2020) confirmed the role that intermediary functions can play in the difficult process of transforming systems. Their argument has been that transition intermediaries support innovation processes from a bottom-up approach by paying attention to established institutions, rules and firms.

Drawing upon the key articles identified with respect to the functions of transition intermediaries (Howells, 2006; Kanda et al., 2019; Kilelu et al., 2011; Kivimaa, 2014; Kivimaa and Kern, 2016; Klerkx and Leeuwis 2009; Lukkarinen et al., 2018; Sovacool et al., 2020; van Lente et al., 2003), this thesis considers that intermediation involves various mechanisms in connecting niches with incumbents. These include dedicated networking, knowledge exchange, resource coordination, and process management. Based on the review of the above articles, this thesis identified six different functions as important for exploring the roles of intermediaries in socio-technical transitions. These are summarised in the following Table 2.5. The definitions are influenced by the work of Hannon et al. (2017) who catalogued intermediary functions to evaluate the performance of middle organisations based on a TIS approach. Additionally, Table 2.5 selected a couple of examples to illustrate how the transition is advanced as a part of each intermediary function. Next, the following subheadings will define each function and provide a brief justification for its inclusion.

Table 2.5 List of transition intermediary functions

Intermediary Function	Definition (influenced by Hannon et al., 2017)	Examples in the literature of how the transition has been mobilised by each intermediary function	Literature Sources
Relationship Building	The facilitation of matchmaking between actors within the industrial sector and the support of long-term relationships for transition purposes.	Intermediaries address sustainability challenges by creating networks of actors motivated by the scale-up of new technologies (Lukkarinen et al., 2018).	Kanda et al. (2019); Kilelu et al. (2011); Kivimaa (2014); Klerkx and Leeuwis (2009); Lukkarinen et al. (2018); Sovacool et al. (2020)
Management of human, technical and financial resources	Improving the innovation capabilities of actors via the provision of infrastructure, funding, and technical experience sharing.	Intermediaries provide critical resources that coordinate efforts among actors to move forward the transition (van Lente et al., 2003).	Howells (2006); Kanda et al. (2019); Kilelu et al. (2011); Kivimaa (2014); Kivimaa and Kern (2016); Lukkarinen et al. (2018); van Lente et al. (2003)
Articulation of transition by knowledge exchange	The strategic dissemination of knowledge between innovation generators and industrial users, which intermediaries use to articulate a vision of technology advancement and thus move forward the transition.	Intermediaries reinforce a grand vision by exchanging knowledge about new technology development that addresses sustainable problems (Sovacool et al., 2020).	Howells (2006); Kivimaa (2014); Kivimaa and Kern (2016); Klerkx and Leeuwis (2009); Lukkarinen et al. (2018); Sovacool et al. (2020); van Lente et al. (2003)
Technology Forecasting	Identification of priority R&D areas for the transition and the creation of avenues for innovation and industrial actors to deliver these.	Intermediaries forecast disruptive innovations emerging from R&D and present feasible pathways for them to reach the market (Kanda et al., 2019).	Howells (2006); Kanda et al. (2019); Kivimaa (2014); van Lente et al. (2003)
R&D Coordination	Coordination of R&D activities across the sector in line with existing transition goals.	Intermediaries facilitate learning among actors when they conduct innovation experiments, enabling the technology development to tackle sustainability issues (Kivimaa, 2014).	Kilelu et al. (2011); Kivimaa (2014); Klerkx and Leeuwis (2009); Lukkarinen et al. (2018); van Lente et al. (2003)
Regulatory Change	Promoting changes in institutional frameworks to support technology innovation.	Intermediaries provide advice on actors influencing how they should interact with the changing regulatory environment (Howells, 2006).	Howells (2006); Kilelu et al. (2011); Kivimaa (2014); Kivimaa and Kern (2016); Lukkarinen et al. (2018); Sovacool et al. (2020)

Relationship building

A fundamental function of intermediaries is connecting heterogeneous actors in the innovation process towards sustainability. TIS has described the interaction of actors –producers and users, entrepreneurs and early adopters, idea generators and funders– as not necessarily coordinated (Hekkert et al., 2007). Consequently, intermediaries have an important function in bringing actors together and facilitating joint activities (Kivimaa, 2014). The intermediation literature initially focused on understanding the relationship building function of middle organisations in relation to technology diffusion (Howells, 2006). In the case of transition intermediaries, relationship building goes beyond by recognising the social barriers to diffuse new technologies (Sovacool et al., 2020). In particular, the institutional rules represent an important obstacle to technology development that create path dependency in the relationship between niches and incumbents (Kivimaa and Kern, 2016). Scholars propose that transition intermediaries can break these patterns by generating networks that consider both technical and social factors as equally important to promote sustainable changes (Kanda et al., 2019).

In sum, this function is defined as the facilitation of matchmaking between actors building long-term relationships for transition goals. Lukkarinen et al. (2018) studied the intermediary function of relationship building through the efforts performed by the Finnish Carbon-Neutral Municipalities to address the challenges of scaling new technologies in the cleantech sector in Finland. They have found that intermediaries positively influence the direction of innovation development by creating a network that increases trust and drives the uptake of sustainable projects by a broad spectrum of stakeholders.

Management of human, technical and financial resources

For holding the network together, intermediaries provide tangible and intangible resources contributing to the development of collaborative innovation (Klerk and Leeuwis, 2009). Among these resources, we can find generic assets that intermediaries offer to identify innovation opportunities, develop strategies and funding to move the project ahead; to more specific support as protecting the outcomes of collaboration through intellectual property rights (Howell, 2006). Lukkarinen et al. (2018) have asserted that resource mobilisation for transition purposes consists of human, technical and financial assets. Human resources are related to individual or group skills that design, manage and evaluate uncertain projects reducing the high risk of innovation. Technical resources support R&D processes conducted for technology innovation. And financial resources are necessary to close infrastructure gaps that the innovation requires to be developed. Through the allocation of these resources, intermediaries influence the direction of innovation through experimentation and learning (Kilelu et al., 2011). These efforts progressively demonstrate the viability of alternative innovation and open the gate to becoming a feasible alternative to incumbent technologies (van Lente et al., 2003). As a result, this function enables intermediaries to position themselves as catalysts of sustainable transitions (Kivimaa, 2014).

In sum, the function of management of human, technical and financial resources is defined as the improvements of innovation capabilities in actors via the provision of infrastructure, funding and technical experience sharing. Van Lente et al. (2003) illustrated this function as essential to coordinate collaborative efforts among innovation actors in their case study of the Californian Fuel Cell Partnership in the US. The present thesis has decided to shorten the name of this function to "Management of Resources" facilitating its presentation in the general analysis.

Articulation of transition by knowledge exchange

In the TIS literature, intermediaries contribute to sustainable goals by articulating new visions and expectations, acting as an impartial voice for the network (Kanda et al., 2019). They take such an approach by mediating the clashes of interest and conflicting values that network members bring when they interact. In this way, transition intermediaries play a critical role in configuring the innovation processes between new technologies and industrial adopters, addressing the urgency of societal needs (Sovacool et al., 2020). Howells (2006) exposed that intermediaries create vision by shaping emerging technology development into feasible trajectories demonstrating the technical advancement to actors. In transition studies, this process is conducted by intermediaries through gathering and processing new knowledge from innovation producers that later are assessed in experimental projects facilitated by intermediation resources (Kivimaa, 2014). According to TIS literature, intermediaries deploy a key function of diffusing and promoting the learning outputs, which in turn have an accumulative effect creating visions, expectations and belief in the innovation potential (Bergek et al., 2008). Consequently, the sustainable transition is progressively articulated through a vision, which is shaped by the intensive exchange of knowledge –including scientific, technological, production, economic and market– facilitated by intermediaries (Lukkarinen et al., 2018).

In sum, this function is defined as the strategic dissemination of knowledge between innovation generators and industrial users, which intermediaries use to articulate a vision of technology advancement and thus move forward the sustainable transition. Sovacool et al. (2020) unpacked this function in their research of five intermediary case studies in the UK, France, the Netherlands, Finland and Norway. They found that intermediaries reinforce a strategic vision by exchanging knowledge about new technologies. Similarly, this thesis shortens the name of this function to "Articulation of transition", facilitating its presentation in the overall analysis.

Technology forecasting

According to the TIS literature, the system functions contribute to each other in the pursuit of innovation processes and positively affect the development of new technologies by stimulating the mobilisation of resources (Hekkert and Negro, 2009). The intermediary function of technology forecasting has an important role in coordinating those efforts in order to present cutting-edge innovation that can be of mutual interest to stakeholders (Kanda et al., 2019). By directing and stimulating research that addresses complex sustainable problems, intermediaries develop future scenarios with a variety of technological options (van Lente et al., 2003). Moreover, intermediaries establish roadmaps by which stakeholders can find pathways to develop radical innovation (Lukkarinen et al., 2018).

In sum, this function is defined as the identification of priority R&D areas and the creation of avenues for transition actors to deliver these for sustainability goals. Kanda et al. (2019) portrayed such an intermediary function by explaining how the Greentech Cluster in Germany helped to forecast disruptive innovations emerging from R&D activities. Consequently, this intermediary example presented a feasible pathway for new technologies to reach the market.

R&D coordination

An important elaboration of the TIS frameworks focused on the dynamics of interactions between the system actors towards R&D efforts (Hekkert et al., 2007). This elevates the key role that transition intermediaries can play in the interfaces of R&D strategies, moving from the primary objective of obtaining R&D results to enhancing the learning process between the research world and end-users (van Lente et al., 2003). In this context, the R&D producers denote the demand side of industrial users, whereas the specific knowledge brokering in this area has a sophisticated role of matching demand and supply of innovation (Kilelu et al., 2011). According to this shift towards a societal-driven demand for R&D activities, transition intermediaries must think outside of the box and promote experimentation of novel ideas addressing the sustainability challenges of production systems (Klerkx and Leeuwis, 2009). To fulfil this R&D coordination function, intermediaries provide resources to actors for performing experiments (Lukkarinen et al., 2018).

In conclusion, this function is defined as the coordination of R&D activities across the sector in line with existing transition goals. Kivimaa (2014) exemplified this function by explaining that intermediaries facilitate learning among actors when they conduct innovation experiments, enabling the technology development to tackle sustainability issues.

Regulatory change

Policymaking has received attention as a driver of innovation in the current knowledge economy. In particular, governmental bodies utilise transition intermediaries as tools to design, test and implement policies that favour new technologies (Klerk and Leeuwis, 2009). Furthermore, intermediaries address system failures by promoting regulatory change as brokering between formal rule-makers or regulators, innovation producers, industrial users, and sustainability targets (Sovacool et al., 2020). To present evidence to policy stakeholders, intermediaries advocate for removing some of the constraining boundaries of existing regulations to conduct innovation trials (Kivimaa and Kern, 2014). Favourable outputs from experimentation are gathered by intermediaries for presenting this information to regulators and modifying the normative framework (Lukkarinen et al., 2018). Therefore, intermediaries promote regulatory change with the aim of facilitating innovation because new policies provide the conditions necessary to make productive use of the technologies they broker (Kilelu et al., 2011).

In sum, this function is defined as the promotion of changes in institutional frameworks to support technology innovation. Howells (2006) exhibited this function through the role played by the BSI Group in the US. On this example, the intermediary function of regulatory change provides advice on innovation actors influencing how they should interact with the shifting environment.

2.2.2.3 Critiques of the TIS approach

Thus far, this literature review has explained how technology innovation is produced using a systemic approach to reduce risks. TIS is seen as an important theoretical starting point for analysing this phenomenon (Bergek, 2019). Nevertheless, as the TIS approach has been more widely adopted, it has also been the subject of criticism. Particularly, as a suitable framework to investigate how socio-technical transitions develop. These criticisms are summarised in the following three key points.

First, TIS has an inward orientation to the specific technology sector that blinds it to paying attention to the external environment (Markard and Truffer, 2008). This has presented doubts that TIS is a feasible framework for analysing the complexity of transitions, triggered by external pressures on industrial sectors to modify unsustainable practices (Smith and Raven, 2012). A central argument to support this criticism is that TIS does not explain the structural rigidities of system actors. Such as incumbent firms and their ties to the dominant design, making them incapable of change (Geels, 2011). This has questioned whether incumbent firms can establish links with other actors of the system for developing technological innovation, as the TIS proposes.

Second, there is a concern about how to delineate a TIS and identify its structures. This would make it difficult to pursue a situational approach for setting empirical cases of transitions. Coenen (2015) has argued that TIS is not capable of tracing the system's structures and the external influences they are subject to. Therefore, there are missing elements that need to be explained. Particularly, how the network is configured and the way some actors exercise power to bias its direction. For this reason, the literature review highlighted the transition intermediary functions as an extension of TIS functions to address this issue.

Third, TIS has been prominent in examining emerging technologies for sustainability purposes, in sectors such as energy, transport, or water treatment. As these innovations scale and diffuse, they will compete with established technologies that have dominated the market for reasons beyond technical efficiency (Markard et al., 2015). In such cases, TIS is considered limited for understanding how technologies gain momentum for dethroning stagnant but powerful incumbent actors during transitions (Geels, 2011). This might require the addition of new functions deployed by TIS actors (e.g., intermediaries) to investigate this issue (Kivimaa and Kern, 2016). This is suggestion taken into consideration by this thesis that proposes to explore how intermediaries reduce the resistance from incumbent actors and empower niches for diffusing new technologies relevant to the energy transition. This thesis aims to explore the dual role of intermediaries in a mutually reinforcing way.

Overall, TIS has been criticised for being a rigid framework with difficulties in addressing the broad societal structures that influence the behaviour of actors (Kern, 2015). Hence, it lacks the theoretical foundations for explaining what drives change and what motivates actors to be part of it. To address these gaps, scholars have attempted to connect TIS with other frameworks of the transition literature. Particularly the Multi-level Perspective (MLP), because the latest emphasises the interactions between different actors in developing innovation (Kanda et al., 2019). According to Geels (2004), the MLP views transitions as the need for profound changes in the technical as well as the social dimensions through the interplay at three analytical levels: niches (the space for radical innovation), socio-technical regimes (established practices and associated rules that stabilise the technology function of a system), and landscape (the broad external environment pushing for a change). TIS can be perceived as focused on the niche and in lesser extent to the regime levels (Kanda et al., 2019). Whilst transition intermediaries mediate between niches and regimes, assuming different functions to facilitate sustainability transitions (Kivimaa et al., 2019a). However, further research is necessary to understand the mechanisms that transition intermediaries use to connect socio-technical niches with incumbent firms in the MLP (Bergek, 2020).

The upcoming sub-section 2.2.3 will introduce how these transition actors have been conceptualised using the MLP as the theoretical base. This will begin by representing incumbents and niches during socio-technical transitions and their behaviour when they are confronted with transformational change. Finally, it will explain how transition intermediaries take a preponderant role in approaching distant positions of both incumbent and niche actors.

2.2.3 Multi-level Perspective (MLP)

MLP explains the substitution of a prevalence regime by another, due to the interplay of events in three levels: macro, meso and micro. Socio-technical regimes are the heart of the meso level, consisting of the interdependence of material structures, which over time co-evolve into a stable configuration enabling the fulfilment of a societal function, like energy provision (Fuenfschilling and Truffer, 2014). As was anticipated in sub-section 2.1.2, technologies embedded in material structures are surrounded by socio elements, such as user practices, regulation, industrial networks, infrastructure and symbolic meaning, reinforcing the societal function (Geels, 2002). Technology and socio aspects blend through time, facilitating the use of artefacts and subsequently generating routines in individuals and organisations. This conceptualisation stresses the institutional character of a regime as a collective outcome that cannot be easily modified (Kemp et al., 2001). Thus, the socio-technical regime imposes a logic and direction for improving practices through incremental change creating a rigid pathway for development.

Socio-technical regimes frequently become into unsustainable configurations (e.g., the energy supply based on fossil fuels), which make it necessary to modify or replace critical elements from the system. The reason motivating these changes is the presence of persistent and unstructured societal problems, located at the landscape or macro level. It is an external structure above the regime where wider events take place over long periods, involving cultural values, economic aspects, political developments and environmental issues from multiple stakeholders (Geels, 2004). The landscape's pressure forces the regime to confront deep changes or transitions (Smith et al., 2005). Nonetheless, the conjugation of social and technological elements that have stabilised the regime's function makes it extremely difficult to achieve transformation from internal forces (Geels, 2014).

For this reason, the source of technological change can be found in niches, insulated spaces away from the regime's influence located at the micro level (Geels and Schot, 2007). Niches are important in socio-technical transition because they offer the possibility for new technologies and early adopters to learn the functionality of emergent innovation.

Geels (2011) has represented in Figure 2.2 how the three levels interact in the socio-technical transition, with the landscape pressuring the regime for substantial change and generating windows of opportunities for technology innovations located in niches to break through into the regime.

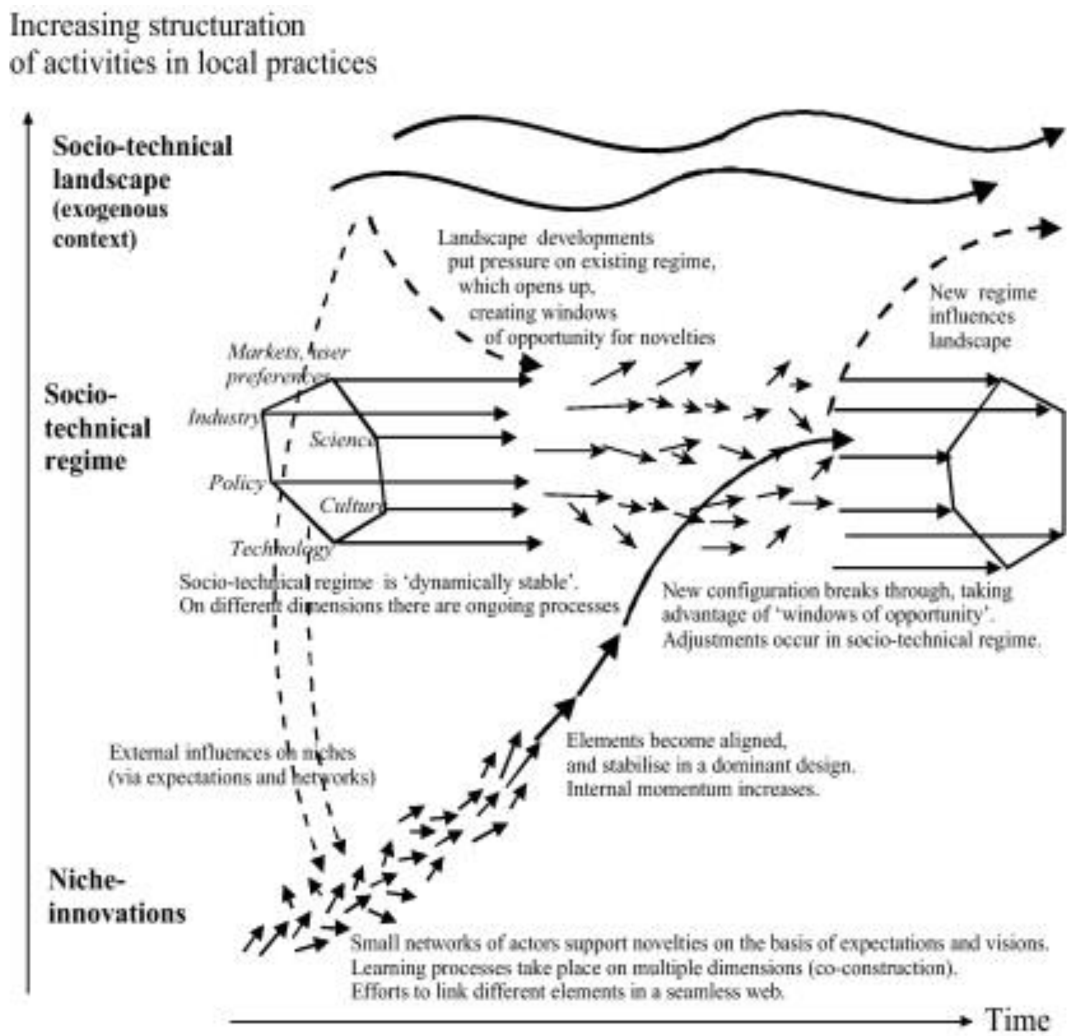

Figure 2.2 Multi-level Perspective
Source: Geels (2011)

The rise of radical innovation from niches can disrupt the dominant regime and produce the transition to a new socio-technical regime. This process is highly non-linear, taking decades to shape up and gain the power to destabilise regimes (Alkemade et al., 2011). As this thesis aims to discover new insights about the collaboration between incumbent firms in the regime and innovation producers in niches, with the help of transition intermediaries, it is important to briefly review how the MLP literature has presented this interrelation.

The next sub-section 2.2.3.1 will define incumbent firms and later critically analyse how they respond to socio-technical change. The following sub-section 2.2.3.2 will apply a similar analysis with socio-technical niches. Finally, sub-section 2.2.3.3 will cover transition intermediaries.

2.2.3.1 Incumbent firms

Under MLP, the role of incumbent firms has been portrayed as a defender of practices in the regime (Geels, 2014). Incumbent firms have been defined as organisations using established technologies that enable them to hold a significant share of the market and have operated their business model for a long period (Lowes et al., 2017). They are also considered powerful actors that have supported the stability of the regime by making investments in technologies, infrastructure, engineering competencies and system belief (Smink et al., 2015). Consequently, a strong argument can be made about incumbents actively resisting the transition to maintain the legitimacy of their business practices and thus executing power to select the entry of new actors (Pinkse and Groot, 2015).

This preceding perception has been gradually changing and reflecting on incumbents' role during transition as a broad phenomenon that is not strictly attached to a unique response of resistance (Bergek, et al., 2013; Berggren et al., 2015; Steen and Weaver, 2017; Turnheim and Geels, 2013). Recent studies have suggested that incumbents can repurpose existing assets and infrastructure to accommodate sustainable technologies, presenting a potential pathway for transition since it presents the re-utilisation of capabilities, technologies and experience in new sustainable formats (Makitie et al., 2018 and 2019). Consequently, incumbent firms are considered critical actors for reaching a sustainable future, due to their control and management of essential infrastructure as well as their knowledge of the customer base (Heiskanen et al., 2018). Therefore, the literature has made a call to examine incumbents beyond the portrait of "villains" who prevent transitions and reflect instead in the multiple types of responses when they face change (Turnheim and Sovacool, 2020). To address these mixed views about incumbency, it is important to first draw on the conceptualisation of incumbent firms and then frame their behaviour during the socio-technical transition under the MLP lens.

Definition of incumbent firms

An incumbent firm has been defined as a company that has core competencies related to the current dominant practices (Smink et al., 2015). For this reason, it is commonly inferred as the backbone of the socio-technical regime (Steen and Weaver, 2017). To explain how incumbent firms have obtained such a position, it is necessary to explore four concepts from different bodies of literature and combine them to understand the evolution of a company until becoming an incumbent firm.

The first of these concepts is the organisational capacity to grow, which partially indicates how a company obtains a dominant position. One of the earliest contributions in that regard was offered by the rule of proportionate effect (Gibrat, 1931). This claims that the expansion rate of an enterprise is independent of its size at the beginning of the examined period of growth. In general, this proposition has been accepted for larger enterprises but not smaller companies. The assumption reflects that smaller companies can grow significantly more compared to larger firms in the same period; in addition, it suggests that other relevant factors, such as age, affect the firm's growth (Sutton, 1997).

In this case, the age of a company influences the amount of learning the organisation has for operating in the market. This is the second relevant concept which means the older the firm, it has accumulated a larger learning. Penrose (1959) has associated the firm's expansion through the acquisition and application of new knowledge to business practices. Thus, the firm becomes more efficient and gets better opportunities for growth, if it is capable of performing repetitive business processes based on the acquired knowledge.

The third concept relates to the high market share incumbent firms have in the industry they operate. By mastering the capability to learn and apply new knowledge that enables it to grow, the firm creates unique resources that allow it to obtain high revenues (Wernerfelt, 1984). Consequently, the firm has achieved a strong market share. It is not rare to find incumbents operating with such a market concentration that the end-user has few options to select alternatives (Hortacsu et al., 2017). As often happens in the energy supply sector.

The fourth concept is the skill to renew organisational resources through the acquisition of technology innovation (Audretsch et al., 2014; Coad and Rao, 2008; Mansfield, 1988; Stam and Wennberg, 2009). In such a regard, Acs et al. (2013) have suggested that companies able to identify technological innovation as a source of business opportunities can generate a great influx of growth and establish a leadership position in the industry. Once the set of novel technologies has been consolidated, the previous group of firms that pushed for those changes usually stop pursuing entrepreneurial opportunities and instead concentrate on the full exploitation of the new products they helped to build (Klepper, 1996). Thus, former companies with a risk appetite have now become established firms, shifting from major transformations to minor refinements as well as focusing on cost reduction to maintain a competitive position. As a result, the firm tends to resist external technologies threatening to replace the resources and capabilities previously acquired through substantial investment (Christensen, 1997). In this situation, fixed routines likely dominate the firm's dynamics, constraining the future skills to compete with emerging companies in evolving environments (Teece et al., 1997). Up to this point, it can be said that the company has been converted into an incumbent firm.

In summary, this thesis defines an incumbent firm as an existent and large enterprise, which has captured a significant market share through the learning of operational efficiency over a long period, and possessing a mature technology base that is close to becoming obsolete.

Incumbents' responses during socio-technical transitions

In the pathway of incumbency development, the MLP literature has paid attention to the way established firms exercise influence to maintain regimes as monolithic structures, difficult to modify once they have gained stability (Avelino, 2017; Burke and Stephens, 2018; Smink et al., 2015). However, the socio-technical regime is not permanently secure and can be undermined by the landscape pressure that is beyond incumbents' control. Thus, the landscape is an additional source of structuration for the incumbent's behaviour (Geels and Schot, 2007). For example, the recent low production of oil and gas in the North Sea has decreased incumbents' profits and created intense market competition based on cost in the UK energy supply industry.

In addition, the social concern about climate change threatens to significantly reduce incumbents' reputations. Most recently, the Covid-19 pandemic and the international conflict between Russia and Ukraine have provided additional factors of instability, affecting the operational cost and hitting the British end-customer with higher prices on energy bills. The combination of these elements exposes utility incumbents to windows of opportunity and eventually being replaced by alternatives, as the MLP has taught us (Geels, 2002).

Under such severe circumstances, the literature has proposed that incumbents face two strategic options to confront change: selection or adaptation (van Mossel et al., 2018). Firstly, selection consists of the environment choosing the set of organisations that are going to survive the transition. This argument derives from the organisational ecology school of thought (Hannah and Freeman, 1989) and claims that the dynamics of the business population are the results of environmental selection (Flier et al., 2003). Meaning that the likelihood of incumbents surviving the landscape's pressure is determined by chance, rather than adaptive efforts that they are unable to produce in time (Aldrich, 1999).

Secondly, adaptation refers to the strategic choices of incumbents to adjust during windows of opportunity. This idea differs from selection in the sense that firms can intentionally and systematically modify their behaviour to survive. Adaptation is supported by the notion that firms sustain competitive advantages with resources difficult to obtain (Barney, 1991). Thus, it assumes that firms can identify an appropriate response to landscape pressure by acquiring new resources –as well as eliminating useless assets– that can be implemented timely by the organisation. This fundamental notion has been proposed by the Resource-Based View of the Firm, which will be covered in more details in Section 2.3. To briefly summarise the concept here, the Resource-Based View takes the standpoint that valuable and difficult to reproduce resources, managed through organisational capabilities, provide a competitive advantage to the firm (Barney, 1991).

Nevertheless, due to the institutional lock-in, MLP argues that incumbents have little flexibility to acquire new resources in the form of technology innovation (Geels, 2014). Based on these considerations, it could be said that incumbents' adaptive skill is limited, and competencies turn obsolete when disruptive events require a substantial technological shift (Sovacool et al., 2017). On the other hand, some incumbents have been able to develop a strategy of adaptation by selecting resources found in niches and not remaining stuck in old technological paradigms (Hansen and Coenen, 2017). Therefore, while combative incumbents can be obstacles to transitions; others can adjust to the transition through an alliance with apparent foes, the niches possessing technological innovation. Such a dichotomy in the literature captures the heterogeneity of incumbents and it nuances the initial MLP approach to describe their behaviour during socio-technical transitions.

The diverse perceptions of incumbency propose a new challenge to the MLP demoting some of their initial assumptions, which this research aims to explore. Now the attention turns to describing socio-technical niches, another fundamental MLP actor.

2.2.3.2 Socio-technical niches

According to MLP, the regime is only capable of generating incremental innovation given its efficient orientation towards stability. As a consequence, radical innovation is produced in a different conceptual space called the socio-technical niche. This is a sheltered area shielded from dominant designs (Smith and Raven, 2012) wherein innovative solutions can be nurtured through R&D projects, piloting technologies, field trials, and gradual exposure to the market (Kohler et al., 2019). These innovation mechanisms can be initiated by new entrant firms, academic R&D and entrepreneurs, who experiment with new technologies seeking to develop sustainable solutions that would solve problems where incumbent firms have been inefficient (Geels, 2019). In addition to experimental trials covering the technical function of emerging innovation, the MLP literature has emphasised the articulation of expectations, social learning and the shape of networks as constituting processes of niches (Raven et al., 2011). These social factors are fundamental to niches because they reduce the cultural and psychological barriers by which the market receives unfamiliar alternatives that are compared with the dominant design (Kemp et al., 1998). For these reasons, this thesis uses the term socio-technical niches to equally consider both dimensions, which are so important to technology innovation as was already discussed in sub-section 2.1.2.

MLP literature has taken a wide criterion to define actors in socio-technical niches. Overall, these are entrepreneurs protected by incubation rooms where resources are provided by strategic investors (public and private) to develop radical innovations. These start from R&D activities and experimental ventures, involving early users, technology producers and public authorities (Geels, 2005a). Socio-technical niches can be created by these heterogeneous actors aiming to prove new technologies. These will potentially disrupt the path dependency and achieve a societal goal by avoiding the selection criteria of the regime (Schot and Geels, 2008).

Socio-technical niches have motivations that usually conflict with the dominant design in the regime (Raven, 2007), leading to a battle according to the MLP approach. Both try to overthrow the other emphasising their weaknesses –unsustainable efficiency versus unpredictable change– rather than seeking linking dots for potential collaboration (Geels, 2005a). This perception has been gradually changing in the MLP and recognised the possibility of socio-technical niches using complementary infrastructure from incumbent firms to solve persistent issues in the regime (Geels et al., 2017). The following subheadings will provide further insights towards that direction, offering an understanding of niches' scale-up, to then discuss their behaviour during socio-technical transitions.

Niches' technological scale-up

It was mentioned that socio-technical niches are defined by MLP as protected spaces, such as public R&D laboratories, subsidised demonstration projects, or small market arenas, where early users have particular demands and are willing to try emerging innovations (Geels, 2011). Niches offer the opportunity to develop technology innovation that deviates from dominant regimes' trajectories. To survive the difficulties of the inherited risk of innovation, socio-technical niches can access a supportive network allowing experimentation to flourish, such as business incubators, subsidised technologies, and living labs (Smith and Raven, 2012). These efforts expect that new technologies will replace the unsustainable practices of the regime, providing the seeds for systemic change to later gain momentum during windows of opportunity and finally replace the outdated technologies.

The MLP literature has distinguished four phases in the niche's evolution through the interplay between different levels (Geels, 2005b). First, technological innovation emerges in niches with various technical forms competing with each other. Actors engage in experiments to find the best design according to the needs of users. Second, the novelty is applied in market niches, which provides critical feedback and improves the conditions to articulate rules. Third, the technology innovation gains in diffusion and commences to compete with dominant designs in the regime. Such an option largely depends on the pressure from the landscape to open windows of opportunity for this competition to happen in the mainstream market. Fourth and finally, the emerging innovation replaces the old technology, which is followed by gradual changes in the dimensions of the incumbent regime.

The literature has considered these processes as the results of multiple initiatives that push a technology innovation created by niches to progress through experiments (Kemps et al., 1998). For these trials to get support, transition actors require strong cross-relations facilitating the development of technology innovation (Geels and Raven, 2006). Therefore, the literature has argued that the adoption and diffusion of technology innovation is a social process that should not be a determinist result of the R&D logic and neither the decision of purely market mechanisms. On the contrary, socio-technical niches aim to establish an open search through the social learning process for the adoption of new technology during windows of opportunity (Hoogma et al., 2002).

In summary, this thesis defines the socio-technical niche as the insulated space away from the regime's influence, whose goal is learning the functionality of a new technology that will make social sense through constant iteration with relevant stakeholders.

The behaviour of socio-technical niches during transitions

Based on the previous conceptualisation, it can be said that the behaviour of socio-technical niches is guided by tackling social threats that cause environmental degradation. Precisely, due to the possibility of nurturing and trying new ideas to solve such problems, socio-technical niches invest resources in developing technology innovation. Even at the cost of accepting a failing result, because they know this will sow the seeds to generate a sustainable regime (Schot and Geels, 2007).

In this journey, niches attempt various directions in technology development. Through the processes of learning, they play with wide possibilities from R&D options, designs, and user preferences (Raven, 2005). The progression of technology innovation proposes these alternatives to the market, formed by economic and institutional elements, which in turn selects new technologies during the learning process (Schot and Geels, 2007). This implies that the behaviour of socio-technical niches is conditioned by the flexibility they have for altering the development of new technologies through feedback from multiple stakeholders. Under this approach, niches with a propensity for adapting to external responses will be able to produce technology with better opportunities to scale.

Based on this standpoint, Smith and Raven (2012) have suggested that socio-technical niches' behaviour can take two options. On one hand, niche innovations are nurtured until they achieve an acceptable performance by the regime and thus the new technology can be included in a way that "fits and conforms" with dominant practices. On the other hand, niche innovations construct new norms and routines that change the regime rather than be subordinated by it. In this form, the niche is empowered through a process of "stretch and transform" that modifies the regime in a new format that favours the niche. This is of particular relevance to this research, which seeks to further explore the "fit and conform" pathway through the intermediation functions. These might connect actors located at different levels of the MLP and collaboratively develop capabilities for interacting with each other to achieve sustainable goals.

In summary, this sub-section 2.2.3.2 proposes that the behaviour of socio-technical niches is based on learning the best manner to diffuse their new technologies. The most flexible niche to pick the lessons the environment provides will be more likely to diffuse a technology innovation. In this process, the fittest niches adapting to external responses will have better chances to connect with regime's actors and in conjunction move the transition forward.

2.2.3.3 Transition intermediaries in MLP

Previous sub-section 2.2.3.2 has described the scale-up of new technology by niches. This made the case that socio-technical niches require a robust relationship with other transition actors enabling the learning for developing technology innovation. In the possibility that such learning processes are not naturally facilitated by the networks of actors, dedicated intermediation is needed to close those breaches (Raven et al., 2008). MLP scholars have suggested that the convulse process of socio-technical transitions can be influenced by impartial entities coordinating the innovation efforts of actors at different MLP levels. In this option, institutional efforts seek to stimulate actors towards sustainable goals. Thus, MLP has considered that the socio-technical transition involve the presence of transition intermediaries, particularly for supporting the diffusion of new knowledge and the creation of norms for adopting it (Geels and Deuten, 2006). Under such a standpoint, MLP has presented the role of transition intermediaries as favouring new entrants in niches (Hargreaves et al., 2013).

Kivimaa et al. (2019a) have questioned this assumption by considering that transition intermediaries can have a much broader role than simply fostering technology innovation in niches. They have described intermediaries as brokers with multiple priorities, interests and knowledge pools for developing shared perspectives to facilitate the transition. In this debate, it is important to notice that the intermediary literature is not tightly placed under MLP (or any other transition framework) but it is rather cross-cutting. For such a reason, this thesis acknowledges a broader conceptual spectrum from the transition literature seeking to explore the links that intermediaries are capable of producing between different actors of the transition.

This view must consider the ecology of intermediaries playing a variety of roles in transition, from agglutinating different organisational cultures to creating new markets for novel solutions, crossing the translation of information and fostering learning on innovation (Kivimaa et al., 2019a). For such a reason, transition intermediaries can take a strategic position in nurturing and protecting niches from the regime's influence (Bush et al., 2017; Schot and Geels, 2008; Smith and Raven, 2012); and, simultaneously, facilitating the technology scale-up by eroding the position of resistant incumbents and regime rules (Kivimaa and Kerns, 2016; Matschoss and Heiskanen, 2018). However, the MLP has not clearly articulated how both dimensions can be integrated around transition intermediation. This reflects the need to add alternative approaches to understand the degree of influence that intermediaries play on the development, diffusion and integration of new technologies during socio-technical transitions.

Having identified the lack of attention paid to the collaborative role of transition intermediaries by MLP in the diffusion and adoption of technology innovation, the next subheadings will discuss how transition intermediary functions make possible the connection between actors at different MLP levels. This focus will provide valuable insights into understanding the mechanisms for enabling the combination of resources between socio-technical niches and incumbent firms.

Transition intermediary functions in the MLP

As the MLP has mainly described transitions as the battle between socio-technical niches and incumbent firms, it has overlooked the systemic elements of technology innovation (Walz, 2018). One of the missing pieces in the MLP has been to define the role of transition intermediaries as capable of connecting actors to jointly address the challenges posed by complex and long-term transitions (Gliedt et al., 2018; Kivimaa et al., 2019b; Matschoss and Heiskanen, 2018). To bring this idea forward is necessary to go beyond the MLP and explore concepts in other bodies of literature. By doing so, transition intermediaries can be presented as boundary organisations bridging incumbent firms and socio-technical niches under a hybrid management approach in order to link these actors for technology experimentation (Marvin and Medd, 2004).

By introducing this perspective on MLP, transition intermediaries can be described as performing functions to reach the goals of sustainable transitions (Kivimaa et al., 2019a). This rationale brings us back to the transition intermediary functions proposed through the TIS approach in sub-section 2.2.2.2. By combining the TIS standpoint on intermediaries with the transition dynamics of MLP focused on actors at different levels, it is possible to pay attention to the functions that transition intermediaries undertake. In particular, by shaping the technology transfer process from socio-technical niches to incumbent firms for addressing sustainable goals.

It is important to mention that this thesis considers the conceptualisation of intermediaries starting from the innovation literature to then permeate the transition frameworks (Kivimaa, 2014; Kivimaa et al. 2019a). Accordingly, the theoretical combination of TIS and MLP allows us to explore the role of intermediaries by examining their interaction with other transition actors (i.e., niches and incumbents). Using as a baseline the transition intermediary functions proposed in Table 2.4, this thesis can contribute to providing valuable insights about intermediaries. Specifically, their role in mediating between destabilisation forces in socio-technical niches with the integrating power of incumbent firms.

2.2.4 Main critiques of MLP

Geels (2011: p. 26) has described MLP as a "*middle-range theory that conceptualises overall dynamic patterns in socio-technical transitions*", based on theoretical assumptions articulated in evolutionary economics, science and technology studies, structuration theory and neo-institutional theory. MLP has become a prominent approach leading to various typologies that vary according to the dimensions it emphasises (Kohler et al., 2019). Moreover, it has been praised for drawing a simple framework of complex phenomena and offering insights into the social nature of technological change (Smith et al., 2010). However, this simplicity has served as a target for three main criticisms.

The first critique has underlined the lack of agency in MLP, stating that this framework is broadly descriptive leaving too much room for interpreting the motivation of actors (Smith et al., 2005). This criticism suggested that the constraints on freedom of manoeuvre in niches to build the best fit between technology and society require further investigation (Genus and Coles, 2008). The lack of agency in MLP's actors has also inhibited the evolution of capabilities –particularly incumbent firms–, which has blocked them from acquiring technological resources to confront the dilemma of change (Lieberherr and Truffer, 2015; Smith et al., 2010). This has converted incumbent firms' trajectory into path-dependent (Weber and Rohracher, 2012), creating the notion that incumbents are passive to transition (Geels, 2014). Van Mossel et al. (2018) have summarised these ideas and concluded that the role of incumbent firms has been under-conceptualised in the MLP.

This first critique has additionally led to questioning the view that MLP has made to transition intermediaries. Although intermediation contributes to transitions through niche creation (Gliedt et al., 2018) and regime destabilisation (Kivimaa and Kern, 2016; Matschoss and Heiskanen, 2018), there are few studies examining its cross-boundary roles linking actors in different MLP levels. Consequently, there is a gap in the literature that has not sufficiently explored how transition intermediaries connect actors in different levels of the MLP framework (i.e., regimes and niches) during a socio-technical transition.

The second criticism relates to the methods used to investigate the dynamics described in MLP. There is a great challenge in integrating this framework to understand both historical and ongoing transitions that can lead to a more rigorous application of MLP in empirical studies (Markard et al., 2012). MLP has mostly employed the historical case study method that recounts the arbitrary nature of transition, deriving from the exclusive use of secondary data sources (Genus and Coles, 2008). This has reduced the opportunity to discover the variety of ongoing processes that connect regime and niche actors by recognising complementarities to avoid unsustainable trajectories (Papachristos, 2018). Such an approach would allow identifying the drivers of current transitions offering the leverage for system reorientation towards a desirable social future, potentially converting the MLP into a predictable tool.

The third critique has been outlined around the scarce variety of pathways to analyse the combination of landscape, regime and niche levels (Turnheim and Sovacool, 2020). It has privileged the bottom-up dynamics by reinforcing a misrepresentation that change comes mainly from niches (Berkhout et al., 2004). This has led to describing regimes as "black boxes", with few studies exploring the role of incumbents in transition (Steen and Weaver, 2017). The under-representation of these crucial actors and their approach to change can be the result of some limitations in the MLP framework (Turnheim and Sovacool, 2020). Nevertheless, the repurpose of MLP has contributed to an active discussion around the socio-technical mechanisms for systemic change, such as presenting the role of incumbents (Stirling, 2019), revealing their active resistance to transitions (Geels, 2014), and acknowledging their patterns of change (Turnheim and Geels, 2013).

In summary, MLP is a workable framework for unpacking socio-technical transitions through the interaction of different layers, where historical accumulation creates momentum for novel technological trajectories to emerge. This research considers MLP a theory that offers a great opportunity to reposition actors through a complementary relationship of collaboration when new technologies commence to be available for adoption. However, this thesis believes MLP is incomplete in investigating the capabilities of actors attempting to form such a link. Consequently, the next Section 2.3 turns the attention to the Resource-Based View of the Firm (RBV) to illustrate how this body of literature can provide further insights and add theoretical pieces to conceptualise a collaboration scheme between MLP actors.

2.3 The exchange of resources among transition actors through the Resource-Based View of the Firm approach

The previous Section 2.2 has defined socio-technical transition as an intense transformation in technological, market and institutional aspects aiming at sustainability. Transitions involve actors grouped at different levels that over time substitute existing technologies, institutional rules and organisational practices at the regime level (Farla et al., 2012). In such regard, the socio-technical transition consists of the integration of new technologies and the reconfiguration of fundamental social aspects that enable the adoption of innovation.

TIS and MLP have been useful in portraying socio-technical transitions but have come at the expense of offering little understanding of the collaborative attempts of actors to diffusing and adopting technology innovation. These gaps in the literature will provide the opportunity to explore the development of capabilities to promote technological innovation. Consequently, it has been proposed that MLP actors can use their distinctive resources to support each other in their innovation efforts (Markard and Truffer, 2008). Specifically, the technology innovation produced by niches can be transferred to incumbent firms in regimes (Raven et al., 2010). This action can be supported by transition intermediaries which contribute to the deployment of TIS functions (Kanda et al., 2019).

These linkages provide integrating legitimacy that allows the technology innovation to scale in the market (Fuenfschilling and Binz, 2018). Such a relationship can be encapsulated under the Resource-Based View of the Firm (RBV), a management framework used to determine the strategic resources an organisation should develop and/or acquire to obtain competitive advantage (Barney, 1991; Peteraf, 1993; Wernerfelt, 1984). In the socio-technical transition context, RBV can provide key concepts to navigate the fundamental shift to which firms are subject.

Subsequently, the next sub-section 2.3.1 introduces the RBV theory. This will be the base to explain how valuable resources can be exchanged during the technology transfer, in sub-section 2.3.2. To proceed with this approach, the literature review will explain that organisations require the capability to diffuse and adopt new technologies, which have been condensed under the theoretical concepts of absorptive and desorptive capacities to be respectively covered in sub-sections 2.3.3 and 2.3.4.

2.3.1 The Resource-Based View of the Firm

The origins of RBV can be found in the notion that an organisation's performance depends on the collection of resources that it possesses and the skills to manage them (Penrose, 1959). Resources are productive, imperfectly imitable and specific to each company, which in combination allows the firm to reach a superior and sustainable position against the competition (Amit and Schoemaker, 1993; Barney, 1986; Dierickx and Cool, 1989; Wernerfelt, 1984). Barney (1991) has defined resources as the strengths the firm uses to design and implement the corporate strategy. He has classified resources into three categories:

- **Physical resources** include technologies, infrastructure and equipment.
- **Human resources** consider training, experience, judgement, intelligence and the relationship between managers and workers.

- **Organisational resources** account for the firm's formal structure and coordination systems, as well as informal relations among groups within the same firm and other companies.

To administrate these resources, the firm requires capabilities (Barney et al., 2001). These are defined as information-based, tangible or intangible processes that are firm-specific and developed over time through interactions with the firm's resources (Amit and Schoemaker, 1993). Phonetically similar but semantically different, capacity refers in RBV to the quantitative measure of the firm to contain, receive and accommodate resources (Vincent, 2008). Whist capability is a collaborative process that can be deployed by individual or organisational competencies in a particular activity of the firm (Amit and Schoemaker, 1993). Both are important definitions that are necessary to establish at this point, before proceeding with the following sections that will apply these core concepts to explain how the firm uses capabilities and capacity to deploy strategic actions. The following sub-section 2.3.1.1 will explain how capabilities help to manage resources in the organisational setting.

2.3.1.1 Capabilities to manage resources

Barney et al. (2001) explored the relationship between resources and capabilities by explaining these as bundles of tangible and intangible assets, including the management skills, processes, routines, and knowledge the firm holds. They have proposed that through the acquisition of complementary assets in a competitive environment, the firm learns valuable capabilities to manage new resources. Therefore, resources and capabilities are closely interconnected, in which the capabilities create specific processes according to the alteration of the firm's resources.

Eisenhardt and Martin (2000) have corroborated this link by asserting that the firm's capabilities are pre-existent and require to evolve for managing the creation and acquisition of new resources. Zollo and Winter (2002) have added that the evolution of capabilities is the result of organisational learning when the firm acquires new resources based on the attempts to manage them for producing different results according to the organisational strategy. The literature has referred to this possibility of adapting existing organisational skills as “dynamic capabilities” (Teece et al., 1997). Lawson and Samson (2001) stated that dynamic capabilities are critical to the firm because they allow it to create new products and processes responding to changing circumstances. Consequently, dynamic capabilities are intrinsically linked to market evolution and the focus of the firm should be put on rapidly creating specific new knowledge that responds to those changing conditions (Wang and Ahmed, 2007). According to this idea, capabilities are dynamic because they evolve to manipulate a different group of resources, blending with the modular base of existing resources into a new combination (Lawson et al., 2015). This allows the firm to increase –or at least sustain– a group of competitive advantages. For this reason, Schoemaker et al. (2018) have concluded that the development of dynamic capabilities is necessary to modify a firm’s current business model and skill sets ahead of disruptive change. The RBV literature has suggested that firms can learn the way to proceed in this challenge by experimentation enabling innovation opportunities to be identified (Easterby-Smith and Prieto, 2008). This thesis follows this consideration expressed by the dynamic capabilities literature and considers that these are pre-existent and can evolve according to the acquisition of new resources. This is a critical perspective to be assessed by this thesis in order to improve our understanding on how the UK energy supply sector can develop different capabilities to face the net zero transition.

In this option, finding the proper balance between the internal technology base against the acquisition of external technology and developing a specific capabilities for such a purpose has become a critical aspect of the firm’s strategy (Jones et al., 2001). To inform such decisions, Grant (1991) has provided a framework that considers five stages, exhibited in Figure 2.3. The first step identifies the opportunities for better utilisation of the current resources. The second step classifies the firm’s capability to maximise resources. Both provide inputs to assess the eventual generation of competitive advantage in the third step. This leads to the fourth stage in which the firm selects the best strategy to exploit external opportunities using existing resources and capabilities. In the final fifth step, it might be that the firm does not have the resources to implement such a strategy. Hence, the firm can be motivated to acquire them from external sources. For instance, organisations with limited innovation resources can opt to obtain these through technology transfer as a feasible option to get crucial assets directly from the technology source (Wahab et al., 2012). This idea is key to understanding the incumbent firm's position for connecting with socio-technical niches and acquiring technological resources that will allow them to navigate the socio-technical transition.

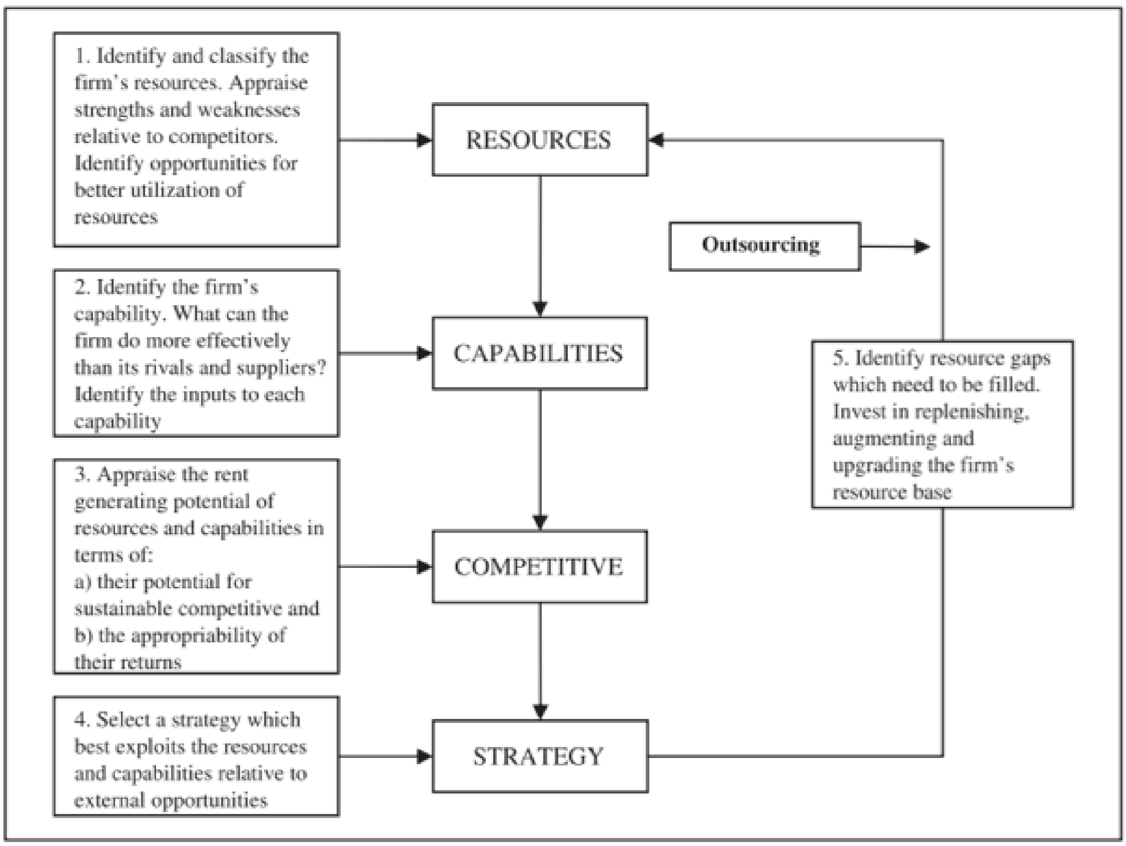

Figure 2.3 A resource-based approach to outsourcing strategy
Source: Espino-Rodriguez and Padron-Robaina (2006) based on Grant (1991)

This means that firms are available to acquire new resources in response to environmental pressure for change. The RBV literature (Barney et al., 2001) has recognised this as an important mechanism, in which the R&D outputs from socio-technical niches can be acquired by incumbent firms. This might happen because the organisation that has produced the technology resources is not capable of fully commercialising them. Thus, it can be preferred to transfer these to a more capable firm for exploiting the innovation (Lichtenthaler, 2016). Consequently, technology transfer is an important process that organisations implement to exchange valuable resources that can lead to a competitive advantage. The next sub-section 2.3.2 turns the attention to defining the relevant concept of technology transfer.

2.3.2 Technology transfer

Technology transfer has been described as the management process of conveying a technology innovation from one end to another end for its adoption (Souder et al., 1990). The specific body of literature has identified five key areas for conducting this process.

- **Transfer object** is the item to be transferred from the donor to the receiver. Bozeman (2000) has described this object as scientific knowledge, a technology device, a technological design, a process, a craft or know-how in general.
- **The transfer mechanism** is the vehicle through which this exchange is conducted. Rogers et al. (2001) have identified the technology transfer occurring via the following mechanisms: a new company is formed with the purpose of possessing the core technology innovation created for later commercialisation; licensing, as the permission to make, use and/or sell the transfer object to another organisation; articles published in academic journals, generally accessible to the public; meetings involving person-to-person interaction in which technical information is exchanged; and cooperative R&D agreements, mostly aiming to transfer technologies from public laboratories to private firms.
- **Intellectual property rights (IPRs)** comprise legal considerations granted to inventors. IPRs give them protection over their intellectual creations. As the technology transfer involves a transaction of an object from the transferor to the transferee (Jaffe and Lerner, 2006), a fundamental requisite is determining the ownership of the new technology. The IPRs are often granted to the inventor for a finite period by a state body, protecting her from appropriability at a lower cost by other organisations. Such regulations and norms form the base of the intellectual property system (Mehlig and Eterovic, 2015). The

inventor's exclusive right to use the technology also allows her to transfer it to another organisation for further technical and commercial development.

- **Absorptive capacity** refers to the skills of an organisation for receiving, understanding, and properly using new knowledge to create a competitive advantage (Zahra and George, 2002). Absorptive capacity will be explained in detail in next sub-section 2.3.3.
- Finally, **support structures** are organisational arrangements that assist in the transfer process, such as transition intermediaries (described in sub-section 2.2.2.1). The literature has concluded that technology transfer goes beyond the transaction of physical properties' rights found in artefacts, processes and systems (Hench, 2005). In addition, it involves other intangible elements such as knowledge and experience transferred from where arise to where are applied (Zahra, 1996). For these reasons, technology transfer has been described as a complex process that requires the presence of different actors to develop and execute specific activities overcoming the barriers located in both the sender and recipient of the technology innovation (Bozeman, 2000).

Based on the RBV approach, technology transfer has been pondered as a feasible pathway to intentionally exchange valuable resources that are complementary to the recipient firm, which in turn can be difficult to access and replicate due to the IPR protection (Gans and Stern, 2003). Thus, the company lacking these strategic resources can connect with organisations possessing them through technology transfer (Das and Teng, 2000). In the context of a socio-technical transition, the incumbent firms –which have a high market share but often an outdated technology base– can be motivated to connect with socio-technical niches –which in turn possess promising new technologies but few resources to scale these up– (Hockerts and Wustenhagen, 2010).

Nevertheless, achieving a technology transfer agreement between both parties is a difficult matter. For this reason, the literature has proposed that they need to cultivate capabilities to diffuse and adopt technology innovation. These are respectively framed in absorptive and desorptive capacities. Consequently, the following sub-section 2.3.3 will cover in the first instance absorptive capacity. Followed by the definition of desorptive capacity, in sub-section 2.3.4.

2.3.3 Absorptive capacity

Based on the RBV approach, firms can modify their commercial offering by acquiring new resources to address the pressure coming from the external environment (Wernerfelt, 1984). In the case of the energy transition, UK incumbent firms might proceed with this option by integrating technology innovation capable of substituting fossil fuels operations. This will allow incumbents to achieve the UK Government's goal of net zero carbon emissions by 2050. Additionally, they can potentially obtain competitive advantages leading to sustainable performance over time based on cleaner technologies. As it was mentioned in sub-section 2.1.1, technology innovation is a source of distinctive resources that can meet both goals.

To capture these resources, the firm requires capabilities of technology adoption. Fitting in this mould, absorptive capacity (Cohen and Levinthal, 1990; Lane et al., 2006; Zahra and George, 2002) is considered a relevant conceptualisation to frame how the firm captures, integrates and exploits external innovation into its technical knowledge base. It has been defined as a learning process in which the firm recognises the value of external information, assimilates it and applies it to commercial ends (Cohen and Levinthal, 1990). This notion is based on the cognitive structure of the firm, which reflects that accumulated prior knowledge increases the capacity to aggregate new information into the organisational memory (Jansen et al., 2005).

Cohen and Levinthal (1989) have considered that a firm's activities on R&D are central to defining the accumulation of learning in a knowledge base. This leads the organisation to integrate complementary information closer to its previous experience. For example, in developing a technological project, the company will test a few configurations through R&D activities, before finding which one performs adequately. This experience builds a base of practice and knowledge that supports the firm in integrating external technologies. In turn, this allows it to develop new products, generating the opportunity to increase profits.

Due to the linear approach of R&D mostly used to investigate this conceptualisation, the study of absorptive capacity has concentrated on corporate R&D as a proxy to measure innovation performance, nullifying the richness of this framework to analyse other types of knowledge integration (Lane et al., 2006). The literature has explained that firms differ in their ability to absorb external knowledge, meaning that companies would not benefit from external knowledge by simply being exposed to it through R&D links (King and Lakhani, 2011). This idea has brought the notion of absorptive capacity closer to being considered a strategic feature (Escribano et al., 2009), which is developed based on the specific capabilities of the firm (Vanhaverbeke et al., 2008). These capabilities can remove structural, cognitive and behavioural barriers that the external innovation presents to the firm (Lemon and Sahota, 2004).

Based on these arguments, Zahra and George (2002) have established four dimensions representing absorptive capacity whereby the firm acquires, assimilates, transforms and exploits external knowledge. They have argued that these dimensions are embedded in organisational high-level routines and processes that are combinative by nature. These confer the firm with a set of options for producing significant innovation outputs. Using this structure, Zahra and George (2002) have stated that the firm can acquire and assimilate knowledge but does not always have the skills to transform and finally exploit it for revenue generation. Consequently, the firm can detect and acquire technology innovation, but due to the lack of capabilities cannot convert it for commercial exploitation.

Based on this discovery, Zahra and George (2002) redefined absorptive capacity in a new framework. The first two dimensions (acquisition and assimilation) are “potential absorptive capacity” and the latter two dimensions (transformation and exploitation) are “realised absorptive capacity”. Both depend on social integration mechanisms to remove the structural, cognitive and behavioural barriers that the innovation process confronts within the organisation. The social integration mechanisms allow the firm to cross from potential to realised absorptive capacity, achieving commercial goals with the launch of a new product. Zahra and George (2002) have considered the previous knowledge of the firm as an activation trigger to conduct additional absorptive capacity. Still, this is mainly obtained through corporate R&D. They also considered that innovation experimentation is an important factor whereby the firm develops a past experience enabling it to absorb further innovation. This consists of exposure to new knowledge in alliance with partners to develop a new product through testing with customers. The firm depends on regimes of appropriability to protect by IPRs the novel outputs achieved through absorptive capacity at the end of this process. Finally, they suggested that absorptive capacity can be a source of competitive advantage, as Figure 2.4 presents.

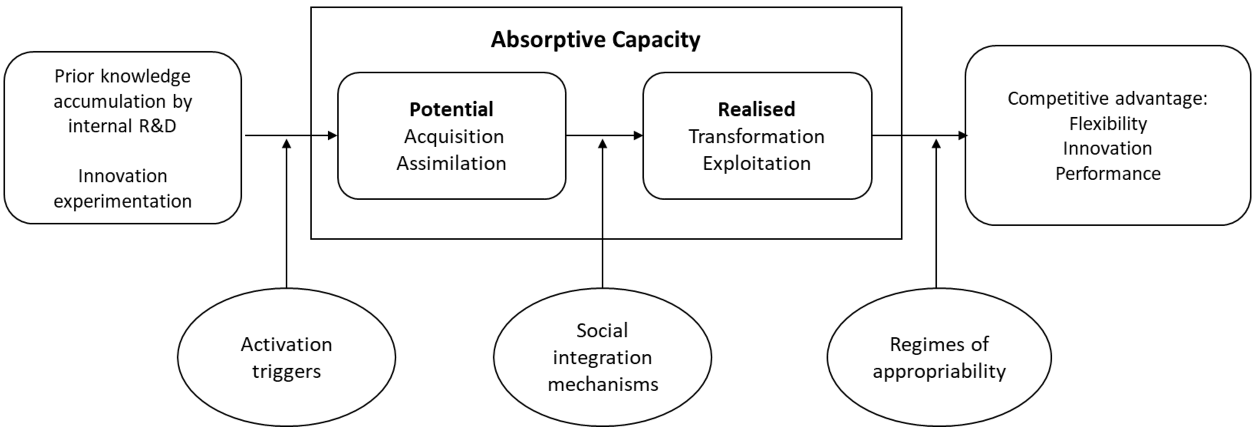

Figure 2.4 Absorptive capacity model based on Zahra and George (2002)
Source: Todorova and Durisin (2007)

Under the literature review, it is important to highlight different lines of study on the absorptive capacity that have called on returning to the original conceptualisation of Cohen and Levinthal (1989), focused on R&D as a provider of previous experience. The contributions of Lane and Lubatkin (1998) and Dyer and Singh (1998) pointed in that direction measuring R&D as the main driver to associate external with internal knowledge at the firm's level. Meanwhile, Todorova and Durisin (2007) have reconfigured the process of absorptive capacity using power relationships as a base learning. Later, the work of Fabrizio (2009), Flatten et al. (2011) and Jimenez-Barrionuevo et al. (2011) addressed absorptive capacity by examining cognitive structures found in the previous experience. Despite their differences, all conceptualisations have referred to absorptive capacity as a capability for addressing changes in the environment, assuming that is a "*high-order competence that consists of different individual capabilities building on each other to yield* *absorptive capacity and gives the firm a foundation on which to achieve a competitive advantage*" (Duchek, 2013: p. 314).

As we can appreciate, a range of studies has been dedicated to exploring the critical aspects of building a firm's absorptive capacity and linking these with innovation results (Patterson and Ambrosini, 2015). The construction of Zahra and George (2002) stands out by proposing a theoretical framework divided into dimensions that emphasise organisational capabilities. This allows the investigation of the development of absorptive capacity in business organisations (Camison and Fores, 2010). However, it is not clear what capabilities must be contained by each dimension to properly absorb external technology innovation for strategic purposes. To address that gap, this thesis will adopt the definition from Zahra and George (2002) and explore the literature to find different capabilities that can be added to each dimension of absorptive capacity (acquisition, assimilation, transformation and exploitation). This will facilitate us to investigate how transition intermediaries enhance these capabilities in incumbent firms looking to adopt new technologies.

2.3.3.1 Acquisition

The first dimension of acquisition relates to the possibility of obtaining new resources in the form of technological knowledge that will serve the firm to develop an innovation output (Muzzi and Albertini, 2015; Negassi, 2004; Zobel, 2017). An important aspect that the firm must consider for acquiring new technologies is the relatedness that these can have with the recipient's knowledge base (Flor and Oltra, 2004; Watts and Hamilton, 2011). This allows the firm to associate novel technologies with business operations more rapidly, reducing risks and uncertainties (Desyllas and Hughes, 2010). Therefore, the first capability needed to acquire new technologies is the ability to identify technology opportunities related to the existing operations and production means of the recipient firm (Negassi, 2004). This capability makes it possible to translate external technology knowledge into the internal development of new products and services (Flor and Oltra, 2004).

Nonetheless, such an approach motivates the firm to focus on acquiring technologies that reinforce the existing business model. As a result, the innovation is mostly incremental and stabilising even further the socio-technical regime. To avoid these results, the firm must seek alternative sources for radical innovation through non-industrial partners, in specific the public science sector (Fabrizio, 2009). Firms can access this knowledge source by integrating networks connecting them with the latest scientific and technological development from R&D organisations (Muller-Seitz, 2012; Rothaermel and Thursby, 2005; Sikimic et al., 2016). For such reasons, the skills to connect with the R&D community is the second capability considered by the literature review in the dimension of acquisition. This consists of the capability to connect and dialogue with outside R&D sources (particularly academic scientists), concentrating on developing risk-taking innovation (Negassi, 2004).

In summary, the review identifies two critical capabilities in the dimension of acquisition. First, the capability to identify new technology opportunities; and second, the capability to connect with the R&D community.

2.3.3.2 Assimilation

The second dimension of assimilation refers to the possibility of understanding the acquired technologies based on the firm's pre-existing knowledge. As the company digests external information that is similar to previous experience, it has a better opportunity to complement the external technologies into current operations achieving the combination of elements to produce a technology innovation (Dedrick and Kraemer, 2015). However, external knowledge rarely appears fully formed in such a form to be immediately adopted by incumbent firms. Therefore, the assimilation of knowledge is modest because the firm cannot understand the new technology using its previous experience as a lens (Dedrick and Kraemer, 2015; Desyllas and Hughes, 2010; Garcia-Romero et al., 2017; Sears, 2017). To mitigate this issue, the firm can get involved through an intense process of non-linear innovation with the support of an R&D facility (Muzzi and Albertini, 2015). This option will assess the assimilation of the new technology into the company's core business activities (Lim, 2004; Veugelers, 1997). In such a case, the goal is to provide stability in the new product's development and reduce the risk in the translation process from invention to innovation (Roper and Love, 2006). Therefore, the capability of de-risking external technologies for the purpose of integrating these into the firm's operation is critical in the dimension of assimilation.

Moreover, a business organisation can visualise the uncertainty of non-linear innovation by assimilating the flow of information in a process of reformulating corporative objectives through roadmapping (Muller-Seitz, 2012). This is the second critical skill in assimilation, consisting of the capability to create technological roadmaps. This serves to keep up to date with the latest developments in the industry, which leads to new interpretations of the technological landscape (Muller-Seitz, 2012).

Overall, the review identifies two critical capabilities in the dimension of assimilation. First, the capability to de-risk external technologies. Second, the capability to create technological roadmaps.

2.3.3.3 *Transformation*

The third dimension of transformation consists of combining external technologies with the internal knowledge base of the firm to produce an innovative output that can be proven truly different in the market. For this reason, the firm attempts to combine external technologies, which have a novelty component with internal assets through a learning process (Wang and Li-Ying, 2014). Thanks to this procedure, it is assumed that the innovation outcomes evolve from incremental to radical because the firm performs entrepreneurial experiments seeking to demonstrate in the market the combination of internal and external knowledge.

However, the literature suggests a lack of organisational capabilities to perform these activities (Dedrick and Kraemer, 2015; Haro-Dominguez et al., 2007; Lim, 2004; Watts and Hamilton, 2011). For this reason, the development of new products and services is preferable to happen according to the existing infrastructure and knowledge market of the recipient firm (Desyllas and Hughes, 2010; Garcia-Romero et al., 2017; Lim, 2004). Therefore, the firm transforms the external knowledge by overlapping the acquired technology with the corporate's internal operation (Ritala and Hurmelinna-Laukkanen, 2013; Sikimic et al., 2016). This helps to unpack the realised absorptive capacity of the organisation (Lawson et al., 2015). In this case, the literature review suggests that the capability to overlap the acquired technology with the firm's internal knowledge is the first relevant skill in the transformation dimension.

Additionally, the knowledge bases between the sender and the receiver in the technology transfer are relatively close to each other, making the threat of imitation high (Ritala and Hurmelinna-Laukkanen, 2013). If technological knowledge provides sufficient novelty with the possibility to disrupt competitors, it is considered a competitive advantage. Thus, technology transfer partners may try to imitate the created technology to obtain similar benefits. Under this context, sharing sensitive information that potentially can damage an internal competitive advantage is regarded as a high capability to conduct innovation (Hurmelinna-Laukkanen and Puumalainen, 2007). Hence, partners should respect the intellectual property that is coming into the organisation, giving credit to the right assignee and not appropriating ideas for imitation. Consequently, the capability to separate knowledge sources and assign them to the proper assignee is the second capability in the dimension of transformation.

In summary, the literature review identifies two critical capabilities in the dimension of transformation. First, the capability to overlap the technology acquired with the firm's internal knowledge. Second, the capability to separate knowledge sources between sender and receiver.

2.3.3.4 Exploitation

Finally, the fourth dimension of exploitation refers to the firm absorbing technologies with the purpose of producing a commercial result that generates profits (Dedrick and Kraemer, 2015). To proceed with this route, the firm might take a strategy for commercial experiments aiming to reach early adopters who can validate the technology innovation (Flor and Oltra, 2004; Kharbanda and Jain, 1997; Lawson et al., 2015; Newey, 2010).

In this dimension, it is important to launch the innovation rapidly to the market (Mahmood and Mubarik, 2020). This provides certainties to the firm about the market preferences for the new product or service and allows it to reach cost advantages quickly (Wang and Li-Ying, 2014). As a result, the single skill detected for exploitation is the capability to speed to market.

The following Table 2.6 summarises the high-level capabilities assigned by the literature review to each dimension of absorptive capacity following the framework proposed by Zahra and George (2002).

Table 2.6 Summary of high-level capabilities on absorptive capacity's dimensions

Dimension	Specific capability found in the literature	Definition of capability
Acquisition	**Capability to identify technology opportunities** Dedrick and Kraemer (2015); Desyllas and Hughes (2010); Flor and Oltra (2004); Haro-Dominguez et al. (2007); Negassi (2004); Veugelers (1997); Zobel (2017)	*"The set of production possibilities for translating research resources into new production"*. Flor and Oltra (2004: p. 138)
	Capability to connect with the R&D community Fabrizio (2009); Negassi (2004)	*"The ability of firms to use connections and collaborations with university and other public sector scientists to gain advantage in accessing and developing public sector science"*. Fabrizio (2009: p. 256)
Assimilation	**Capability to de-risk external technologies** Garcia-Romero et al. (2017); Vanhaverbeke et al. (2008); Veugelers (1997)	*"Own in-house R&D activities are often indicated as reducing some of the inefficiencies and problems associated with external acquisition, if only it allows to modify and improve external acquisition"*. Veugelers (1997: p. 304)
	Capability to create technological roadmaps Muller-Seitz (2012)	*"Roadmapping serves to keep constantly up-to-date with the latest developments in the industry. (…) This might lead in turn to new interpretations of the technological landscape"*. Muller-Seitz (2012: p. 94)
Transformation	**Capability to overlap the technology acquired with the firm's internal knowledge** Lawson et al. (2015); Ritala and Hurmelinna-Laukkanen, 2013; Sikimic et al. (2016); Watts and Hamilton (2011)	*"The firm will need overlapping (internal) knowledge to absorb the technical knowledge developed (externally) in order to realize the technology's potential, discover the complementarities of their resources"*. Lawson et al. (2015: p. 766)
	Capability to separate knowledge sources between sender and receiver Ritala and Hurmelinna-Laukkanen (2013)	*"Because the possibility of relatively fast imitation exists, various types of knowledge protection mechanisms are even more required"*. Ritala and Hurmelinna-Laukkanen (2013: p. 158)
Exploitation	**Capability to speed to market** Wang and Li-Ying (2014)	*"The sooner a firm can launch a new product, the more certainty it will have in forecasting customer preferences and extending a product's sales life, creating an opportunity to charge a premium price, and allowing development and manufacturing to reach cost advantages quickly"*. Wang and Li-Ying (2014: p. 45)

Concluded the identification of the capabilities of absorptive capacity's dimensions, this thesis will now conduct a similar work on desorptive capacity in the next sub-section 2.3.4. This will provide the opportunity to explore the skills necessary to diffuse technology innovation from the niche's standpoint.

2.3.4 Desorptive Capacity

The concept of desorptive capacity derives from the natural science that considers desorption as the process in chemical organisms to repel components from nature, opposite to adsorbate which consists of the capacity to contain chemical elements (Zytner, 1992). Innovation management has borrowed this idea to propose desorptive capacity as the organisational skill to outwardly transfer the internal intellectual creations to a recipient firm that can provide more efficient commercial exploitation compared to the inventor (Lichtenthaler and Lichtenthaler, 2009).

Lichtenthaler and Lichtenthaler (2010) have described desorptive capacity as a complement to absorptive capacity. They have argued that firms with R&D departments can supplement their internal knowledge by absorbing external ideas. This improves the process of invention and the subsequent technological result can be transferred to external partners. Thus, the technology transfer of internal knowledge is considered a form of commercial exploitation that can provide additional income. Companies like Procter & Gamble, IBM and Lucent Technologies exemplify the positive results of such a strategy, having obtained substantial revenues from licensing (Lichtenthaler and Lichtenthaler, 2009). For these reasons, it has been argued that desorptive capacity can be framed within the broad concept of open innovation (Lichtenthaler and Lichtenthaler, 2010). A paradigm that assumes firms can use external as well as internal ideas when the firm looks to advance in their technology development (Chesbrough, 2006).

Desorptive capacity consists of two main dimensions (Lichtenthaler and Lichtenthaler, 2009): identify transfer opportunities; and facilitate the reception of knowledge in the recipient. For practical reasons to presenting these terms, Ziegler et al. (2013) abbreviated them to simply "identification" and "transfer". This thesis will follow that suggestion. Both can be grouped into two clusters: before (planning and intelligence) and after (negotiation, realisation and control) pursuing the specific opportunity for transferring the technology innovation (Bauer et al., 2018). The first does not necessarily involve external collaboration –so it is exclusively internal– and the second requires a partner who will receive and apply the new knowledge. According to Bauer et al. (2018), these clusters can be also referred to as potential and realised desorptive capacities.

Desorptive capacity is influenced by antecedents that configure a previous experience. The first of these preconditions demands a significant patent portfolio that increases the opportunities for the organisation to outwardly transfer technology and thus learn about out-licensing (Bianchi and Lejarraga, 2016). Desorptive capacity literature has proposed that for crossing from potential to realised capacity is necessary a large patent portfolio developed by the firm. This allows the organisation to have greater opportunities to repeat licensing agreements until it learns the process of diffusing innovation (Bianchi and Lejarraga, 2016). The second antecedent involves a prior experience of the organisation in transferring technology innovation to external partners (Lichtenthaler and Lichtenthaler, 2010). Previous experience supports learning from failure (Chiesa and Frattini, 2011), which can be critical to enhance possibilities for the firm to conduct further licensing technology (Lichtenthaler, 2011). Accordingly, the experience of the firm is enhanced by success, reinforcing technology trajectories through similar application fields. This explains desorptive capacity as path-dependent, similar to absorptive capacity (Lichtenthaler and Lichtenthaler, 2010).

As can be seen, desorptive capacity is tightly related to the concept of technology transfer (sub-section 2.3.2). Lichtenthaler and Lichtenthaler (2010) have asserted that mastering the skills to effectively send the innovation to a suitable recipient for adoption creates specific management heuristics, such as technology transfer best practices and routines. Consequently, this helps the firm to profit from investment in organisational mechanisms that foster outward technology transfer activity and by repetition the firm can reduce transactional costs. This model of desorptive capacity developed by Lichtenthaler and Lichtenthaler (2009 and 2010) is shown in Figure 2.5.

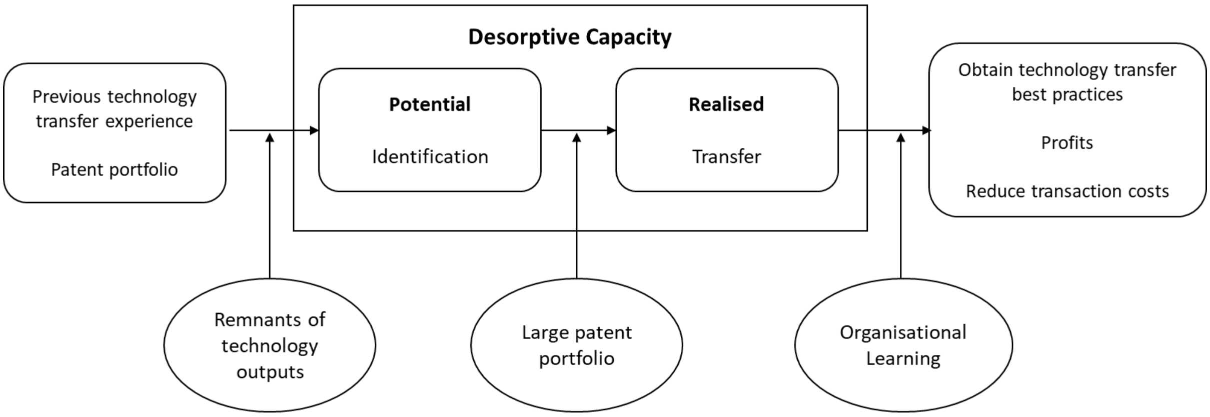

Figure 2.5 Desorptive capacity model
Source: Based on Lichtenthaler and Lichtenthaler (2009 and 2010)

Another important similarity that desorptive capacity shares with absorptive capacity is the lack of theoretical construction proposing specific capabilities in each dimension. To address such a gap, this thesis will adopt a similar approach as sub-section 2.3.3. Based on the foundational definition of desorptive capacity from Lichtenthaler and Lichtenthaler (2010), the literature review will search for capabilities that the organisation should possess to unfold the desorptive capacity's dimensions of identification and transfer. This will enable us to examine how transition intermediaries cultivate these capabilities in socio-technical niches intending to diffuse new technologies.

2.3.4.1 Identification

This first dimension of identification relates to the entrepreneurial attempts to disrupt the equilibrium by producing innovation that can be diffused to external actors. In desorptive capacity, the niche seeks to diffuse innovation outputs to an external partner (Bauer et al., 2018; Chiesa and Frattini, 2011; Lichtenthaler, 2013; Ziegler et al., 2013). In this process, the socio-technical niche accumulates experience that improves future attempts to generate purposeful innovation. At the same time, this serves as a basis for identifying suitable partners for transferring innovation results (Lichtenthaler, 2011; Sikimic et al., 2016).

Under these efforts, the socio-technical niche establishes a closer tie with potential recipient firms (Angue et al., 2014; Lichtenthaler, 2011; Neshati and Daim, 2017) that serves to exchange information for reducing uncertainties in the innovation process. As the network consolidates the development of new technologies into possible trajectories, the collaborative process of innovation advances complementing the knowledge base between the sender and recipient (Lichtenthaler, 2013; Walter, 2012; Ziegler et al., 2013). In this case, both ends require a similarity to link the new technology. Therefore, the niche's skill to understand the technology base in the recipient firm is considered the first capability for identification (Lichtenthaler, 2013).

Centred on this capability, the niche can build a strategic alignment with the recipient's absorptive capability (Ziegler et al., 2013). This understanding of the technology base in the recipient provides learning to the niche that defines the function of the technology innovation and detects other recipient firms interested in commercialising it (Bianchi et al 2014; Lichtenthaler, 2011). The competence to inform how the technology functionality satisfies a recipient's need enables it to find partners and reduces the cost of the transaction (Bianchi et al., 2014). Consequently, the skill of technology marketing is the second capability related to the identification dimension.

In summary, the literature review has detected two critical capabilities in the dimension of identification. The first is the capability to understand the technology base in the recipient, and the second is technology marketing.

2.3.4.2 *Transfer*

The second dimension of transfer calls for an active participation from the socio-technical niches to enable the application in the recipient firm. The approach can be achieved through demonstration of the technology innovation and its later insertion in the recipient's routines. This idea can be linked with the work of Smith and Raven (2012) in the transition literature. This explains how niches remove their temporary shield to develop new technologies, then nurture the development of path-breaking innovation, and finally niches are empowered to permeate the regime with either incremental or radical innovation.

To proceed in this route and become a feasible technology option, niches must consider important assessments in innovation development. In the first instance, the socio-technical niche depends on the degree of novelty that the technology presents to the recipient firm[6]. A radical innovation will require more intervention from the socio-technical niches to facilitate the adoption (Lichtenthaler, 2013; Robertson et al., 2012; Wang et al., 2013). Thus, in addition to present an explicit technology, it is necessary to transmit implicit knowledge that allows the recipient firm to run the innovation (Ziegler et al., 2013). This includes expert assistance for specific training and demonstration (Wang et al., 2013). Thence, the technology's source can propose the reconfiguration of new processes to fully integrate the new technology in the recipient firm (Bianchi et al., 2014). This action should reduce barriers that recipient firms might face for abandoning the dominant design due to the learning cost of the technological change. Therefore, the first capability that socio-technical niches must cultivate is the transformation of pre-existing processes to favour the adoption of the technology innovation (Robertson et al., 2012).

Another action suggested to carry out is related to demonstrating new technology. Specifically, this should generate a preliminary understanding in the recipient firm of the technology innovation by showing an initial device that can be used (Wang et al., 2013). The literature review has proposed that the capability to manufacture prototypes enhances this understanding in the recipient. Prototypes enable market testing and appropriation of the technology's application (Bianchi et al., 2014). Thus, it is a very important element to reduce resistance in the adopter of the new technology.

Overall, the literature review has detected two critical capabilities in the dimension of transfer. The first is the capability to transform pre-existing processes, and the second is the capability to manufacture prototypes of the new technology.

The following Table 2.7 summarises the high-level capabilities assigned to each dimension of desorptive capacity according to the definition from Lichtenthaler and Lichtenthaler (2010).

[6] The issue of incremental and radical innovation was discussed in Section 2.1.

Table 2.7 Summary of high-level capabilities on desorptive capacity's dimensions

Dimension	Specific capability found in the literature	Definition of capability
Identification	**Capability to understand the technology base in the recipient** Lichtenthaler (2013); Ziegler et al. (2013)	"*The need for sufficient technological and market knowledge in the specific fields to successfully link two firms in the technology markets*". Lichtenthaler (2013: p. 148)
	Capability for technology marketing Bianchi et al. (2014); Neshati and Daim (2017)	"*Market knowledge informs how the technology functionality satisfy customer needs, and what value the customers place on satisfying those needs*". Bianchi et al. (2014: p. 153)
Transfer	**Capability to transform pre-existing processes** Robertson et al. (2012); Wang et al. (2013); Ziegler et al. (2013)	"*New products frequently require changes in processes when they involve techniques unfamiliar to the firm*". Robertson et al. (2012: p. 823)
	Capability to manufacture prototypes Bianchi et al. (2014)	"*The creation of prototypes and earlier market testing are experiential practices of successful product development […] and offer potential licensees' proof of technology*". Bianchi et al. (2014: p. 153 & p. 154).

2.3.5 Main critiques to Absorptive and Desorptive Capacities

The RBV approach has assumed that firms are profit-search entities directed by rational managers operating towards a predictable equilibrium (Bromiley and Papenhausen, 2003). It considers that information about the value of future resources is equally distributed among actors depending on prior trajectories the industry has used to build competitive advantage (Kraaijenbrink et al., 2010). Therefore, firms in the same sector pursue identical resources from similar sources. This presents RBV as a reductionist standpoint viewing firms as bundles of resources.

Furthermore, under the complexity of technology transfer, RBV tends to discard holistic approaches that connect incumbent firms needing technological resources with niches capable of creating these. Moreover, RBV has paid little attention to the variety of intermediaries promoting such a link through learning and feedback functions. Although absorptive and desorptive capacities are considered frameworks deriving from the RBV theory, they have made scarce use of the capabilities approach to investigate how the relationship between innovation producer (i.e., niche) and adopter (i.e., incumbents) can be achieved. Instead, both frameworks have made arguments that the learning of diffusing and adopting knowledge is related to the firm's previous experience constructed by internal R&D.

This option demands significant organisational resources, such as scientists employed by the firm, laboratories and equipment, a patent portfolio generated from R&D, and investment dedicated to new projects (Lenart, 2014). These factors establish an important limitation to the organisational capacity for diffusing and absorbing technology innovation, imposing costly and difficult to manage pre-conditions (Van den Bosch et al., 1999). Part of these arguments has been used to explain the difficulties that both ends of the technology transfer (incumbent firms and socio-technical niches) have in developing skills for diffusion and adopting technological innovation (Hill and Rothaermel, 2003).

In the case of absorptive capacity, this approach does not fully reflect the process of knowledge flow and the skills to integrate it into the firm. Instead, the stream of research has taken this construct for granted, with effects on the validity of studies (Lane et al., 2006). Replying to these constraints, the RBV literature has proposed that absorptive capacity can be a set of high-level skills that influence the firm's performance by acquiring new knowledge and effectively exploiting it (Zahra and George, 2002). Nevertheless, this school of thought has developed a limited understanding of the specific capabilities enabling the inflow and integration of knowledge (Zobel, 2017). Few studies have broken absorptive capacity down into multiple components and investigated these in terms of underlying capabilities (Volberda et al., 2010). Therefore, the literature has a restricted understanding of how such capabilities can be enhanced by the action of technology innovation system actors, such as transition intermediaries. Possibly, this collaboration can enable the adoption of critical resources in the form of technology innovation and update the practices in industrial sectors characterised by institutional lock-in (Unruh, 2002).

In terms of desorptive capacity, this has been considered a complementary organisational function to absorptive capacity (Lichtenthaler and Lichtenthaler, 2009). As the firm has developed inventive capacity due to the integration of external knowledge, it has created technology outputs that are preferable of being commercialised by external partners (Lichtenthaler, 2011). Under such an assumption, the desorptive capacity body of literature has constrained its study to the technology transfer strategy in large companies. These have a large number of resources allowing them to absorb external knowledge and convert it into a new technology under an open innovation paradigm (Lichtenthaler and Lichtenthaler, 2010). This standpoint has framed desorptive capacity as part of the firm's strategic goals to reduce transactional costs in technology markets as a result of learning. But it has remained silent about how smaller organisations, like those allocated in socio-technical niches with limited resources, build capabilities for outwardly transferring technology innovation. Scholars have attempted to investigate this issue with inconclusive results and made further calls to explore desorptive capacity as a stand-alone organisational skill. Possibly, this can be shaped through the development of capabilities (Robertson et al., 2012) and as a result affecting the firm performance in open innovation (Ahn et al., 2016).

About the general issue of developing capabilities in the technology transfer. RBV has framed this process as a bottom-up activity, in which one organisation act as the technology source and another as the recipient firm (Das and Teng, 2000). Thus, the technology resources flow in one direction. Upon these conditions, the recipient needs sufficient absorptive capacity, and the source requires desorptive capacity for the technology transfer to work. This has been an issue that the RBV literature has solved by using high-technology sectors in which resources are flexible, and the organisational capabilities seem naturally inherited by actors (Lichtenthaler and Lichtenthaler, 2010). Attempts to replicate such models in stagnant industrial sectors, like the energy supply sector, have been an exception. In less dynamic contexts, core resources and capabilities are rigid and hence much more difficult to mobilise (Matthyssens et al., 2005). Thus, the spontaneous development of technology transfer capabilities for diffusing and adopting new knowledge is rare in sectors like the energy supply.

Consequently, this thesis argues there is a need to improve the understanding of how capabilities are developed in rigid industrial sectors facing a socio-technical transition. Absorptive and desorptive capacities literature have significant conceptual backgrounds by assigning dimensions that can broadly depict their operationalisation. Nevertheless, these constructions lack the depth for understanding what capabilities are needed to deploy diffusion and adoption of technology innovation. As outlined in Section 1.3, this thesis seeks to address these gaps by investigating the influences that transition intermediaries play on the cultivation of both groups of capabilities, when a crucial industrial sector faces the urgency of a socio-technical transition.

2.4 Chapter summary

The literature review has demonstrated that both TIS and MLP have paid insufficient attention to the collaboration links that incumbent firms and socio-technical niches can build with the support of transition intermediaries to promote technology innovation during socio-technical transitions. To delineate such collaboration, additional bodies of literature are necessary.

The review has suggested that RBV is a feasible approach that can provide the theoretical elements to analyse the organisational change that socio-technical niches and incumbent firms must perform to achieve collaboration. In the case of socio-technical niches, the literature points to developing desorptive capacity; whilst incumbent firms require absorptive capacity. Both can enhance the skills for transferring resources from socio-technical niches to incumbent firms, promoting technology innovation in a complementary relationship. This can produce a sustainable future in an industrial sector difficult to modify, such as the UK energy supply sector.

The literature has considered both absorptive and desorptive capacities as dynamics by nature, but with important theoretical lagoons that constrain their application in socio-technical transitions. The most relevant is the lack of understanding of how specific capabilities for diffusing and adopting technology innovation can be used for analysis.

Consequently, there is a pressing need to integrate the concepts of RBV into the TIS and MLP approaches to explain how technology innovation is produced in collaboration during the turbulent period of socio-technical transitions. The combination of theories will support the examination of functions that transition intermediaries deploy to cultivate capabilities in both desorptive and absorptive capacities.

Taking these factors into account, this thesis now moves to Chapter 3 to introduce the conceptual framework this research adopts to address the main research questions proposed in the Introduction Chapter (pp. 3-4).

3 Conceptual Framework

This chapter presents the conceptual framework to be used for studying how transition intermediaries support the development of absorptive and desorptive capacities in the UK energy supply industry. The framework will integrate the theoretical concepts from the Technology Innovation System (sub-section 2.2.2), Multi-level Perspective (sub-section 2.2.3) and the Resource-Based View of the Firm (Section 2.3) to proceed in the investigation.

A conceptual framework explains the key factors, constructs or variables to be studied, and the presumed relationship among them (Miles and Huberman, 1994). Scholars have proposed that conceptual frameworks can be built from a range theories, with each playing an integral role in tentatively presenting relationships between theoretical concepts. These links are investigated through the analysis of data, with the conceptual framework providing interpretations of social reality (Jabareen, 2009). For this reason, the conceptual framework helps to undertake analysis by using elements that deconstruct a specific phenomenon (Maxwell, 2005). Therefore, the conceptual framework can guide the structure of the empirical investigation and support the process of making sense of the subsequent empirical data by understanding what various aspects are involved and how they might be related to each other (Robson and McCartan, 2015).

Sub-section 2.3.5 has underlined the incomplete understanding of the organisational capabilities contained in the dimensions of absorptive and desorptive capacities. Moreover, the literature has not paid sufficient attention to exploring how such capabilities can flourish during a socio-technical transition in sectors characterised by an apparent lock-in, such as the UK energy supply industry. To address these gaps, this investigation takes the initial approach based on TIS, which brings actors together to promote technological innovation through functions (Bergek et al., 2008; Hekkert et al., 2007). This is consistent with the idea highlighted in sub-section 2.2.2 pointing out that the generation of technology innovation is the result of a collaborative effort from a variety of systemic actors who provide inter-related support (Bergek et al., 2008). By taking this standpoint, transition intermediaries are positioned at the heart of the conceptual framework. Specifically, intermediary functions (Kivimaa et al., 2019a) can deal with complex issues of developing technology innovation by facilitating links of collaboration, as sub-section 2.2.2.2 has discussed.

Through these links established by transition intermediaries, actors can exchange technological resources to address sustainability goals. The MLP (sub-section 2.2.3) offers a conceptualisation that describes the patterns of actors located in different levels, during a socio-technical transition. Specifically, MLP proposes that socio-technical niches can produce the innovation necessary to amend the unsustainable practices in the regime (Schot and Geels, 2008). The MLP explains that the technology innovation is usually not fully formed and incumbent firms have scarce flexibility to continue its development due to strategic decisions oriented to operational efficiency (Smink et al., 2015). To deal with this issue, sub-section 2.3.1.1 argued that both actors must learn capabilities to manage a possible relationship in which niches will transfer new technologies to incumbents, according to the RBV school of thought (Barney et al., 2001).

The purpose of building a conceptual framework is to deepen the understanding of how these capabilities can be developed by the action of transition intermediaries. The application of the conceptual framework aims to improve the comprehension of the following key issues:

- The mechanisms that transition intermediaries deploy for enhancing capabilities for absorbing and desorbing new technologies. Notwithstanding, this thesis focuses on examining such a phenomenon in the UK energy supply sector, the conceptual framework could have value for other industrial sectors facing a socio-technical transition.
- The organisational barriers within the actors of the technology transfer process (i.e., incumbents and niches) in the UK energy supply sector that prevent employing such capabilities to the extent required by the net zero transition.
- The particular functions that intermediaries unfold to enhance capabilities for diffusing and adopting technology innovation during a socio-technical transition.

Figure 3.1 illustrates the visual representation of the conceptual framework. This starts with the assumption that technology innovation moves from bottom to top, as was explained in sub-section 2.2.3. In this configuration, niches produce technological innovation and diffuse it to incumbent firms, portrayed as the main adopters. Accordingly, the conceptual framework combines on one end the dimensions of absorptive capacity (Zahra and George, 2002) in incumbent firms (covered in sub-section 2.3.3) and on the other end desorptive capacities (Lichtenthaler and Lichtenthaler, 2010) in socio-technical niches (defined in sub-section 2.3.4). Each dimension has been assigned with specific capabilities found in the literature review (see Table 2.6 for absorptive capacity, and Table 2.7 for desorptive capacity). Mediating between both, the conceptual framework positions the transition intermediary functions (sub-section 2.2.2.2). This approach will help to unveil the mechanisms that these functions deploy to cultivate capabilities for diffusing and adopting low-carbon technologies in the UK energy supply industry. Such mechanisms are tentatively drawn with arrows in Figure 3.1, illustrating the possibility that intermediary functions can influence the capabilities to diffuse and adopt technology innovation at both ends. The research will establish with more precision these links in the analysis of Chapters 5 and 6.

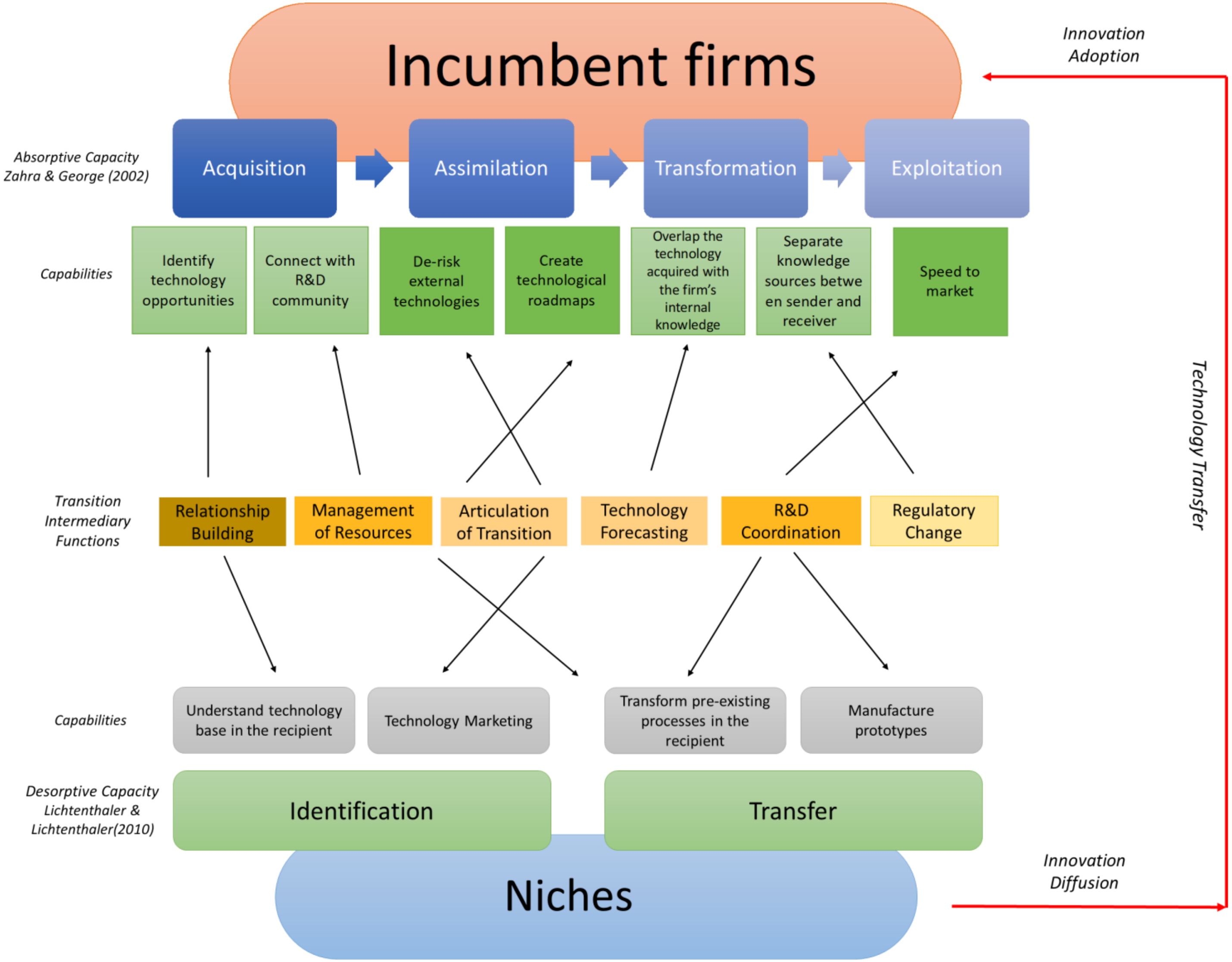

Figure 3.1 Conceptual framework

The following Section 3.1 will unpack the conceptual framework by defining the core components and how these fit together. Later, Section 3.2 presents the theoretical development of the conceptual framework, elaborated for covering the critical gaps detected in the literature review made to TIS, MLP and RBV. Finally, Section 3.3 summarises the key steps implemented for building the conceptual framework.

3.1 Core components of the conceptual framework

The conceptual framework is formed via the synthesis of three main theoretical strands. The first comes from the RBV literature, including absorptive (Zahra and George, 2002) and desorptive capacities (Lichtenthaler and Lichtenthaler, 2010), which are assigned to both ends of the technology transfer process. The second derives from the TIS literature that contains the transition intermediary functions (defined in sub-section 2.2.2.2) as the central component capable of influencing the enhancement of specific skills for absorbing and desorbing technology innovation. The third comes from the MLP, which has presented the difficulties that transition actors have for collaborating (Geels, 2002). Under this approach, intermediaries have been portrayed as critical interveners that can foster the relationship between niches and incumbents (Kivimaa et al., 2019a). The following key points will unpack these three elements, their components and the justification to be used in the conceptual framework.

First, the absorptive and desorptive capacities were selected as a double theoretical base that can explore how niches diffuse and incumbents adopt technology innovation. Both are feasible constructions containing dimensions to explain how innovation inputs are converted into outputs. Either way to improve their competitive position by creating new products, as absorptive capacity has taught us; or by fostering the organisational invention capacity, as desorptive capacity has indicated us.

Nevertheless, as was discussed in Section 2.3, both conceptualisations lack the specific organisational capabilities to deploy in their respective dimensions. This gap was addressed by proposing a group of high-level capabilities deriving from the literature review in sub-sections 2.3.3 for absorptive capacity and 2.3.4 for desorptive capacity. These are important building blocks because they provide a clear structure that identifies individual capabilities in each dimension. This will allow the conceptual framework to explore the influence that external actors –such as transition intermediaries– play in developing both absorptive and desorptive capacities.

This option was chosen because it can guide the investigation to collect and analyse qualitative data. For example, concerning the dimension of acquisition, the inquiries can cover the capabilities assigned, asking to participants how the organisation identify technology opportunities, as one of the capabilities detected by the literature review and summarised in Table 2.6. Later, with the information collected, the analysis of this capability can be conducted by the researcher.

This approach offers the opportunity to investigate the different dimensions of absorptive and desorptive capacities beyond the traditional proxy of prior R&D, addressing the critique formulated in sub-section 2.3.5 by Lane et al. (2006). In this case, the conceptual framework will investigate the mechanisms for enabling capabilities and how these can emerge through the dynamics of a TIS network via the intervention of transition intermediaries. Additionally, it can be argued that by putting aside the previous R&D activities of the firm, the framework appropriately considers the rigid context of the UK energy supply sector where utility companies perform scarce scientific research and technology development[7].

Thus, it will offer higher chances to cover the richness of absorptive and desorptive capacities and help to open the black box of both constructions. This will contribute dynamically to understanding how capabilities are generated for diffusing and adopting technology innovation. This replies to the calls made by Lane et al. (2006) and Lichtenthaler and Lichtenthaler (2010), suggesting to further investigate the development of capabilities respectively in absorptive and desorptive capacities.

Second, the transition intermediary functions were selected as they are capable of opening up spaces for new technologies by aligning multiple actors behind them. By allocating these functions in the conceptual framework, we could understand the mechanisms that middle organisations implement among actors engaged in diffusing and adopting technology

[7] This low R&D investment in incumbent firms was discussed in sub-section 1.1.4 of the Introduction Chapter.

innovation for sustainability goals. This is consistent with the definition provided by Kivimaa et al. (2019a) about the role of transition intermediaries as a body of actors involved in profound reconfiguration processes, overcoming systemic failures of technological development that generate momentum for socio-technical change. Sub-section 2.2.2.1 has pointed in this direction suggesting that transition intermediaries have a great influence on the coordination of TIS actors conducting the complex activities of technology transfer between socio-technical niches and incumbent firms.

The third and final theoretical strand includes the MLP approach (Geels, 2002). This has conceptualised that socio-technical niches and incumbent firms have extreme difficulties to collaborate and exchange resources. To theoretically solve these issues, sub-section 2.2.3.3 has stated that transition intermediaries are key to facilitate learning processes by congregating both ends in technology innovation (Marvin and Medd, 2004). In this sense, the transition intermediary functions proposed in Table 2.5 can help to analyse the connections between both niche and incumbent actors by influencing their approaches towards new sustainable technologies.

According to these three theoretical strands, it can be argued that transition intermediary functions provide a powerful analytical component. These can contribute to understanding how by mediating between transition actors they can develop key capabilities for speeding up the diffusion and adoption of technology innovation. Consequently, the combination of these components will support establishing links in the conceptual framework. Precisely, around the means that transition intermediary functions implement to enhance capabilities to manage technology innovation in each of the absorptive and desorptive capacities dimensions.

The design of the conceptual framework will help to examine what is the current state of the specific set of capabilities, and how the intervention of transition intermediary functions overcomes the most significant barriers to developing such organisational skills. To explore these issues, the research will use the current net zero transition of the UK energy supply industry as the main empirical context. Furthermore, the conceptual framework has considered the variety of participants from the three levels of actors (incumbent firms, socio-technical niches and transition intermediaries). This will allow it to capture the richness of data from multiple standpoints and reveal the complexity of diffusing and adopting technology innovation from a mixture of TIS, MLP and RBV perspectives.

In summary, through this schematic model, the data collected can be analysed making connections between the transition intermediary's functions and the specific capabilities of absorptive and desorptive capacities. This will help to infer how the capabilities are developed by the action of transition intermediaries, addressing the main research questions.

3.2 The conceptual framework's response to critical gaps in the literature

The conceptual framework takes elements from three main bodies of the literature (TIS, MLP and RBV) to empirically investigate the network of collaboration that incumbent firms and socio-technical niches can establish with the support of transition intermediaries. In conceptual terms, the arrangement of these three perspectives can uncover how capabilities for diffusing and adopting technological innovation are inter-crossed. The critical review of the literature highlighted the lack of attention that transition frameworks have paid to management theories, such as the RBV. This has limited the exploration of collaborative bridges that transition actors can build. The present sub-section will briefly discuss the identified critiques of TIS to then link these with the wide context proposed by the MLP and RBV. These are explained in the following key points.

A recurring critique of the TIS approach relates to a perceived lack of attention to external factors (Markard and Truffer, 2008). As a consequence, this omission has generated difficulties in delineating the boundaries of the system and considering the influences of external actors on the development of technology innovation (Smith and Raven, 2012). This would make it difficult for TIS to pursue a situational approach for setting an empirical case in which intermediaries influence incumbent actors to accept or reject networks with emerging participants (Coenen, 2015). Therefore, TIS would benefit from including missing conceptual elements that can contribute to explaining how the network is configured. In this regard, the literature review has proposed that transition intermediary functions can address this issue by considering these as an extension of TIS functions (sub-section 2.2.2.2).

Importantly, intermediary functions can be implemented to explore how the bias of powerful actors can be altered (Sovacool et al., 2020). While, simultaneously, the same functions supports technology novelty emerging from niches (Bergek, 2020).

Addressing this important point, Kivimaa and Kern (2016) have suggested that new intermediary functions and processes are needed to cover these issues. Specifically, creative functions of niche support combined with destruction functions of regime destabilisation. According to Kivimaa and Kern (2016), the destruction functions have been less implemented. This shows the difficulty of eroding the position of incumbent firms towards technology innovation that might diminish their dominant position. The conceptual framework aims to cover such issues by integrating new transition intermediary functions that equally consider the position of incumbent and niche actors. These can serve as a means to identify the intervention mechanisms deployed for linking both types of actors. This approach will contribute to unveiling the dual role of intermediaries in a mutually reinforcing way among niches and incumbents. Based on this key aspect, the conceptual framework will expand our understanding of how new technologies collaborate with incumbents under the TIS approach. The previous set of ideas summarised the omissions found in the TIS literature. We will now connect these with the broader context that the MLP presents in the first instance, to later proceed with the RBV.

As was explained in sub-section 2.2.3.1, MLP has modified its perception of incumbency, proposing a wide phenomenon that presents numerous positions when faces change (Turnheim and Sovacool, 2020). Similarly, sub-section 2.2.3.2 described the open position that MLP has taken regarding the behaviour of socio-technical niches. Geels et al. (2017) suggested that niches can exploit complementary resources found in incumbent actors to test new solutions addressing persistent problems in the regime. Sub-section 2.2.3.3 discussed that transition intermediaries can build these links as bridging organisations for technology experimentation. By bringing this renewed perspective from MLP, the transition intermediary functions suggested by the TIS approach in sub-section 2.2.2.2 can be used to analyse how the exchange of technology resources occurs among this triad of MLP actors (incumbents, niches and intermediaries).

Consequently, the conceptual framework will seek to identify and describe unlocking mechanisms implemented by intermediaries whereby regime and niche actors recognise complementary resources to develop technology innovation and avoid unsustainable trajectories. This would allow us to describe the leverage unfolded by transition intermediaries to guide niches and incumbents towards collaboration and achieve a desirable sustainable future. This is possible to conceptually formulate by inserting the transition intermediary functions –elaborated as an extension of TIS functions as the intermediation literature suggested– to reduce the tensions in MLP actors (i.e., incumbents and niches). This integration of different theoretical elements in the conceptual framework can shed light on how new technologies are diffused by niches and then adopted by incumbent firms. Making an important contribution to explain these processes in the TIS and MLP approaches.

Regarding RBV, the third body of literature that the conceptual framework will use. This will be included as a broad theory that emphasises the acquisition of strategic resources in the firm to achieve a competitive position. The main critiques of RBV are related to offering a reductionist standpoint viewing firms as bundles of resources. In such a regard, the RBV has been questioned for assuming that rational managers can understand the value of future resources and accordingly pursue these (Kraaijenbrink et al., 2010). This approach has important limitations in the technological market in which the risk of novel resources makes them problematic to diffuse and adopt. Therefore, RBV has conceptual difficulties in defining the links between incumbent and niche firms when they exchange technological resources. A relationship that is even more complex to establish during the unstable conditions of a socio-technical transition.

A pathway that this thesis has proposed to address these problems in the RBV is by paying attention to the roles of intermediaries. The transition literature has assessed that these can promote links through learning and feedback mechanisms in technological development. This idea presents an alternative, under the RBV perspective, for firms to find adequate resources when they face external turbulences.

Absorptive and desorptive capacities are considered derived constructs from the RBV literature. Correspondingly, they suffer from the same general criticism made at RBV, which sees firms as bundles of assets with common procedures to modify resources. Such an idea has taken absorptive and desorptive capacities as granted constructions with a limited understanding of the underlying capabilities that enable the flow of knowledge (Volberda et al., 2010). The conceptual framework aims to address these issues by integrating a set of capabilities assigned to each dimension of both absorptive and desorptive capacities. This decision will enable us to explore in detail how capabilities are developed in rigid industrial sectors –such as the energy supply industry– facing a socio-technical transition, using elements from TIS and MLP to support this analysis.

In summary, the conceptual framework attempts to link three theoretical bodies (TIS, MLP and RBV), and apply these to the empirical case related to the transition in the UK energy supply industry. By discussing the challenges that these three literatures present, this section has considered relevant theoretical support that each of them can offer to strength the application of the conceptual framework in the specific empirical research setting. Consequently, the combination of these three fields of knowledge provides the necessary conceptual pieces to explore the collaborative efforts of incumbents, niches and intermediaries to achieve a socio-technical transition in the UK energy supply sector.

3.3 Chapter summary

The purpose of this section was to design a conceptual framework based on the theoretical assumptions drawn upon from the literature review. The conceptual framework will be used to understand how a set of capabilities can be enhanced by the mediation of transition intermediaries facilitating the exchange of technological innovation between niches and incumbents. The conceptual framework has been built through the following key steps:

i. Taking the position occupied by actors suggested by MLP (Geels, 2002), the conceptual framework has allocated socio-technical niches at the bottom as capable actors to produce technology innovation and transfer it to incumbent firms at the top of the framework.
ii. For this relationship to happen, the conceptual framework has considered that the ability to diffuse technology innovation must be contained by socio-technical niches. This was referred to as desorptive capacity by the literature (Lichtenthaler and Lichtenthaler, 2010). Whilst incumbent firms require the skill to adopt the technological innovation, called absorptive capacity (Zahra and George, 2002).

iii. According to the literature, both desorptive and absorptive capacities have dimensions by which the firm can diffuse and adopt technology innovation. The conceptual framework opens these dimensions by inserting capabilities into them, obtained from the literature review (sub-sections 2.3.3 and 2.3.4).

iv. To investigate how capabilities are developed, the conceptual framework borrows the transition intermediary functions proposed in sub-section 2.2.2.2. The conceptual framework will indicate, through the analysis of collected data, which function has a stronger influence in developing each of the specific capabilities for diffusing and adopting technology innovation. The analysis will identify the mechanisms employed by transition intermediaries to unfold their specific functions for enhancing capabilities.

The conceptual framework will be used to investigate the empirical context of the UK energy supply industry facing a socio-technical transition. However, the framework could be potentially applied to other industrial contexts confronting similar constraints during transitions. Particularly, sectors that are ruled by incumbent firms whose business operation is intrinsically linked to a dominant technological system, in which social practices are profoundly embedded and therefore difficult to modify. To break this pathway is necessary the presence of transition intermediaries, as middle organisations that promote capabilities to deal with both technical and social aspects.

This chapter has explained and justified the design for a conceptual framework. It provided a means by which theoretical constructs can be linked to support the empirical investigation and consequently assist in addressing the research questions. The next chapter turns to the research method, which will be formulated to apply the conceptual framework with a complementary modus of data collection and analysis.

4 Method

The previous Chapter 3 presented the conceptual framework this thesis will employ for identifying the role that transition intermediary functions play in developing capabilities for absorptive and desorptive capacity in the UK energy supply industry. Now, this present chapter turns the attention to introducing the method this research will employ to investigate such a phenomenon.

This study is based on a social constructionism assumption that utilises a qualitative method based on abductive reasoning. The investigation considers two main phases for data collection and analysis. First, primary data will be obtained from semi-structured interviews with relevant informants, to later use thematic analysis to search for patterns of meaning. Second, public reports will be used as secondary data to build case studies that will be used to compare the findings in the first phase.

This approach will help to reduce the concerns regarding the qualitative investigation as being too dependent on the researcher's interpretation. Such a limitation will be minimised with the comparison between primary and secondary data. Both sets of information will be obtained from three categories of samples elaborated with the support of the conceptual framework: incumbent firms, transition intermediaries and socio-technical niches. Following this procedure, the thesis will offer significant opportunities to produce results that address the main research questions.

The present chapter offers the epistemological position in Section 4.1, based on social constructionism. This is followed by the research design in Section 4.2, which employs abductive reasoning as the approach for conducting qualitative research and examining how absorptive and desorptive capacity are strengthened by the functions of transition intermediaries. Section 4.3 explains the mobilisation of the qualitative research, divided into phases of investigation for data collection and subsequent analysis of the information. To conclude with the limitation of the research method in Section 4.4.

4.1 Epistemological position

Epistemology is concerned with the nature of knowledge and learning about the world, and how it can be acquired (Ritchie et al., 2013). Importantly, it influences how researchers frame their attempts to create knowledge, examining the relationship between the researcher and what is researched (Collis and Hussey, 2009). Therefore, by looking at the relationship between subject and object, it can be explored the epistemological assumption and how it influences research design (Creswell, 2007).

Essentially, there are two main epistemological assumptions according to Easterby-Smith et al. (2012). Positivism assumes that reality exists outside of the individual mind, thus phenomena that are only observable and measurable can be validly regarded as knowledge (Collis and Hussey, 2009). On the other hand, social constructionism stems from the view that reality is not objective but is socially constructed and given meaning by people; especially through sharing experiences with others via the medium of language (Easterby-Smith et al., 2012). Social constructionism has been referred to as an interpretative method (Habermas, 1970), in which the researcher observes the different constructions and meanings that people place upon their experience (Ritchie et al., 2013).

The epistemological position of this research is consistent with the social constructionism stand, which aims to explain the development of technology innovation as a social elaboration between multiple actors. The next sub-section 4.1.1 will unpack the basic assumptions of this epistemological viewpoint.

4.1.1 Basic assumptions

This thesis analyses the factors, drivers, and mechanisms influencing the development of capabilities as a social construction to diffuse and adopt new technologies. The focus will be put on the complexities of the process by developing a multi-layered form of explanation, in which the three categories of participants (incumbent firms, transition intermediaries and socio-technical niches) are equally relevant to achieve the transfer for new technologies. This implies that the diffusion and adoption of new technology is a collaborative process in which the analysis of different participants' experiences, expressed through their opinions, can offer critical insights into these issues.

How such a complex process should be investigated within the social reality that affects it? The question can be answered from the epistemological position this research assumes, which corresponds to social constructionism. This will provide a philosophic grounding for proposing what type of understanding is feasible and deciding the appropriate scientific procedure to interpret the complexity of the social world.

Arrow et al. (2004) have considered that reality is a social construction built by a variety of participants rather than being separate within each individual. This creates a crossover of perceptions, due to the combination of symbolic formation from social actors where individuals share interpretations employing debate and particularly by cognitive learning processes (Potter, 2003). This philosophical approach leads to preferring a qualitative investigation as a research strategy that emphasises the analysis of opinions and embodies a view of social reality as a constantly shifting emergent property of individuals' creation (Bryman and Bell, 2007). This point of view can be useful to explore the configuration of norms and the leverage of resources for technology development by observing individuals as creative and informed agents actively interacting with each other (Arthur, 2010). This epistemological assumption is aligned with the social constructionism standpoint, considering individuals' experience as a source of information capable of describing the elements of change to promote profound social transformations (Easterby-Smith et al., 2012). Hence, this thesis has an intrinsic social constructionism position, which serves as a base for analysing non-linear processes at organisational levels conducing to diffuse and adopt technological innovation.

This perspective is opposed to the positivism standpoint in which the research strategy seeks to achieve empirical testing about the correlation between variables through replicability over time (Poole et al., 2000). The continuity of such causality generates a certain trajectory in society reducing individuals to passive receptacles (Darlaston-Jones, 2007). That approach is on the contrary avenue of this thesis, which attempts to explore how change is enabled in the context of complex social transformations. Hence, it would be difficult to elaborate on the interplay of variables as these could not necessarily unveil how change happens. For such reasons, this type of research approach was discarded.

This thesis is instead aligned with the constructionism argument that reality is collaboratively assembled by the individuals who experience it (Lewis-Beck et al., 2004). It also assumes that their actions are shaped by the cultural, historical, and social norms that operate within a specific context and time (Easterby-Smith et al., 2012). These can be different for each person, according to the unique interpretation of the social world and their independent experience of it (Darlaston-Jones, 2007). Under such a perspective, this thesis employs a research design that meets those criteria in the following manner:

- The conceptual framework (Chapter 3) recognises the roles of multiple categories of actors in the technology transfer process, in which some of them diffuse new technologies and others primarily adopt these. Such interplay is based on social collaboration aiming at technological change, replacing unsustainable practices.
- The approach to social collaboration recognises that each participant has a specific and complementary role to play in the technology transfer process. Through a social constructionism stand, this investigation will look at understanding participants' meaning, interpreting ideas as they emerge and contributing to the evolution of new theories. Particularly, it is expected that this investigation will obtain relevant insights into the organisational interplay between each participant in the technology transfer process.
- This occurs while the research is mobilised in a non-linear model of heuristic for studying collaboration in the technology transfer process. This approach is complemented by paying attention to the efforts of a variety of actors and their collaborative efforts for achieving socio-technical transitions. The social constructionism approach will guide this investigation to recognise the value of multiple sources of data and perspectives. Thus, it will explore diverse trajectories to emerge through the search for case-specific patterns.

4.2 Research Design

This section introduces the research design to be adopted for examining the collaboration between technological innovation producer and adopter, a relationship that can be supported by transition intermediaries in the UK energy supply sector.

The research design is based on an abductive approach, which is deemed appropriate to qualitatively investigate the complex phenomena of collaboration in technology transfer. In particular, the design will use a reflective cycles operation that allows the researcher to constantly compare data and theory, aiming at generating novel theoretical statements. This approach fits with the social constructionism proposed in the previous Section 4.1.

4.2.1 Abductive reasoning approach

This thesis investigates the factors, drivers and mechanisms by which the transition intermediary functions support the development of organisational capabilities in the sender as well as the receiver in the technology transfer process. The empirical setting of this research is the UK energy supply industry, a critical sector that must achieve net zero carbon emissions by 2050 (Pye et al., 2021). As was outlined in preceding sections, the three-way relationship in which intermediaries provide support to cultivate capabilities to diffuse and adopt technology innovation has been enclosed by the conceptual framework (Chapter 3). This assumes that cooperation within the context of a socio-technical transition can be investigated by the arrangement of theories and concepts that the framework has proposed. As was discussed in the literature review, TIS, MLP and RBV provide important conceptual elements which organised in combination provide the foundational basis to further explore the collaboration between different actors to modify an essential socio-technical system, such as the energy supply sector. Accordingly, the critical elements of capabilities within absorptive and desorptive capacities and transition intermediary functions, allocated in the conceptual framework, constitute preliminary themes which will act as a roadmap guiding the course of this research.

Therefore, this study considers the abductive approach (Coffey and Atkinson, 1996; Tavory and Timmermans, 2014) an appropriate research option for analysing that complex social phenomenon. This thesis defines abduction as a mode of qualitative reasoning or inferences in social science that uses a selective and creative process to examine how the data support or modify assumptions obtained from the literature (Thornberg, 2012). The abductive school of thought in qualitative research (Bryant, 2009; Carson, 2009; Eco, 1981; Truzzi, 1976) seeks to make comparisons and interpretations in data searching for patterns that can provide logical explanations of a social phenomenon. Abduction reasoning endeavours to be sensitive to data, while allowing to apply existing theories as inspiration to identify as well as interpret those patterns (Alvesson and Skoldberg, 2008). Consequently, abduction demands an iterative interplay between data and theory, which constantly challenges the initial assumptions to resolve complex issues (Kennedy and Thornberg, 2017).

In this thesis, the existing literature is the starting point by which data collection and analysis are conducted. This is reinforced by the abductive approach, which uses the main themes proposed by the literature and proceeds with the analysis to establish the relationship suggested by the conceptual framework. Miles and Huberman (2009) refer to this method as a feasible approach that reflects a balanced trade-off between theory and data, which are captured through the analytical lens of the conceptual framework.

To proceed with this method approach, Alvesson and Karreman (2011) suggest that the researcher must *defamiliarise* himself with known terrains and instead open the study to undiscovered places. This will allow him to obtain surprising findings and then re-think the dominant theories (Kennedy and Thornberg, 2017). This could permit the elaboration of wild inferences whereby the abductive approach has been criticised (Paavola, 2004). Nevertheless, the conceptual framework has the characteristic to bring the researcher back to the essential topics that concern him.

In summary, the abductive approach recommends moving back and forth between data and theory iteratively. According to this perspective, abduction reflects the process of sensing the data and possibly double-checking these inferences with additional information (Timmermans and Tavory, 2012). Therefore, the abductive approach includes a preliminary literature examination to identify research problems and areas to look for data (Coffey and Atkinson, 1996). This procedure enables the researcher to examine the main topic of study from theoretical areas where the insights obtained from the analysis can be explained by extant literature (Timmermans and Tavory, 2012). Such emerging theoretical contributions transcend the specific empirical setting in which the investigation is set and offer a visible link with broad existing knowledge (Coffey and Atkinson, 1996). Consequently, methods for data collection and analysis must enable such insights to emerge from the observed data in combination with the existing literature, allowing the abductive reasoning to illuminate the grey areas of knowledge by its intrinsic recursive approach.

4.2.2 The reflective cycles operation

According to Blaikie and Priest (2017), the application of abductive logic involves a series of reflective cycles. These consist of six interwoven activities that confer to the researcher an accumulative sense of interpretation around the main topic of investigation.

- *Sensitising* is the methodological examination of the literature related to the research topic. This is used to alert the researcher of the issues to be investigated.
- *Questioning* involves the cross-checking of participants' accounts with the critical review of the literature.
- *Exploring* captures the experience of participants by asking them starting questions, followed by further interrogations that seek clarification on apparent contradictions, gaps or dilemmas.
- *Analysis* transforms these units of data into abstract and compact descriptions that still account for their meaning. This step can be achieved by grouping information into categories related to the problems of investigation.
- *Theorising* is an iterative process that analytically generates insights about the relationship between the typologies of data. This step provides a deeper understanding of the main topic of the research.
- *Checking* is the reflective process whereby the researcher contrasts with additional sources of data the degree of understanding achieved in the previous steps.

Each step may raise new issues to be explored or data to be cross-checked, contributing to improving the next engagement with sources of information (Blaikie and Priest, 2017). Importantly, the outputs produce meaning that the researcher obtains from the data interpretation. These are the results of abductively linking subsets of elements, fitting into plausible themes that have been inferred from a tentative conceptual framework derived from the literature review (Miles and Huberman, 1994).

This can help to reduce the inconsistent and ambiguity that abductive reasoning may initially present with existing explanations (Ezzy, 2002). For Eco (1981), this is one of the challenges that the abductive approach represents, in which the researcher must overcome the dominant principles that govern human knowledge and propose new ideas. The reflective cycles of the abductive approach point in that direction by involving a logical process of reasoning that produces inferences to address the research questions. The abductive approach is an important part of theory building and data collection by shuttling back and forth between general theoretical propositions and empirical data in the process of discovery.

The process takes shape and findings are made, being the result of the continuous contrast between the data collected and the researcher's conceptualisation (Morse, 2015). When the constant comparison becomes dense and no additional data pertinent to the category keeps emerging, then it can be said that "saturation" has been achieved (Saunders et al., 2018). This refers to the point where all data express similar ideas to the conceptualisation, and nothing new is emerging from the observation in the field; therefore, no further data collection and neither analysis is necessary (Bowen, 2008).

Most qualitative method presents the risk that the researcher might only follow his epistemological predilection and neglect those that potentially are surging through the interaction with the study site, participants and subsequent data (Miles and Huberman, 1994). This relates to how the researcher interprets and provides meaning to symbols, such as language and actions shared by individuals within a culture through a process of socialisation (Eco, 1981). Nonetheless, these pitfalls can be avoided by abductive reasoning due to the potential to yield both theoretical concepts and the empirical world, improving the quality of analysis (Dubois and Gadde, 2002). That possible situation is methodologically addressed by this research through a conceptual framework built from the literature that will be qualitatively investigated in a specific empirical context.

4.2.3 Qualitative data collection

Chapter 3 has discussed that the combination of existing theories provides sufficient elements to propose a conceptual framework that will explore the generation of capabilities supporting a socio-technical transition. Nevertheless, the conceptual components still present challenges that the framework aims to address. Transition intermediary functions have been proposed as an extension of TIS functions creating a network that connects actors for sustainable goals. However, the literature has partial insights to describe how the intermediaries minimise the influence that powerful actors exercise to select new entrants into that network. This issue brings us to the addition of the RBV as a possible theory that can contribute to reducing some of these barriers with conceptualisations explaining the adoption and diffusion of technological resources. Absorptive capacity literature has mostly considered that the possibility of integrating external technology is conditioned by internal R&D capacity. Consequently, numerous studies on absorptive capacity have used a quantitative approach attempting to probe such a correlation (Lane et al., 2006). In the case of desorbing capacity, it is more mixed with no predominant line of method on this issue. In both, the idea that organisational capabilities can play a role in adopting and diffusing innovation has not been fully explored.

The current socio-technical transition in the UK energy supply industry provides a suitable context to discover the form in which business, academic and research organisations are encouraged to develop innovation for sustainable goals by intermediary bodies. Thus, the personal experience of individuals directly involved in such activities can serve as a fitting source of data. For example, it will provide the base to nuance the incumbents' position during those fundamental changes, playing a role in facilitating radical modifications in the socio-technical regime where they operate. This is opposed to a large portion of the transition literature claiming that they are resisting external innovation (Turnheim and Sovacool, 2020). On the other hand, it will serve to investigate the flexible behaviour of socio-technical niches in the journey for scaling-up technology innovations into commercialisation. Finally, it will inspect the decision-making of transition intermediaries, fostering the collaborative links between an organisation that requires disruptive technology to navigate a transition with another that possesses it but struggles to find the business certainties to validate the innovation.

Quantitative methods are considered inappropriate for sustaining such a type of investigation because they fix meaning previously to data collection instead of allowing it to arise (Pidgeon and Henwood, 1997). Therefore, this research selects a qualitative method that is better equipped for a holistic analysis of complex events and causes, particularly described by those who directly experience such circumstances (Timmermans and Tavory, 2012). This approach considers the meanings that participants construct for social and economic interaction as an acceptable type of knowledge (Marshall and Rossman, 2014). Moreover, it offers an appropriate way to get insights into the factors that shape an empirical phenomenon.

Qualitative methods, such as semi-structured interviews, case studies and thematic analysis, have been employed to capture data needed for the research aims (Hussey and Hussey, 1997). For this research, such methods fit with the social constructionism proposed by Easterby-Smith et al. (2012). Thus, this thesis will collect individuals' experiences and interpret them contributing to explain how such a social construction is accomplished.

4.2.4 Summary of Research Design

This sub-section provides a summary of the research design that according to Tie et al. (2019) can be performed in phases, presented in Figure 4.1. Nowell et al. (2017) have suggested that such a step-by-step approach is an iterative and reflective process between phases, instead of linear reasoning, generating criteria for trustworthiness during each phase using abductive reasoning as the main form of logical inference.

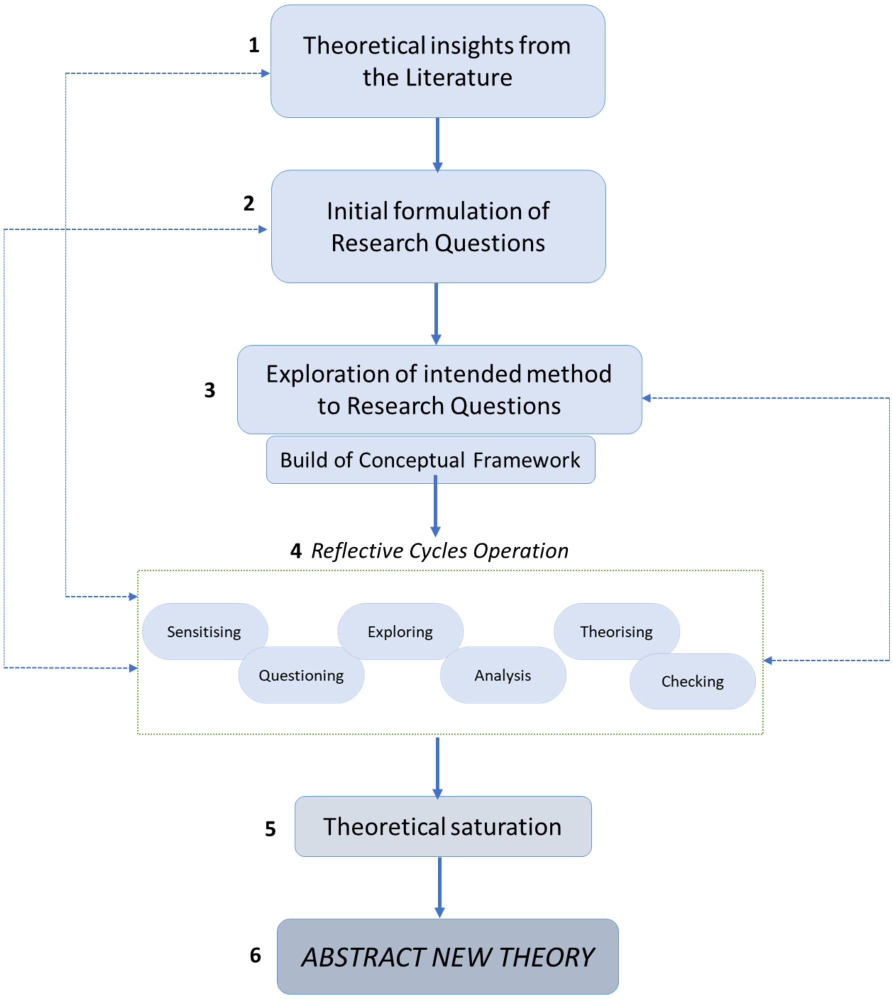

Figure 4.1 Summary of research design strategy
Source: Based on Tie et al. (2019)

Phase 1

The exploration of literature in the research area is conducted at the beginning. It stimulates theoretical sensitivity that guides initial observations and enables the rising of possible questions that have been incompletely addressed by previous studies. Whether it is possible, the researcher can bring personal experience to compare with existing literature.

Phase 2

The investigator starts with a set of research questions, which constitute statements about the phenomenon to be studied. These questions provide an orientation to consider the method to be implemented. A rudimentary and unstructured conceptual framework can be proposed in this phase.

Phase 3

The researcher has obtained theoretical sensitivity that enables him to generate concepts and the properties of data. Importantly, this interaction allows him to relate to both. A tentative method for data collection emerges. In parallel, the conceptual framework gains robustness.

Phase 4

Data collection and analysis are undertaken in conjunction with the literature. This is aligned with the reflective cycles operation. The emphasis lies on the researcher's ability to give meaning to the data and the efforts to separate the pertinent from what is not. After intensive analytical development, the researcher must decide if more data collection or analysis is needed. This phase contains important iterations explained below.

Phases 5 and 6

Through permanent iteration with data and literature, the level of saturation has been reached (phase 5). Then, the researcher is in a position to generate an abstract theory to explain the experience of participants that approximates the reality intended to be represented (phase 6). Although the proposed theory emerges from the subject of study, it transcends into abstract concepts that can be related to other research contexts.

Iterations

The research strategy is not intended to be linear by any means and the researcher makes permanent efforts on iterations that will allow him to progress towards the development of the theory. The iterations facilitate making decisions about proceeding towards the next phase or returning to a previous one. Most iterations occur in phase 4, during the reflective cycles operation. Overall, the stages of analysis provides sufficient elements to compare the data with theory development (Ezzy, 2002). This will assess whether is necessary to iterate with the previous phases in the following way (Nowell et al., 2017):

- Iteration with phase 1 - The researcher needs to return to phase 1 and feed with the theory that illustrates an explanation of the phenomena part of the empirical research.

- Iteration with phase 2 - The researcher reconsiders redefining the research questions. For instance, the original research questions seem unrepresentative of the subjects under investigation and must be reformulated.
- Iteration with phase 3 - The constant entailment of data analysis and theoretical development iteration probably would point towards that further collection of evidence and observations are required to arrive up to theoretical saturation.
- Iteration with phase 4 - A new period of reflective cycles operation can be conducted, allowing the researcher to make informed decisions about progressing to phases 5 and 6.

Abductive reasoning is used in the iterations. This consists of the examination of data and the materialisation of a few assumptions that are then evaluated during this process (Birks and Mills, 2015). In this way, the reflective cycles operation detects consistencies and differences, setting it apart from a simple descriptive analysis. Therefore, the research design assists in advancing, refining and expanding a body of knowledge, establishing facts and/or reaching conclusions using a systematic inquiry. This represents a disciplined and flexible approach to conducting the investigation (Tie et al., 2019).

4.3 Mobilising the research design through phases of investigation

In line with the abductive approach, the research was structured for simultaneous data collection and conceptualisation. To enable this association, the research was divided into five different stages (see Figure 4.2).

1. Development of the sampling categories.
2. Pilot study. It is the first instance of primary data collection via interviews and examination of these using open coding analysis.
3. Main study. It is the second instance of primary data collection via interviews and examination of these using thematic analysis according to the categories established in the conceptual framework (Chapter 3).

4. Continuation of the main study by collecting secondary data for building case studies, presenting these in vignettes (Jenkins and Noone, 2019) within the main text of analysis. Later, the investigation will compare the secondary with the primary data for triangulation purposes.
5. Finally, the theoretical saturation refers the complete range of theory constructs are fully represented by data and consequently the analysis is terminated (Saunders et al., 2018).

Each stage allowed the researcher to make sense abductively of the data. As the research stages were mobilised, the whole process serves to account for the progress in answering the research questions. The conclusion of each phase offers the chance to come back to the literature, providing more clarity on the observed events and assessing extra data collection and analysis.

An additional motive for dividing the research into different phases was to create the opportunity to triangulate the interpretations made after the data analysis from interviews (phase 3) with secondary data (phase 4). This approach is considered an important form of validating data in qualitative analysis and well aligned with the abductive approach (Rubin and Babbie, 2016). Consequently, this offers the opportunity to obtain a rigorous examination and comparison from multiple sources for later arriving at a concise theoretical saturation. In summary, the analysis from secondary data obtained in phase 4 contrasts the primary data collected and analysed in phase 3, through the reflective cycles operation described in sub-section 4.2.2.

Another important reason to divide the research into stages was to shift the focus from a technology innovation system of a particular industrial sector (i.e., UK energy supply sector) to specific case studies. These exemplify the precise mechanisms used by determined intermediaries to enhance innovation capabilities in the producer and adopter of new technologies in the UK energy supply industry. This will implement it in the following manner. The system-level research (phases 1 and 2) commences first. This facilitates the identification, through the analysis of interviews, of the general mechanisms that intermediaries deploy to create innovation management capabilities in participants of the technology transfer process. To later find these general mechanisms through secondary data and present the case studies as vignettes in the finding sections (Chapters 5 and 6). This marks the end of the research stages achieving theoretical saturation.

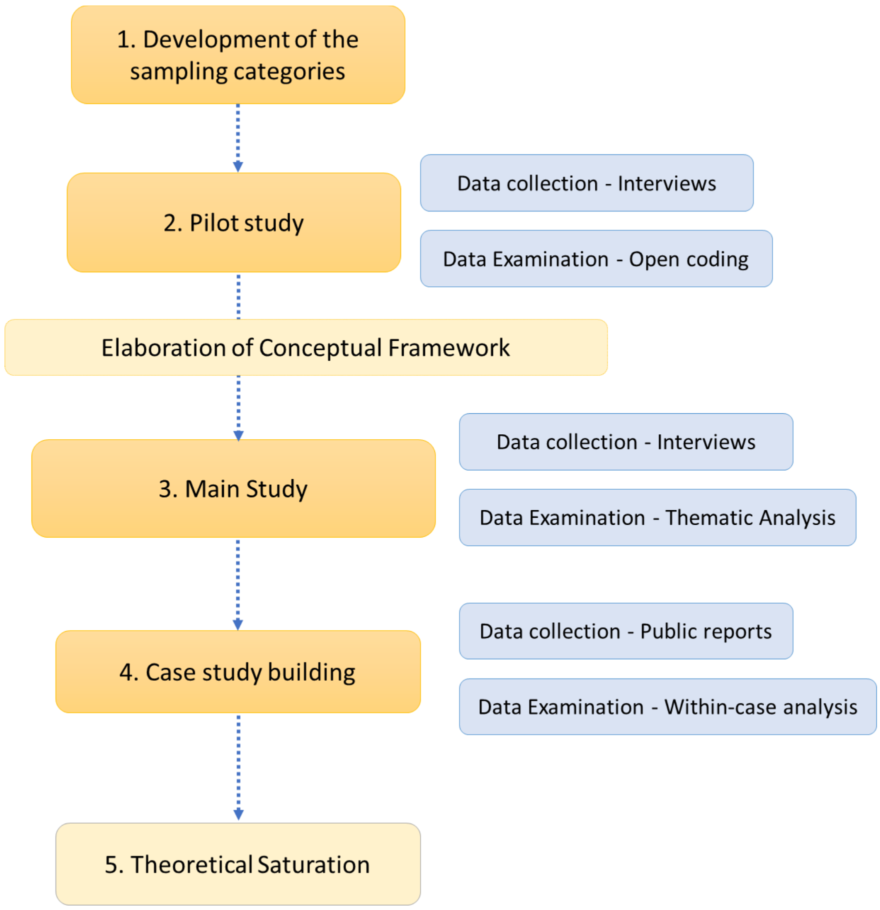

Figure 4.2 Research stages

Having described in general terms the phases to conduct the research, the next sub-section 4.3.1 now proceeds to explain these in more detail.

4.3.1 Development of the sample categories

Once the research questions are tentatively established, the thesis moves to the following phase of the investigation. This consists of the identification of an appropriate data sample. Using the conceptual framework (Chapter 3) as a guide, the researcher can identify three main categories of actors within the technology transfer process (incumbent firms, transition intermediaries and socio-technical niches). The development of these categories first requires setting the geographic borders of the empirical investigation to detect purposeful samples in the UK energy supply innovation system. Then select the group of participants with links in the three categories. Consequently, this section is divided into the two following subheadings to explain both aspects.

4.3.1.1 Scope of the empirical investigation

The context for this research is the UK energy supply industry, a critical sector that must achieve net zero carbon emissions by 2050, as explained in the Introduction (sub-section 1.1). As was outlined in previous chapters, the three-way relationship in which transition intermediaries provide support to cultivate capabilities to diffuse new technologies in socio-technical niches and adopt these in incumbent firms can play an important role in achieving this goal. The choice of the UK energy supply industry was made due to the ongoing socio-technical transition (Foxon and Pearson, 2014), where intermediaries are providing intense support to develop and integrate low-carbon technologies (Kivimaa et al., 2019a).

Related to the participants of the technology transfer process in the energy supply sector, the UK presents an appealing case because of the government's target to reduce carbon emissions to net zero by 2050 (HM Government, 2021). The Climate Change Act was adopted in 2008 to set a comprehensive framework expressed in Carbon Budgets, which are pushing the energy suppliers to decarbonise operations by integrating technological innovation that will allow them to achieve the net zero goal (CCC, 2020).

In the UK energy supply industry, six firms have dominated the market for over 30 years thanks to fossil fuel operations. Now, they have to significantly reduce carbon technologies as part of the great sustainability challenge these companies need to address and continue with their industrial leadership (Kattirtzi et al., 2021). For energy suppliers, the transition must be fulfilled in two critical aspects that are intimately intertwined. Henderson and Sen (2021) have set these as the integration of the necessary technological innovation that will allow them to decarbonise operations, while maintaining the current level of energy supply. According to the MLP (sub-section 2.2.3), technology innovation producers, such as academic R&D and start-up firms, are expected to promote the radical technologies that will help to achieve the energy transition (Smith and Raven, 2012). However, the diffusion of innovation in the power sector is extremely difficult due to the interconnection of technological pieces. Any integration of new technologies into the energy supply system requires a modification in another area with unpredictable effects on society (Negro et al., 2012). This presents a great opportunity to investigate how the interaction between two distinct types of organisations and the support they receive from transition intermediaries can enhance the capabilities necessary for diffusing and adopting technology innovation.

The scope of this research is limited to the three categories of actors (incumbents, intermediaries and niches) in the technology innovation system exclusively to the UK energy supply sector. This is opposed to a comparison between multiple countries. Nevertheless, the latter option could provide valuable lessons into the role that intermediaries play in the socio-technical transitions of different nations. The decision is preferable because studying the phenomenon in numerous countries demands extensive resources. As the doctoral candidate lives in the UK, it makes the research less resource intensive by framing the study purely in this country.

The scope of the research was also limited to the suppliers of energy to residential and commercial end-customers. These energy firms are the recipients of new technologies for achieving net zero emissions. This is a decision taken due to the social importance that the downstream segment in the supply chain of energy has in delivering a sustainable transition of this magnitude (Kattirtzi et al., 2021). Thus, the investigation excludes the upstream segment of the energy industry, as these are involved in the exploration and extraction of natural resources, mainly oil and natural gas in the North Sea.

Although such minerals are considered critical for maintaining the energy system running (Grubler, 2012), the oil and gas industry has proceeded cautiously with its approach to adopting technological innovation (Shojaeddini et al., 2019). Leading the researcher to consider that the upstream sector is not subject to an intense socio-technical transition. The downstream sector is in a similar position towards innovation; however, the industry is pressured by the net zero goal enactment to find novel technologies that can reduce carbon emissions, generate stronger stability from renewable sources, system integration and deployment of alternative fuels (e.g., bioenergy and hydrogen), leading to a transformation pathway (Geels et al., 2016).

The combination of both sectors would have made it difficult to produce generalisations, due to the different natures of their core businesses. This is the fundamental reason for selecting only the UK energy supply sector.

4.3.1.2 The different categories of participants

Creswell (2007) has proposed that the route to finding informed individuals and getting access to them is a key component for collecting relevant data. Hence, the sample intentionally selects groups of people who could better inform the research questions. The conceptual framework offered an orientation for developing the purposeful sample by guiding the researcher to look for participants in three categories of the UK energy innovation system: incumbent firms, socio-technical niches and transition intermediaries. Nonetheless, the framework does not provide the characteristics of each category and it is necessary to define these. The following subheadings offer such descriptions.

Incumbent firms

In this case, the researcher will focus on contacting current and former employees from the "Big 6" utility companies in the UK market. These firms are British Gas, EDF Energy, E.ON UK, RWE npower, Scottish Power, and Southern and Scottish Energy (SSE), which concentrate around 70% of the electricity and gas supply in the British market (Ofgem, 2020). The Big 6 firms deploy a wide range of operational activities for supplying energy to end customers, which is considered their core business. These activities have been organised under the different downstream stages of the energy supply chain, including generation, transmission, distribution, retail, and delivery to end-consumers. Due to scale economies and steep investment requirements, these stages were vertically integrated within the Big 6 during the past quarter of a century (Walsh and Todeva, 2005). These have recently been unbundled as the result of mergers, increasing competition, and policy regulation.

Nevertheless, now Ofgem simply uses the term "large suppliers", the Big 6 still managed most of the energy value chain through separate legal entities. As so, they are critical to delivering the net zero transition in the UK. On top of those activities, the utility firms have transversal business units enabling the corporate management to take a systemic approach to the downstream side of the energy supply chain. These business units are strategic planning, finance, and regulations and policy.

Socio-technical niches

These entities are much smaller in comparison to incumbent firms and they are focused on developing new technology for a specific application sector (Smith et al., 2005). According to IEA (2019: p. 119), these application sectors are:

- Smart systems (including storage).
- Power sector (including renewables).
- Homes (including renewables).
- Transport (including electric vehicles and batteries).
- Natural resources (including land use and waste).
- Business and industry (including fuels and carbon capture, utilisation and storage).
- Cross-sectoral clean technology innovation.

Therefore, the researcher will contact individuals who have participated or are currently collaborating on those projects, within the variety of roles related to the innovation process. Either in technical or business positions. Similarly, the technology innovation could be in any level of development. Consequently, the participants could be members of R&D teams in universities, founders or members of start-up firms, et al. Such a decision was the result of reflecting on the non-linear and cross-over activities of the innovation process, explained in sub-section 2.1.1.

This thesis has selected some of these actors, who are mainly technology producers, from individual inventors and academic researchers, including young firms up to middle-range companies with a rich history of technology commercialisation but whose main innovation concept is still not mature. This is the main reason to exclude large original equipment manufacturers in the energy industry, such as Siemens, GE and Vestas, as part of the socio-technical niches. This is an ongoing debate in the transition literature that has traditionally considered emerging organisational entities as the core actors of socio-technical niches (Geels et al., 2007). With the current competitive landscape in constant change, large companies are increasingly getting involved in early technology development and acting as entrepreneurial firms, as Lichtenthaler and Lichtenthaler (2010) have proposed. Hence, it is problematic to set boundaries in socio-technical niches and this research decided to only include those developing new technologies in the UK energy supply sector.

Transition intermediaries

Finally, transition intermediaries are positioned according to the specific support they provide in the development of low-carbon technology innovation. Intermediary organisations can have diverse goals, developed through the identification of gaps in the technology innovation system (Kivimaa et al., 2019a). Most of these fissures are concerned with minimising the risks of developing a technology innovation (Section 2.1) providing support to overcome the technical and social barriers confronted during a socio-technical transition (Section 2.2). The intermediaries can have a policy motivation, in which the government has detected a failure in the system and has created a public organisation to support the technology innovation. Alternatively, they can have a different origin, where industry associations involved in policy work have pointed out a gap in the system and have formed organisations to offer support to the sector's members. Similarly, this type of help is provided for collective needs in which the technological innovation can eventually reach different actors and processes in the technology innovation system. Therefore, these intermediaries have a semi-public nature (van Lente et al., 2003).

In this broad spectrum of transition intermediaries whose organisational purpose is to enable innovation, Kivimaa et al. (2020) have enumerated these in the following list:

- Innovation and economic development agency funders.
- Technology transfer offices.
- Public policy task forces.
- Funding research institutes.
- Innovation and technological project developers.
- Technology demonstration centres.
- Science or technology or business parks.
- Business incubators.
- Research consortia.

- Industry and trade associations.

These organisations serve as facilitators of the technology transfer process from niches (producers of technology innovation) to incumbents (adopters of these), bridging the organisational gaps that often exist between them, as sub-section 2.2.2.1 has previously discussed.

4.3.2 Pilot study

Once the sample categories are outlined, the next phase in the investigation is to conduct a pilot study. This consists of a small version running as a trial in preparation for the major study (Polit and Beck, 2010). The goal of the pilot study is to give warnings about where the main research project could fail, whether proposed methods are inappropriate or research protocols may not be followed (Van Teijlingen and Hundley, 2001). It is a critical aspect when a large-scale investigation will proceed with qualitative data collection and analysis on a relatively unexplored topic, using the results of the pilot to reinforce the subsequent phases of the research (Tashakkori and Teddlie, 1998). Moreover, the pilot study offers the opportunity for the researcher to enter the field relatively "cold" and minimise his observer's bias. To then determine the best course of action in establishing access to participants and evaluating issues in the research design before proceeding with the main study (Sampson, 2004). Consequently, the pilot study ensures that the research design runs appropriately and provides preliminary results that are valuable to initiate the theory building (Bryman, 2012).

The pilot study uses a semi-structured interview method to collect data and later this qualitative information will be examined using an open coding analysis. The following sub-sections will explain the rationale for using these methods and the lessons extracted from the pilot study.

4.3.2.1 Semi-structured interviews

These are selected as the first method of data collection because they offer direct information from the individuals who have lived the situation or phenomenon to be investigated. They ultimately provide an understanding to the researcher of their common experiences

(Creswell, 2007). The semi-structured interview approach is designed from a guide that the researcher has obtained from the literature to ascertain subjective responses regarding the phenomenon (McIntosh and Morse, 2015).

In this case, the theoretical insights provided from the literature review are relevant to elaborate the interview guideline and subsequently translate into questions to be proposed to participants. They are free to respond to these open-ended questions as they wish and the researcher may probe these responses, offering the semi-structured aspect of this method (Bartholomew et al., 2000). Therefore, the semi-structured interview allows a purposeful conversation to arise between the researcher and participants, gathering descriptive data through the interviewees' own words. Thus, the researcher can develop interpretations about how participants see the social world (Carruthers, 1990).

Harrell and Bradley (2009) have explained that interviews can be used as a primary data method collection to gather information from participants about their practices, beliefs, or opinions, either from past or present experiences. Even they can also elaborate on what could happen in the future. This allows the researcher to get closer to important insights from a list of experts. Harrell and Bradley (2009) have additionally suggested that interviews can be placed on a continuum of structure, from unstructured to highly structured format, placing in the middle a semi-structured design. It will depend on how much control the interviewer will have over the conversation. For this reason, testing the instrument of data collection was an important objective in the pilot study to later inform the main study.

Semi-structured interviews provide the information in a conversation style (Robson and McCartan, 2015), which in this instance are used to delve into the general topic of technology transfer in the UK energy supply sector. Therefore, the participants were invited to discuss how the interplay interaction between incumbent firms, transition intermediaries and socio-technical niches have influenced the various dimensions of diffusing and adopting technology innovation in the UK energy supply sector. During the pilot study, the semi-structured interviews allowed the researcher to conjecture about how this relationship might develop new dynamics during the present net zero transition. In some instances, participants referred to previous influences that transition intermediaries have had in shaping the socio-technical transition in the energy supply sector. In other instances, they insinuated future developments in the relationship pointing at the difficulties of changing the energy supply system to integrate sustainable technologies that would modify industrial practices. This usually means that the conversation went into different areas that the researcher had not previously considered, providing relevant information to the study (Robson and McCartan, 2015). As a result, the semi-structured interview offered the researcher with a flexible option for covering and integrating additional conceptualisation (Collis and Hussey, 2009). Moreover, it allows him to ask further questions on answers that require an extra explanation from the participants, helping the researcher to profoundly inquire into the topic and understand thoroughly the responses provided (Robson and McCartan, 2015).

In total, five interviews were conducted during the pilot study (see details in Table 4.1). These were recorded with permission to be later transcribed and analysed through an initial open coding, according to the recommendations of Saldana (2009). This analysis consists of taking a short phrase that symbolically assigns an essence-capturing or evocative attribute for a portion of language-based data found in the interview transcripts. These were first impressions contrasted with the literature, seeking to make sense of the information gathered. Frequently these impressions were interpreted in the form of written memos by the researcher during the data analysis (Tavory and Timmermans, 2014). This enabled him to reflect on passages of the interview and decipher their core meaning through a process of decoding (Saldana, 2009).

4.3.2.2 Lessons from the pilot study

Semi-structured interviews offered advantages in terms of capturing open-ended responses from participants. This was possible thanks to an interactive two-way communication that stimulated the discussion resulting in collecting in-depth information (Creswell, 2007). In this regard, the pilot study aided in refining the interview questions by separating questions that worked from those that did not, as well as aspects of the research design that were not completely suitable (Kim, 2011). This offered the prospect of editing the research design as the pilot was providing critical insights on the access, analysis and compilation of data. The pilot study was important in improving the approach to select participants from the three sample categories, as well as establishing links they exhibited as technology transfer partners.

These developing criteria had a significant role in shaping the sample categories and guiding the interview questions (van Teijlingen and Hundley, 2001).

The pilot study was active in examining the theories provided by the literature and comparing these with the initial qualitative analysis (Mora et al., 2020). The small portion of information captured by the pilot study through five interviews made it possible to start the reflective cycles operation and iteration of phases from the research design, summarised in sub-section 4.2.4. During the pilot study, the collection and analysis of data were generally driven by the TIS, MLP and RBV literatures, with participants mentioning the significance of technology transfer with the support of intermediaries as a critical factor. It was during this phase that the researcher realised the need to develop a clear conceptual framework that will present this triad of relationships aggregating additional theoretical concepts that will guide the research (i.e., intermediary functions, absorptive and desorptive capacities). This made sense of the phenomena observed at this point and supported the redefinition of the research questions, noticing a clearer gap in the literature.

Nevertheless, interviews privilege the participant as the main information source, making this method limited to the subjective knowledge of the individuals' experience (McIntosh and Morse, 2015). In the same way, Harrell and Bradley (2009) have clarified that participants' descriptions may not provide a complete account of events, because the personal experience can be biased on representing the collective proceedings. To reduce these issues, Carruthers (1990) has recommended triangulating data from a variety of methods. This allows it to examine the same phenomenon from multiple perspectives, enriching the understanding for deeper dimensions to emerge and minimising the deviance from participants' answers.

For these reasons, the researcher became aware that a second type of data collection to contrast the information gathered through interviews would be recommendable. McIntosh and Morse (2015) reaffirm this option by suggesting that results obtained from interviews can be collated in conjunction with other qualitative methods. Based on these recommendations, the researcher decided to team two methods in a way that the weakness of one will be compensated by the strength of the other. This option will allow him to establish if similar findings are made using both methods and thus support the analysis to reach sufficient stability (Carruthers, 1990). In this case, the pilot study contributed to detecting the importance of the secondary data to be found in public reports, as these examples were mentioned from the voices of participants during the preliminary interviews.

The main lessons from the pilot study improved the research design and allowed it to enter into the following phase of the main study, as Figure 4.2 suggested. The next sub-section 4.3.3 describes the main study, which comprises a renewed instance of data collection and analysis.

4.3.3 Main study

The main study represents a continuation of the pilot study. The main study conducted additional 35 semi-structured interviews, which combined with the pilot study summed 40 in total (see Table 4.1). The main difference between the pilot and the main study was that in the later phase, the conceptual framework was fully employed, the interview questions were redefined, and further secondary data was collected. Thus, the conceptual framework was completely adopted to inquire participants about the factors, drivers, and mechanisms by which the transition intermediary functions support the development of organisational capabilities in the sender as well as the receiver of the technology transfer process. For example, the adoption of the absorptive capacity conceptualisation helped to build interview questions investigating how transition intermediaries support the dimension of acquisition of technology innovation in incumbent firms, such as "How do transition intermediaries encourage incumbent firms to acquire new technologies?".

Table 4.1 Summary of data collection from primary data

Phase	From	To	Number of interviews
Pilot	28/8/2019	30/10/2019	5 Interviews (1 incumbent; 3 intermediaries; 1 niche)
Main	10/1/2020	25/6/2021	35 Interviews (12 incumbent; 13 intermediaries; 10 niche)

The redefined questions were proposed to participants in the main study. This approach was facilitated by the conceptual framework, which made it plausible to identify participants who could inform profoundly about the research problem under investigation. Thus, the sample categories developed in sub-section 4.3.1 allowed the researcher to find participants according to the particularities in each of the three categories. As Figure 4.3 presents, the participants from the pilot study were assigned with a pink circle; whilst the participants from the main study were coloured with a grey circle. Each participant contains an interviewee reference. For example, "INT 8" or "INT B" was used. The first three letters relate to the participant's position in any of the three sample categories (i.e., incumbents, INC; intermediaries, INT; and niche, NIC) and the second number or letter constitutes the phase of the study (a letter is a participant of the pilot; a number is a participant of the main study). The reader can use these codes to access additional information on participants through the interviewee lists provided in Appendix A.

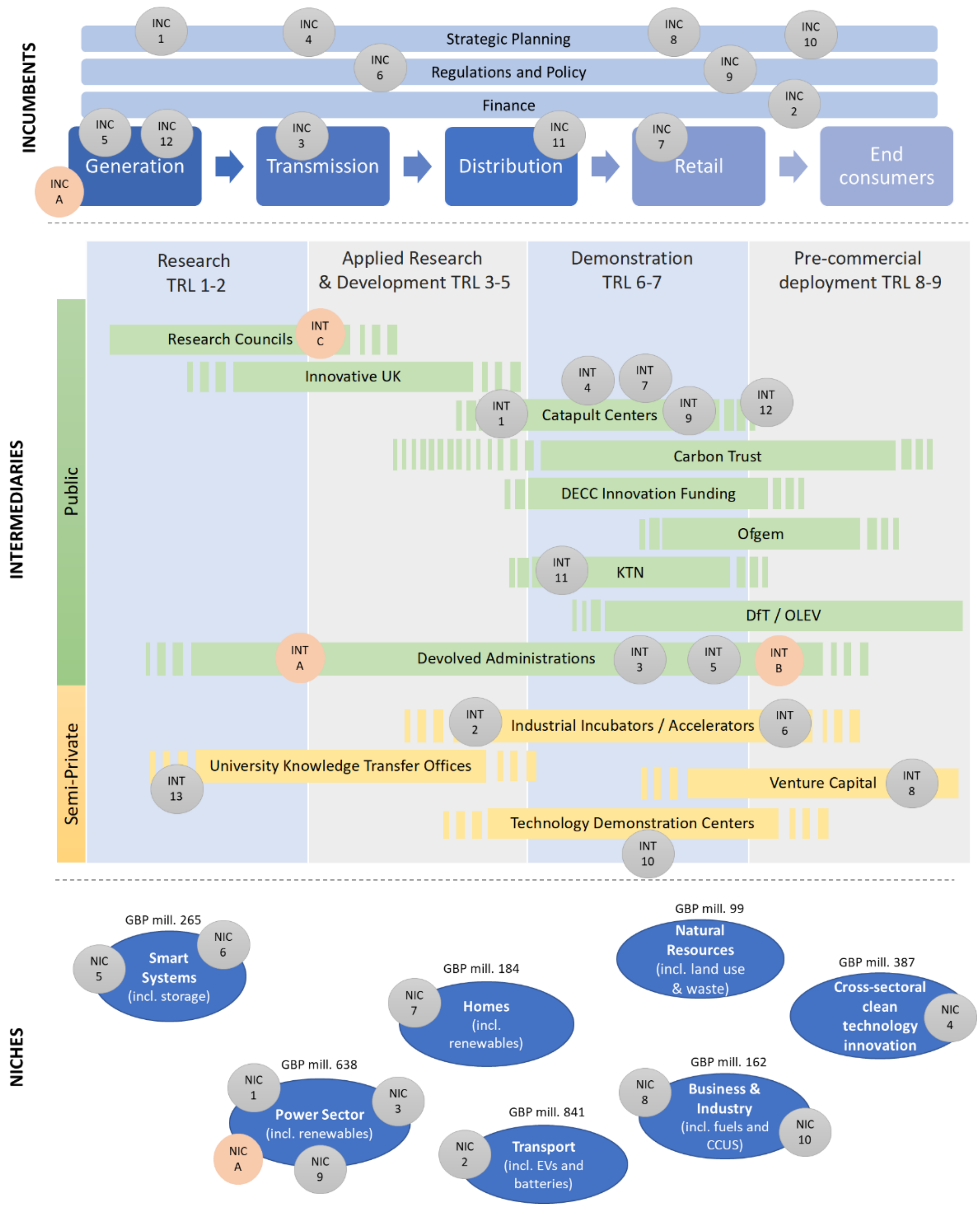

Figure 4.3 Allocation of participants according to sample categories development

The main study selected participants through purposeful sampling from the categories described in sub-section 4.3.1.2. These imposed practical factors affecting the research about time and place, which were also considered. As the scope of the investigation was in the UK, this meant looking for participants in a vast geographic area in which the researcher needed to develop protocols about the most efficient data collection approach, such as e-mail messages and online calls. At the same time, a snowball approach was used, asking participants to recommend other individuals as potential subjects of this study (Creswell, 2007). These elements helped to accelerate the process of data collection.

Another difference between the pilot and the main study was that during conversations in this latter phase, the researcher attempted to find secondary sources from the opinions of interviewees. Participants mentioned these spontaneously without referring with precision where to find them; thus, it was later a researcher's task to locate them in public databases.

Thus far, the method of investigation has explained the collection of primary data. The next sub-section 4.3.4 describes how this information will be examined using a thematic analysis approach. Later, sub-section 4.3.5 defines the process for collecting and analysing secondary data for case studies.

4.3.4 Analysis of data collection through interviews

This sub-section will describe thematic analysis as the method to examine the primary sources of data obtained through interviews and the justification for selecting such a type of analysis.

4.3.4.1 Thematic analysis of primary data

The thematic analysis consists of a search for themes that emerge from the qualitative data and are considered important by the researcher to describe the topic of investigation (Fereday and Muir-Cochrane, 2006). Moreover, thematic analysis supports the identification and encoding of patterns of meaning from qualitative data (Braun and Clarke, 2006).

To obtain those interpretations, this thesis used an abductive approach of reasoning in two ways. A top-down, theoretical process; and a bottom-up, data-driven process. The first approach produced a set of *a priori* (or pre-empirical) themes (Crabtree and Miller, 1999). These have emerged from the literature review and fed the conceptual framework in the form of "capabilities" for each dimension of absorptive and desorptive capacity, explained in sub-sections 2.3.3 and 2.3.4. Moreover, the same approach generated a list of transition intermediary functions incorporated into the framework (sub-section 2.2.2.2).

Whereas the second approach developed a *posteriori* (post-empirical, or after the fieldwork) codes derived from the examination of data collected via the interviews with participants (Boyatzis, 1998). Such an analytical method is in concordance with the abductive reasoning, described in sub-section 4.2.1. Similar approaches have been followed by McGhee et al. (2007) proceeding with this type of data analysis process. This approach is flexible enough to allow theory and data to iterate in a reflective process that generates a criterion of trustworthiness in management research (Tavory and Timmermans, 2014).

It is important to mention that the conceptual framework (Chapter 3) proved to be critical in this instance, supporting to make sense of the data collected in interviews by comparing it with a set of sound categories. These were systematically linked through statements from participants to investigate the relationships that make possible the social construction around the phenomenon under investigation (Easterby-Smith et al., 2012). To perform such an approach, the thematic analysis was conducted following these suggestions from Saldana (2009):

- Initial open coding: A short phrase that symbolically assigns an essence-capturing or evocative attribute for a portion of language-based data found in the interview transcripts. These were first impressions contrasted with the literature, seeking to make sense of the information gathered with the conceptual framework. Frequently, these were written in the form of memos by the researcher. This approach was already implemented in the pilot study, in a previous step that allowed the researcher to perform this technique with more precision in the main study.
- Axial coding: The main study extended the analytical work from the initial coding to strategically reassemble the codes that were fractured. The axis fixed a category discerned from the conceptual framework grouping the initial coding into categories for analysis.
- Theoretical coding: It accounts for all codes and categories formulated in the qualitative analysis. The categories were systematically linked with the central theories, providing explanatory relevance for the phenomenon. This step was validated through a relationship from the conceptual framework's categories which needed further refinement in this phase.

Importantly, the conceptual framework (Chapter 3) has a great influence on the coding categories. The framework offers a list of *a priori* themes that emerged from the literature review (see Tables 2.5, 2.6 and 2.7), assigning intermediaries functions as the main driver to develop capabilities to each dimension of the absorptive and desorptive capacities' conceptualisation. The next sub-section will explain how the thematic analysis will be conducted using the conceptual framework.

4.3.4.2 Thematic analysis through the conceptual framework

Once the information has been collected, the conceptual framework offers the opportunity to examine the data. This will be conducted by associating the gathered information with the theoretical concepts embedded into the conceptual framework, which will be mobilised in four main steps according to Figure 4.4:

- First, the researcher selects a capability presented in the conceptual framework and starts analysing the data related to this theme. This example will work around the dimension of acquisition in the absorptive capacity of incumbent firms and select one of the capabilities assigned by the literature review available in Table 2.6.
- Second, the researcher identifies and describes blocking behaviours configured in the inaction of transition actors and the barriers that have undermined the development of that specific capability.
- Third, the researcher detects mechanisms whereby transition intermediaries address such issues. These actions support the development of organisational capabilities either for diffusing or adopting technology innovation for the net zero goal in the UK.
- Fourth, the researcher uses the previous step for assigning a transition intermediary function from the categories proposed by Table 2.5. To then connect this function graphically, drawing an arrow with the specific capability in the conceptual framework.

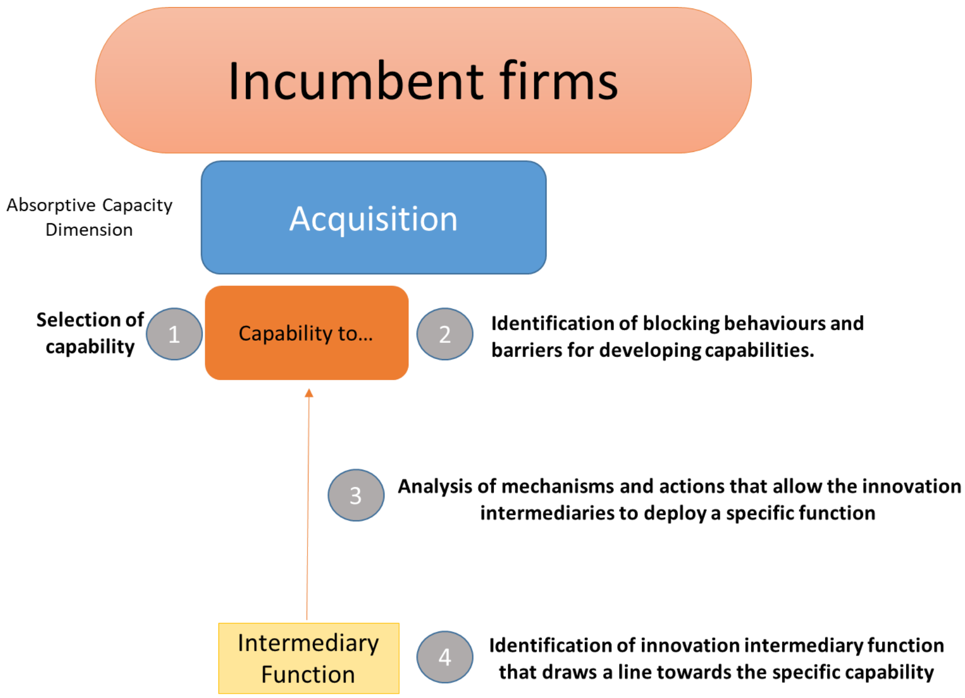

Figure 4.4 Worked example mobilising the conceptual framework for thematic analysis

This working example in Figure 4.4 will be replicated in all the capabilities of absorptive and desorptive capacities (detailed lists in Tables 2.6 and 2.7), using the conceptual framework as the main guideline for this purpose (Figure 3.1). This analytical process will enable the researcher to code the intermediary's influences on the development of these capabilities and assign an intermediation function (Table 2.5). The results of this analysis will facilitate finding an illustrative case study in the secondary data and to be presented within each capability analysis. This approach forms the basis of analysis to be applied for each capability at both ends of absorptive and desorptive capacity respectively in Chapters 5 and 6.

Therefore, empirical data are coded according to the building blocks from the conceptual framework. For all this work, Creswell (2007) suggests a data analysis software package, helping the researcher to organise, analyse and find a relationship in the qualitative information. For this reason, this study will use the software NVivo for organising and analysing large volumes of unstructured data.

4.3.4.3 Nvivo

The researcher will employ the Nvivo version 12.6, available via the digital library at the University of Strathclyde. The selected software organises evolving and complex coding systems into formats as hierarchies and networks for "at a glance" user reference (Saldana, 2009). Moreover, it facilitates the arrangement of information in the intensive stage of thematic coding. Nvivo helps to store and systematise the qualitative data, which can be easily located once the codes are associated with a category and compared between them. This allows the researcher to conceptualise different levels of abstraction and provides visual illustrations of codes and themes; moreover, allowing him writing memos as the analysis moves forward.

Figure 4.5 illustrates through an example a tentative number of open themes assigned under each dimension of absorptive and desorptive capacity. On the right hand, "Files" points to the number of interviewees that provided a commentary (codes) in that category; and "References" to the number of codes offered by all interviewees in that category.

As can be seen, NVivo is valuable in organising information to address the research questions. Additionally, it can assist for developing theory around the intermediaries' support to enhance innovation capabilities between the technology producer and adopter in the UK energy supply industry.

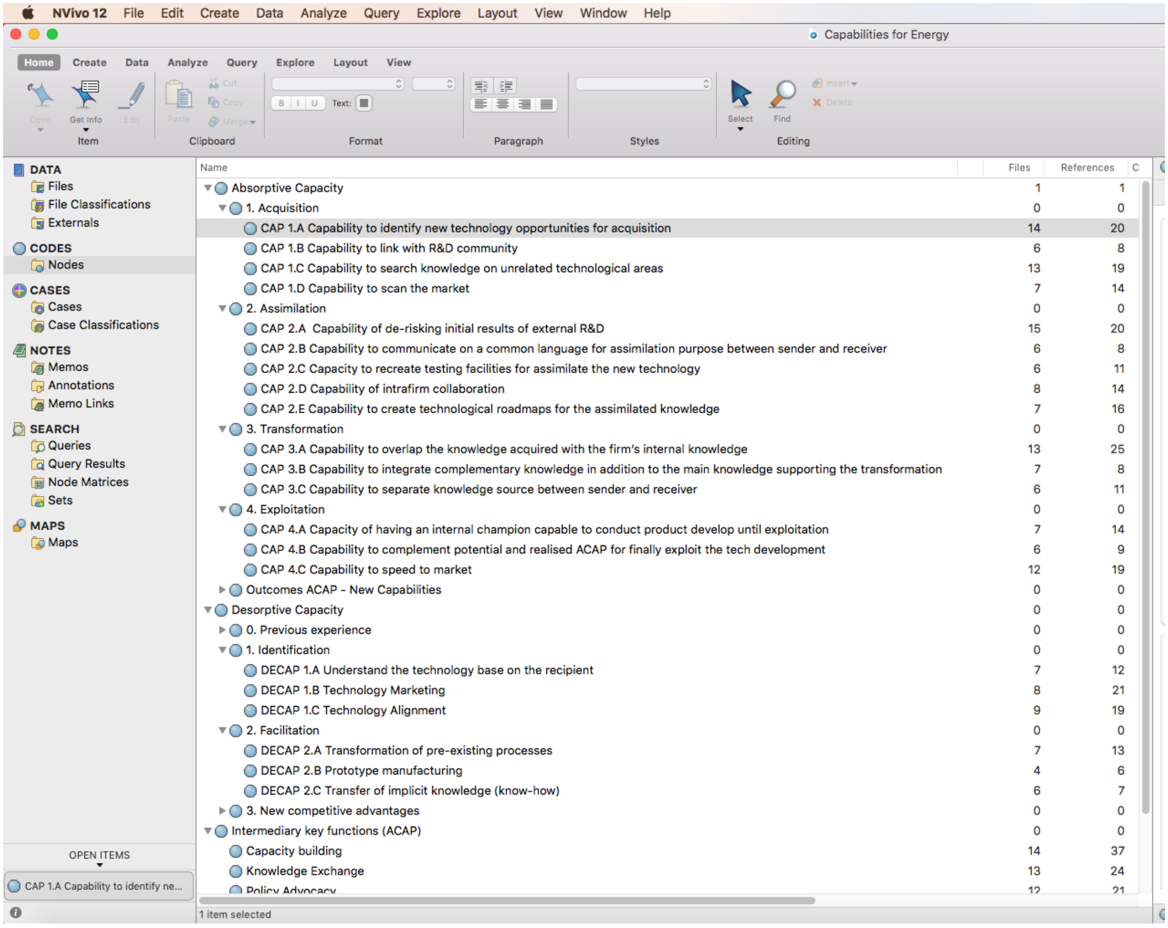

Figure 4.5 NVivo screenshot of thematic analysis

4.3.5 Case study

While thematic analysis is flexible, it can lead to inconsistency and a lack of coherence when developing themes derived from the data (Holloway and Todres, 2003). As with most qualitative examinations, the thematic analysis could present subjective results, and as so it holds against validity (Braun and Clarke, 2006). To reduce these concerns, this research additionally uses a case study method to offset biases and validate findings by verification with qualitative databases. This makes the results more convincing if the findings in one analysis fit another dataset (Jonsen and Jehn, 2009).

The case study has been regarded as a plausible method to empirically contrast information found in the natural setting of the phenomenon under investigation, without experimental control or manipulation by the researcher (Creswell, 2007; Eisenhardt, 1989; Gimenez, 2006). A case study is an empirical method that can collect data from different organisational units by direct observations of the phenomenon under study (Eisenhardt, 1989). In this thesis, the methods and tools employed to collect data are considered exclusively qualitative, having the common goal of understanding the phenomenon under investigation by verification (Bonoma, 1985).

Such a combination of qualitative methods enables the investigation by a comparison of different sources of data whereby precise information is sought to shed light on areas that constitute gaps in the developing theory (Miles and Huberman, 1994). A similar suggestion is expressed by Carruthers (1990) suggesting that multiple qualitative approaches can resolve the variances of a phenomenon by verifying evidence. A likewise position is sustained by Thompson (2022) who claims that crafting different methods strengthens the abductive approach by comparing findings. Based on these arguments, the researcher selected the case study as a complementary method for three reasons found in the pilot study:

- During the collection of primary data from the interviewees' experience, participants constantly mentioned the opportunity to corroborate their opinions with public reports. Such documents are in the form of secondary data, which offers the chance to triangulate with the primary sources. Then, building case studies from secondary data allowed the opportunity to compare one form of study in which data was collected and processed (public reports) to then be re-analysed in a precedent analysis of primary data (interviews). Such a complementariness of methods allowed to increase the reliability of the qualitative research (Rubin and Babbie, 2016). Consequently, the concerns about using secondary data for building case studies lying around the possibility of finding outdated information, weaknesses in the original research design, and data not sufficiently compatible with the area of inquiry (Rubin and Babbie, 2016), are minimised thanks to the combination of a dual method.
- Gathering and analysing secondary data allows the researcher to build an example illustrating an intermediary function enhancing a capability to diffuse or adopt technology innovation in the UK energy supply sector. Therefore, it was possible to place each case study as a "vignette" next to the analysis of primary data, explaining how a particular capability is strengthened by the action of transition intermediaries. A vignette is a self-contained presentation adjunct to other research techniques, allowing a further interpretation of the occurrences with additional context to be explored (Jenkins and Noone, 2019). This clarifies some of the issues presented in the

main method of analysis (Barter and Renold, 1999). Such an option made an appealing alternative to present findings in Chapters 5 and 6 about the development of capabilities to adopt and diffuse technology innovation in the UK energy supply industry.

- Additional benefits associated with using secondary data include efficiencies in the use of research resources, through the maximisation of essential data that might otherwise lie dormant; and, most importantly, it reduces research obtrusiveness and the burden placed on participants for collecting data (Whiteside et al., 2012).

Overall, the justification for incorporating a case study as a complementary method is consistent with the interpretative approach that investigates social and organisational contexts using the abductive reasoning (Tavory and Timmermans, 2014). Furthermore, by using the techniques of constant comparative analysis and submitting questions for each code (i.e., what does this mean? and what does it represent?), concise interpretations can be made by the researcher in the specific context set by the investigation. Thus, there is a close link between semi-structured interviews and case studies with the abductive approach by suggesting that the researcher can start with a defined problem and a set of research questions. This guides him to seek the data to collect. Without such a direction, the researcher is tempted to collect everything (Yin, 1994). Identifying these previous constructs guides the researcher to design a preliminary conceptual framework that serves to investigate through the data collection stage (Eisenhardt, 1989).

In the case of this investigation, the conceptual framework suggests variables even without forming a relationship between these, serving to explore them using the dual method. The case study approach can find new factors to be added as the theory saturation takes shape. Therefore, the combination of interview data collection during the first stage with the secondary data for case studies in the second stage is acceptable by the abductive reasoning.

4.3.5.1 Selection criteria for case studies

The first filter for selecting the case study is that the organisation must be located within the UK borders. The second filter is that the intermediary role satisfied the classification proposed by sub-section 2.2.2.2. This ensures that the selected middle organisation deploys a course of action that can be assigned to an intermediary function. This allows the researcher to observe if the case study would fit with the information analysed from the primary data. The third filter is that access to information must be available through public databases for documentary analysis.

The initial list of case studies was obtained from Figure 4.3. In there, the category of transition intermediaries proposes an inventory of middle organisations dedicated to promoting energy technology innovation in the UK. These are:

- Research Councils
- Innovative UK
- Catapult Centres
- Carbon Trust
- DECC Innovation Funding
- Ofgem
- Knowledge Transfer Network (KTN)
- Department of Transport (DfT) and Office for Low Emission Vehicles (OLEV)
- Devolved Administrations
- Industrial Incubators and Accelerators
- University Knowledge Transfer Offices
- Venture Capital Organisations
- Technology Demonstration Centres

4.3.5.2 Method of analysis for case studies

In broad terms, Yin (2014) has distinguished three types of analytical approaches that can be applied to the case study method.

- *Descriptive*, in which the purpose is describing the phenomenon in detail within its real context.
- *Explanatory,* in which the study seeks causal factors explaining a particular phenomenon. The primary focus is to analyse "why" and "how" certain conditions come into being by explaining the mode in which events occur.

- *Exploratory,* with the purpose of exploring a phenomenon to identify emerging research questions which can be used in subsequent studies in a more extensive way.

This thesis will take the explanatory approach focusing on how intermediaries deploy a particular function to support technology innovation in the UK energy supply sector. In specific, the analysis will seek common patterns as a strategy for data analysis. This consists in comparing the predicted theoretical pattern with an observed empirical pattern (Hammond, 1966). The underlying assumption is that the researcher can make sense of the empirical context by comparing what he observes externally to internal mental models, without necessarily the use of quantitative schemes (Sinkovics, 2018).

This thesis will use this approach by comparing the primary data obtained from the interviews with the secondary data obtained from the available public reports of UK transition intermediaries. The analysis of the latter information will be conducted through textual analysis, seeking to deconstruct the document in terms of the vantage point of the author, acting in representation of the intermediary organisation (Priya, 2021). These insights will allow it to reflect on the mechanisms that the middle body uses to deploy its transition function.

These correspond to isolated factors within the case study that are worthy of substantive attention (Yin, 1981). It consists of an interpretative technique designed for individual accounts providing a wealth of contextual information (Ayres et al., 2003). For this thesis, the purpose of the case study analysis is to create a single unit of information on the intermediary function. This is possible by using secondary data to develop a self-contained narrative based on the case study approach.

Once the case study analysis is assembled using the secondary data, the researcher proceeds to compare these with the primary information. This allows him to identify factors which are common between both sets of primary and secondary data. This analytical operation is conducted in the following way:

i. Once the categories are identified from the voices of participants, the researcher reconnects the relevant statements found in the interviews with the case study analysis.

ii. This permits searching for patterns in the primary data by comparing secondary information that was similar to the original statements from interviews, without introducing new ideas not represented in the original accounts (Ayres et al., 2003).
iii. Such an approach enables the researcher to reach theoretical saturation by triangulating data using a variety of methods (Carruthers, 1990).

In summary, the explanatory type of analysis obtained from the case studies can offer relevant insights that contribute to comparing the opinions expressed by the interviewees and observing if these match with the secondary data. Consequently, the comparisons will allow to establish a generalisation that enhances the reliability of results. Moreover, this provides illustrative accounts of the intermediary functions during the socio-technical transition in the UK energy supply sector.

4.4 Limitations

This section succinctly considers the limitations of the qualitative research method proposed. To address these, the criteria introduced by Lincoln and Guba (1985) will be used to discuss trustworthiness in this investigation. These are credibility, transferability and dependability.

4.4.1 Credibility

Guba and Lincoln (1989) have stated that credibility can be a serious problem in a qualitative investigation because the analysis of information lies with the researcher’s interpretations. This can lead external stakeholders to formulate doubts about the research process. Nonetheless, this issue can be addressed when the primary data fits the researcher's representation (Tobin and Begley, 2004). One of the techniques to increase such a fit is the prolonged triangulation of data (Lincoln and Guba, 1985). This constitutes the central purpose for using secondary data to develop case studies in this thesis.

4.4.2 Transferability

It refers to the generalisability of inquiry (Nowell et al., 2017). This study will attempt to provide broad descriptions –particularly using the conceptual framework from Chapter 3– that can serve scholars to conduct similar investigations in other industrial sectors and judge the transferability of the approach used in this thesis. As the research has a clear scope defined in sub-section 4.3.1.1, it will be applied to the context of the UK energy supply sector. Then, the Discussion Section (Chapter 7) will assess the transferability of the conceptual framework to other empirical contexts.

4.4.3 Dependability

This criterion refers to ensuring that the research process is logical, traceable and lucidly documented (Tobin and Begley, 2004). This study considers a substantial volume of data that could be difficult to trace for an external auditor. In turn, it could lead to arriving at comparable but not similar conclusions, questioning the theoretical and method decisions. However, this thesis can offer the documents for conducting an eventual cross-checking of the inquiry process, as Anney (2014) recommends. NVivo has the raw data from the interview transcriptions, observational notes, documents and records collected from the field in a single software document.

4.5 Chapter summary

This chapter presented the research method this investigation will employ, providing a rationale for selecting a specific method over other options. It illustrated how the epistemological assumption made it possible to select the qualitative research, based on the principles of the abductive reasoning. The method involves a mixture of qualitative approaches separated into two main stages. First, the study collects primary data from semi-structured interviews with relevant participants. This information will be analysed through a thematic analysis to arrive at results related to the development of capabilities in incumbents and niches by the influence of transition intermediary functions. Second, the study collects secondary data from public databases to configure case studies to be presented as vignettes next to the main text of the analysis. This information will be examined seeking patterns and comparing the data collected in the first stage. In all this process, the conceptual framework (Chapter 3) had a great influence on designing the qualitative research. The next two chapters will present the results obtained by this investigation.

5 The development of absorptive capacity in UK incumbent energy firms by transition intermediaries

This chapter presents the qualitative analysis of the development of capabilities that incumbent firms have cultivated with the assistance of transition intermediaries to absorb technology innovation. The main goal of this chapter is to address Research Question A (see p. 3 on Chapter 1). This question will be answered using the conceptual framework (Chapter 3), guiding to explain how transition intermediary functions influence the development of capabilities for each dimension of absorptive capacity.

The analysis in this chapter is presented according to the steps previously detailed in the mobilisation of the conceptual framework in the Method Chapter (Section 4.3). Thus, the following analysis is divided into the four dimensions of absorptive capacity: Section 5.1 Acquisition; Section 5.2 Assimilation; Section 5.3 Transformation; and Section 5.4 Exploitation. These dimensions contain a specific group of capabilities, according to the conceptual framework (Figure 3.1). This helps us to structure the analysis in the following way: sub-section 5.1.1 discusses the capability to identify new technology opportunities; sub-section 5.1.2 capability to connect with the R&D community; sub-section 5.2.1 capability to de-risk external technology; sub-section 5.2.2 capability to create technological roadmaps for the assimilated knowledge; sub-section 5.3.1 capability to overlap the knowledge acquired with the firm's internal knowledge; sub-section 5.3.2 capability to separate the knowledge source between sender and receiver; and sub-section 5.4.1 capability to speed to market. Each of these sub-sections is accompanied by case studies presented in a vignette format, following the method approach described in sub-section 4.3.5.

It is important to note that through this section, a referencing system is used for quoting the statements made by the interviewees as a means of increasing the transparency of the analysis. Additionally, it provides a significant characteristic of each participant of this research through their job title, without compromising their identity. These are used in conjunction with quotes; whilst in other cases, the interviewee reference is used to emphasise findings in the narrative, without necessarily quoting a statement. For example, a reference such as "Incumbent Head of Merger and Acquisition (INC 2)" is made. The first part relates to the level of the participant in this research (in this case she/he works for an incumbent firm); the second part constitutes the professional capacity of the interviewee; and finally, the third part is the reference code that the reader might use to locate complementary information on the interviewee via the Appendix A.

5.1 Acquisition

5.1.1 Capability to identify new technology opportunities

According to the analysis, incumbents' capability to identify new technology opportunities has been traditionally associated with finding solutions that can improve energy efficiency. Interviewees have discussed how this incumbents' capability mainly concentrates on maintaining or improving the existing technology base as opposed to disruptive innovation. According to Niche Senior Consultant (NIC 4), utility companies are very risk averse and have problems taking advantage of new technology opportunities. This is due to their preference to add improvements to the current centralised energy supply system to make it more efficient. In his opinion, this option increases the capacity of energy distribution using existing infrastructure and avoids the risk of introducing new technology. "*They are familiar with running the business as is today. But making the transition on the business of tomorrow is really difficult for them*", Niche Senior Consultant (NIC 4) has said.

Nonetheless, the public policy announcement by the UK Government to achieve a net zero target by 2050 has pushed utilities to consider different technology opportunities, deviating from their usual expertise on energy efficiency. According to Incumbent Former R&D Director (INC 8), utilities have not yet embarked on pursuing these opportunities, due to the long timeframe required to move the lab-scale idea through technical and commercial development. In a journey that demands complex demonstrations in the power system that will probably affect energy security. In the words of Incumbent Investment Director (INC 1): "*Many technology companies are there for years developing innovation that never comes to market*". Such a prospect is not suitable for the profile of corporate shareholders in the energy supply industry, who prefer to have stable businesses when they invest in utility firms. Thus, the inclination to finance known activities restricts the capability to identify new technology opportunities. In other words, the risk is too large for utilities to consider technology opportunities related to the net zero transition. "*The only innovation and investment on research we tended to see is operational and how utilities can improve that type of performance in the energy supply, rather than to develop a whole new technology*", Incumbent Former R&D Director (INC 8) has mentioned.

Transition intermediaries attempt to remedy this situation by supporting the identification of different technology opportunities, by reducing the level of risk to an acceptable level for incumbent firms. Thus, transition intermediaries work towards connecting the incumbents' needs with niche innovations to address technology opportunities that can bring new solutions for the net zero goal. Intermediary Chief Technology Officer (INT 1) has explained that transition intermediaries collect information from utility firms to understand what the technology opportunities are that incumbent firms have not fully addressed. With this information at hand, the transition intermediaries engage with socio-technical niches to target these opportunities assessing what technology innovations are available for linking both sides. "*The work that we do has helped to shift how the energy companies think about innovation and they have recognised that external innovation plays a great role in achieving the objectives they are supposed to reach*", Chief Technology Officer (INT 1) has commented.

Consequently, the findings of this research can state that the most influential transition function for shaping the capability to identify new technology opportunities in incumbent firms is **Relationship Building**. By implementing this function, transition intermediaries connect players who have little history of previous collaboration. Nevertheless, working together can effectively solve a technology opportunity of relevance for the net zero goal. Associated with these efforts, intermediaries implement the function of Relationship Building in four steps.

The first step involves intermediaries holding initial discussions with incumbent firms to identify technology opportunities that sit outside their business as usual based on operational efficiency and energy security. Such insights allow intermediaries to outline transition priorities from the incumbent firm's perspective and then seek the technology development located in socio-technical niches, such as university departments, R&D centres, or technology start-ups. The expectation is that these links will generate different innovation outputs, able to accelerate the decarbonisation of the energy supply industry. Intermediary Operational Director (INT 4) has added on this matter: "*We need to understand from utility firms what are the challenges for them. So, when we engage with innovation suppliers and academics, we can target those priorities*". In his opinion, this intermediary action facilitates the identification of technology solutions that serve a transition goal in incumbent firms; therefore, utility companies will be more receptive to working with niches. Consequently, the transition intermediary function of Relationship Building heightens the capability to identify new technology opportunities for incumbent firms.

In the second step, the intermediaries intensively search for innovative solutions closer to commercialisation, including even those that do not belong to the energy sector but could have a potential application in the energy industry. This option is assessed against the needs identified through the previous dialogue with utilities. In such cases, the function of Relationship Building is focused on making the proper links between a niche organisation having a technology concept that would solve an incumbent firm's problem. Thus, the main interest of this intermediation function relates to producing a technology transfer connection in which the innovation can be acquired by the incumbent firm. Even if this means involving cross-sectorial organisations. "*We do a lot of this, where small companies have put equipment that could be moving across other sectors, such as energy*", Intermediary Senior Manager (INT 11) has commented. He has added that this is possible due to the neutral position of the transition intermediaries, sitting in the middle and pushing actors in the appropriate direction connecting the small player with the big company.

The third step consists of the presentation of the new technology to the incumbent firms. Sometimes, the intermediaries arrange this encounter by asking the socio-technical niche to do a presentation in a pitch format. If the niche is capable of demonstrating that the innovation addresses the incumbent's need, it can proceed to the fourth step, where the new technology will receive corporate investment, arriving at a formal acquisition by the utility firm. The Intermediary's Technology Accelerator Director (INT 2) has confirmed that incumbent firms are receptive to acquiring socio-technical niches when these are introduced by the action of transition intermediaries. He has added that this intervention "*makes utility position more engaged with clean technologies and net zero type solutions*". The following

Case Study A illustrates the intermediary function of Relationship Building executed in four steps.

Case Study A – Knowledge Transfer Network (KTN)
Intermediary function of Relationship Building

KTN is an example of the Relationship Building function, leading the four steps process for enhancing the capability to identify new technology opportunities in incumbent firms explained in 5.1.1. KTN is located in the interface of the public and private sectors building links between innovators and larger business partners "*beyond their existing thinking, accelerating ambitious ideas into real-world solutions*", as declared on its website (KTN, n.d.[a]). A specific programme created by KTN in 2019 is KTN-iX. This aims to support the technology transfer from a smaller innovative firm to an energy incumbent (KTN, n.d.[b]). To deliver this programme, KTN has identified, with key industry stakeholders, specific challenges through a series of guided workshops.

The challenges are grouped around themes, with a particular utility firm seeking innovation to solve issues of the net zero transition. One of these themes is "Solutions to Decarbonise Heat" (KTN, n.d.[c]), where the Engie Group, a multinational utility company with operations in the UK, is looking for new technologies that validate the provenance of low-carbon fuels and allow heat networks to integrate with other energy systems.

The candidates submit a proposal that is evaluated by the Engie Group, with the support of KTN. The pre-selected innovation projects have the opportunity to pitch the new technology to the incumbent firm. Finally, the niches capable of demonstrating that the innovation addresses the goals of the heat decarbonisation challenge will receive corporate investment.

The awarded project will obtain 50% funding from Equans, an autonomous business unit within Engie Group. The other half will come from an Innovate UK grant negotiated by KTN. The project will cost a maximum of £ 1.2 million to be equally divided between the private partner, as an equity investment, and the public partner, as a non-dilutive grant.

The response from incumbent firms to the intermediary function of Relationship Building has resulted in an increased commitment to exploring technology opportunities out of their operational radar. For instance, Engie Fab is the new business unit investing in technology opportunities of the utility company Engie, which are organised through thematic programs (Engie, 2019). The selected projects are commercially evaluated before investment through corporate acceleration. Currently, the company has accelerated three innovation projects: (i) clean cooking; (ii) distributed energy management system; and (iii) blockchain for renewables. The last two have been implemented in the UK.

In summary, transition intermediaries contribute to developing capabilities for identifying new technology opportunities in incumbent firms by detecting the profound needs of the industry responding to transition goals. Accordingly, the transition intermediary function of Relationship Building seeks solutions around a different group of new technologies, even outside of the energy application, and presents these at incumbent firms. Thanks to such intermediation efforts, incumbents are more receptive to investing in socio-technical niche projects. The following Figure 5.1 illustrates the analysis presented in this sub-section, using the conceptual framework (Chapter 3).

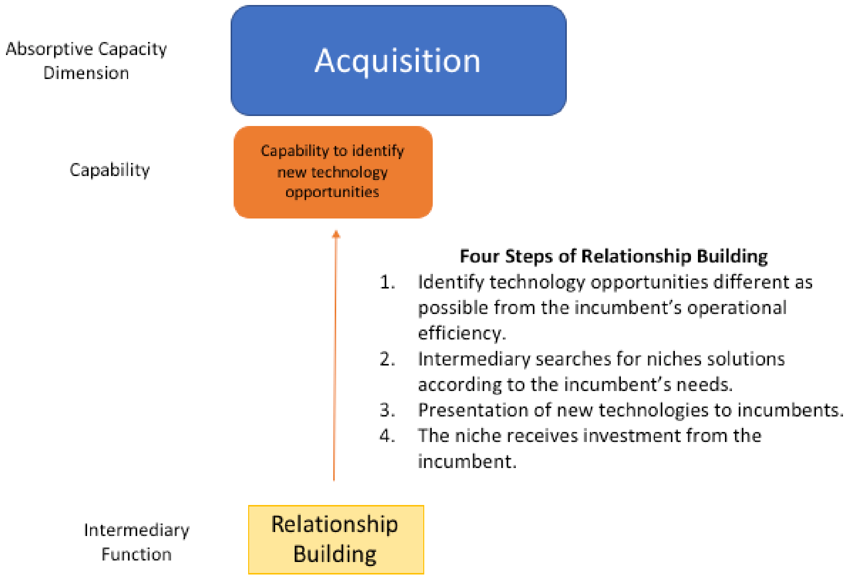

Figure 5.1 Intermediary function to develop the capability to identify new technology opportunities

5.1.2 Capability to connect with the R&D community

The possibility for incumbent firms to connect with the R&D community can benefit both sides. The R&D community connects to industrial partners who understand the final user and "*provide the opportunity to test new concepts in a real environment*", according to Niche Researcher (NIC 1). Whilst incumbent firms can benefit by obtaining privileged access to relevant technological spillovers, rarely available in the private sector. For this reason, they are interested in collaborating with public R&D institutions, such as universities, faculty departments and government research centres to generate leverage of resources. "*In that way, we can do fundamental research without having to do it all by ourselves*", Incumbent Head of Innovation (INC 4) has explained.

For instance, Incumbent Innovation Manager (INC 5) has pointed out that a complex technological challenge requiring additional research is the integration of large-scale energy storage with renewable sources. In his opinion, the increasing share of variable renewables in the energy supply system is calling for a technology that can store excessive energy production when an energy source like the wind is high, and later use this power to provide generation when the demand increases. This will contribute to reducing the dependency on fossil fuels and achieve an important goal of the net zero transition, according to Incumbent Head of New Technology (INC 3): "*It is an emerging market that we see as an enabler to allow additional renewable penetration into the network*".

However, there are important issues about how the technology will perform combined with wind turbines in the UK. Specifically, understanding what type of technologies and operation strategies are needed to satisfy customers' demands at the right time. "*We have to find out those answers in collaboration with the academia and pan out a whole route to explore possible technologies meeting such questions*", Incumbent Innovation Manager (INC 5) has reflected on the links between utility firms and the R&D community.

This example illustrates that utility firms are inclined to connect with the R&D community and accessing for particular technological knowledge when this is not available in the private sector. However, uncertainties around this relationship make it difficult for the R&D outputs to reach the commercialisation stages. The analysis of interviews has indicated two significant barriers in the links between academia and the UK energy supply sector.

First, the slow response of institutional regulations to support a certain technological pathway. This could allow utility companies to make investment decisions in the long term for specific technology development. In this case, the incumbent firms would prefer to have a strong indication from energy regulators that new technology areas would not be affected by changes in the market framework. Consequently, an energy firm will have the assurance that the investment in new technologies will be stable. Intermediary Technology Director (INT 2) has identified such constraints in regulation as the main reason for technology adoption.

In his opinion, the acceptance of new technology in the energy supply sector requires a long time, negatively influencing the relationship between incumbent firms and the R&D community for acquiring innovation. "*It is extremely capital intensive and companies want solid ground that investment won't be affected*", has commented.

Second, the high investment to acquire new technologies, particularly to create new or alter existing infrastructure. This action usually depends on public funds provided by a transition intermediary –such as Innovate UK, the main public body for research and innovation in the country–, rather than private funding coming from utility firms. Incumbent Former Research Director (INC 8) has mentioned that this is simply because shareholders who invest in utilities are looking for a safe bet: "*They are not at the high-risk investments, which is what you have with technology development*". Thereby, corporate governance can be considered an important constraint to this capability, due to the costly experimentation necessary to move the innovation forward through subsequent development stages. Precisely, the hesitancy of incumbent firms to acquire a new technology coming from the R&D community can be attributed to additional investment in infrastructure that the innovation might require to operate. "*If this were the case, the payback for investors is much longer and quite often uncertain, making it very difficult to convince corporate boards to acquire new technology coming from academic R&D*", Incumbent Head of Policy (INC 9) has explained.

Transition intermediaries intervene in these issues by deploying the function of **Articulation of Transition by Knowledge Exchange**. They seek to gather information by organising demonstration projects of R&D results in real conditions, involving the collaboration of socio-technical niches and incumbent firms. In these trials, intermediaries lift some of the regulations, allowing the technology to experiment more freely. Later, this information is analysed by transition intermediaries and presented to energy regulator institutions, like Ofgem. In this way, transition intermediaries influence public policy decisions to adjust legal restrictions to adopt new technologies.

Intermediary Integration Manager (INT 7) has detailed how the learning derived from demonstration projects "*can facilitate those challenges where the R&D is coming up against legal barriers and indicate the course of action needed for regulators to move forward the innovation*". In this case, Intermediary Innovator Support Manager (INT 12) has stated that the role of intermediaries is to show how the markets could be developed by gathering evidence on trying a solution at a larger scale. Based on this evidence, the intermediary presents recommendations to regulators: "*Then, the business has the opportunity to move into commercialisation much faster*", he has said. This resolves part of the barriers affecting the link between incumbent firms and the R&D community.

Additionally, the transition intermediary function of Articulation of Transition by Knowledge Exchange helps to evaluate the real cost of upgrading elements in the energy supply system, which can be necessary to integrate new technology. Incumbent Head of Policy (INC 9) has explained that materialising a demonstration project in this way provides certainties about the trajectory that the new technology would have in the future. In this regard, incumbent firms become more comfortable with the acquisition of a technology coming from the R&D community by knowing the upfront cost and the prospects of regulation. This provides a better argument for internal discussions "*about how to proceed with the cost-benefit analysis and feeling more confident that the regulatory framework will point in that direction too*", Incumbent Head of Policy (INC 9) has said. The following Case Study B confirms the findings extracted from the interviews.

Case Study B – Innovate UK

Intermediary function of Articulation of Transition by Knowledge Exchange

An example of the interaction between incumbent firms and the R&D community with the support of transition intermediaries is the Fusion Project. This aims to develop a smart energy network, where energy flexibility and demand-side response can be bought and sold (Imperial College of London, 2018).

The project is led by the Imperial College of London and has received funding of £6 million from Innovate UK. Scottish Power is one of the industrial partners required by the rules of this innovation competition. The utility company has been testing the new technology developed by the academic partner in East Fife, Scotland. Scottish Power has declared on its website that the possibility to operate more flexibly the network means that it can meet local demand whilst ensuring stability and security of supply, enabling more low-carbon technologies to connect (SP, 2020).

Under this project of collaboration, the Department of Business, Enterprise and Regulatory Reform (DBERR) lifted some of the regulations to test this new technology and ensure that the main learning goal was met (SP, 2020). This action resolved the first barrier described in the relation between incumbents and the R&D community in sub-section 5.1.2.

Moreover, the utility firm through this project with the R&D community was capable of alleviating localised network congestion without requiring costly and time-consuming network reinforcement. Fusion Project presents a realistic business case that could save customers over £236m, in addition to 3.6 mtCO2 by 2050 (SP, 2020). This aids in overcoming the second barrier described in the relationship between incumbents and the R&D community.

In summary, through the function of Articulation of Transition by Knowledge Exchange, transition intermediaries collect information from the interaction between the R&D community and incumbent firms to later influence the decision on regulatory institutions.

Figure 5.2 illustrates this intermediary function, which it deploys to overcome two main barriers in the relationship between incumbent firms and the R&D community. The first is the slow response of institutional regulations to support an emergent technological pathway. In this instance, the transition intermediary helps to collect data from demonstration projects to be later used for influencing regulator institutions and facilitating the elaboration of a new policy that favours the adoption of specific technology trajectories. The second barrier is the high investment needed to insert the new technology produced by the R&D community into the energy network. In this instance, the transition intermediaries collaborate in providing important inputs for the economic analysis of adopting the innovation by incumbent firms. This action elucidates the new infrastructure required, evaluating the level of capital required and forecasting the return on investment. This presents a clearer case of technology investment to corporate shareholders making it possible to acquire the innovation generated in the academic world, in a form that makes sense with the incumbent's economics.

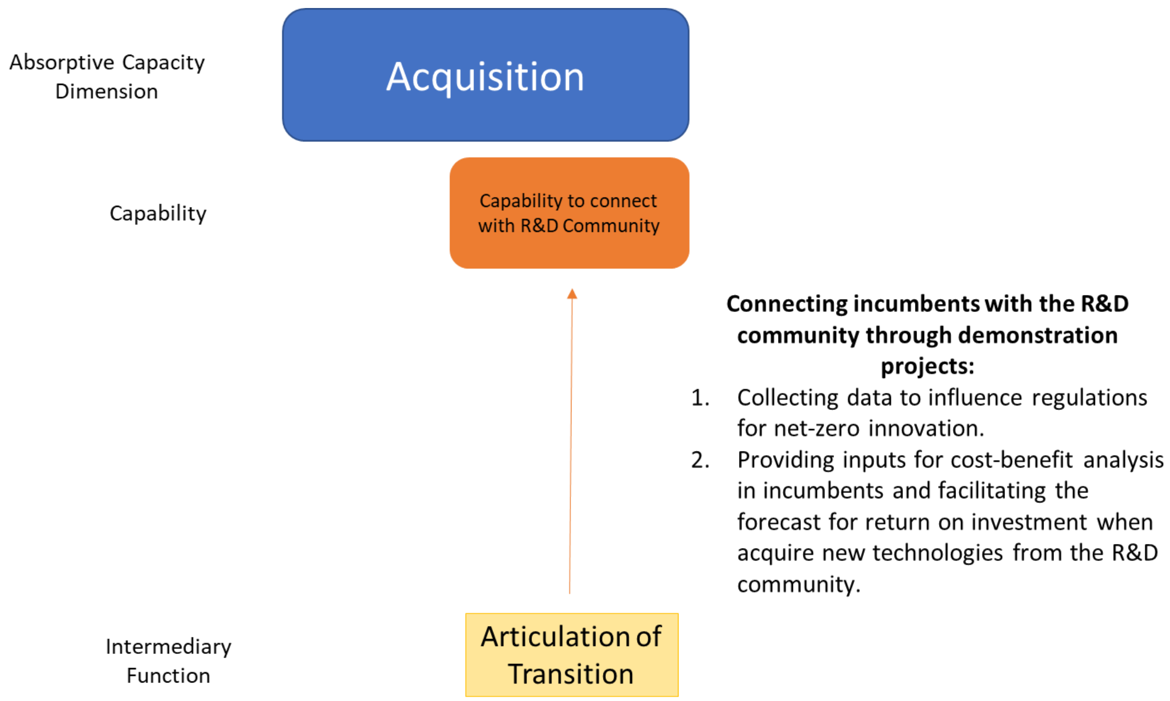

Figure 5.2 Intermediary function to develop the capability to connect with the R&D community

5.2 Assimilation

5.2.1 Capability to de-risk external technology

A critical aspect mentioned in the interviews about the assimilation of external technologies is the uncertainty that the innovation presents in terms of imperfect functionality to potential acquirers in the energy supply sector. The elements causing imperfection must be edited or de-risked to get a proper integration into the energy supply system, reducing the concerns that the external innovation proposes to the internal know-how of utility firms.

Participants of this research have commented that energy incumbents are not particularly inclined to develop such activities because they could damage the stability of the current energy supply system. Niche Researcher (NIC 1) has observed that incumbent firms "*prefer a robust system, instead of a flexible one because the first provides energy security*". This claim is supported by the substantial investment that incumbent firms have made to reach constant energy provision to large population areas in the UK. As a result, utilities are not in a favourable position to modify these aspects for integrating new technologies that potentially will reduce the stable performance of the energy supply system. Intermediary Project Manager (INT 6) has commented that due to this reason is hard to find companies willing to assimilate new technology and integrate it into their operations: "*Everybody is second to adopt something in the energy supply industry*".

The analysis identifies two critical aspects deterring the capability to de-risk new technologies. First, the external technology needs to demonstrate how it will not generate disruption in incumbent firms' supply of energy. Second, the new technology has to offer economic value to incumbent firms, coming close to offering a similar energy production at the same cost as the current energy supply system does.

In this regard, participants have considered that one of the main functions of transition intermediaries in the energy supply sector is to provide facilities for removing the risk in the early development of new technologies. This action enables the assimilation of external innovation in incumbent firms, without using the real energy supply system as a laboratory for experimentation. Consequently, the transition intermediary function of **Management of Resources** provides specific facilities for demonstrating new technologies and moving the innovation closer to the goal of being assimilated by the incumbent firms. These facilities consist of dedicated spaces in which new technologies are tested with the purpose of accelerating them towards commercialisation.

Participants of this research have detailed that the core offering of transition intermediaries is to identify elements of the new technologies that are not reliable enough, proposing the opportunity to correct these issues. This will improve their potential integration into the energy supply system. Intermediary R&D Director (INT 10) has explained that the main goal of a demonstration centre is to accelerate the speed of de-risking a new technology moving it towards complete assimilation into the energy supply system. "*We take the data on this demonstration centre, and we say this is how the device or even the system is working, investigating what went wrong and what caused the problem. We can reduce this process from the range of three years, if you want to do it in the real network, down to a couple of months*", he has said. Consequently, demonstration centres solve the first uncertainty expressed by incumbent firms related to the operational reliability of external innovation. Case Study C presents an illustration of the transition intermediary function of Management of Resources.

Case Study C – Power Networks Demonstration Centre (PNDC)
Intermediary function of Management of Resources

PNDC is a research and testing site for multi-vector energy systems located in Glasgow, Scotland. PNDC was founded by the government, industry and academia in 2013 to provide "*a platform to accelerate the deployment and integration of energy networks and technologies through advanced capabilities in system integration and collaborative industrial research*" (PNDC, 2013).

PNDC has a research team in connection with the University of Strathclyde to support technology demonstration. This consists of simulating an energy system that can receive a technology innovation for testing. The goal is to reduce the uncertainties that new technologies present to supplier companies by demonstrating the operational feasibility of the new technology in a simulated energy system. As a result, this activity moves the innovation closer to being assimilated by the utilities without altering the stability of the energy supply system.

Additionally, the intermediary function of Management of Resources accompanies the technical testing with further analysis for reducing the economic cost of the technology. This solves the second concern of incumbent firms in terms of economic feasibility. Such an intervention was described by Niche Researcher (NIC 1) as the construction of a "*business* *case*". This consists of the evaluation of the financial benefits and costs of the intended solution compared to dominant alternatives. A support that Niche Research (NIC 1) has received from transition intermediaries. Precisely, he has collaborated in optimising the size of a new storage infrastructure to connect it with the energy produced by wind turbines and later distribute it to the electricity network. In such technology trials, he has consigned that in addition to technological development, economic variables are considered within the intermediary's testing facilities. As the economic calculation was carried out and reached an adequate value for the industry, the transition intermediaries facilitated the assimilation of the new technology in the commercial sphere of incumbent firms. Then, the technology development arrived at a point where the utility firm wanted to connect the innovation to the real network for validating the performance achieved in the demonstration centre. "*So, with the help of an intermediary organisation, we are going to install the new technology in a wind farm, confirming if the economic inputs and outputs to be obtained are those expected*", Niche Researcher (NIC 1) has confirmed. Case Study D presents an instance of this transition intermediary's function of Management of Resources.

Case Study D – Catapult Centre in Offshore Renewable Energy (ORE)
Intermediary function of Management of Resources

An example of the support that intermediaries provide to build a business case is ORE. In 2020, ORE facilitated the validation of a new technology that utilised existing optical fibre networks to transfer electrical parameters. These parameters are required by electricity network operators for primary and ancillary monitoring functions. Such a solution prevents subsea cable failure, which creates a significant loss of power generation from offshore wind turbines to the onshore network.

The developer of such technology is the start-up company Synaptec, whose sensors can achieve this task without power supplies or data networks. ORE installed this technology in their demonstration turbines in Levenmouth, Scotland, during a year-long trial. The goal of testing the technology in a realistic environment was to "*establish the cost savings and long-term benefits of using the technology to monitor cable performance*" (ORE, 2020).

The results demonstrated that the technology was economically competitive and allowed Synaptec to have access to a larger trial with the European Offshore Wind Deployment Centre in Aberdeen, Scotland. This time with the collaboration of the Swedish multinational power company Vattenfall. ORE acts as a link between both companies, providing expertise in engineering, coordination, planning, dissemination and marketing support (ORE, 2020).

In summary, the analysis found that incumbent firms have a limited capability to assimilate external technologies into the energy supply system. Instead, incumbent firms can outsource pilots of new technologies to intermediary demonstration facilities.

Figure 5.3 shows that the intermediary function of Management of Resources is deployed through demonstration centres, reducing the uncertainties of innovation in two main aspects. First, the demonstration centres support the reduction of risks on new technologies in both technical and economic aspects, facilitating the assimilation of external innovation into the incumbent firms. This solves a critical issue for utility companies without compromising the stability of the energy supply. Second, Management of Resources helps to build business cases, validating the technology performance in economic terms. In this way, utility firms can assimilate the external innovation by learning not only its technical performance but also the economic outputs bringing the new technology closer to being integrated into the energy supply system.

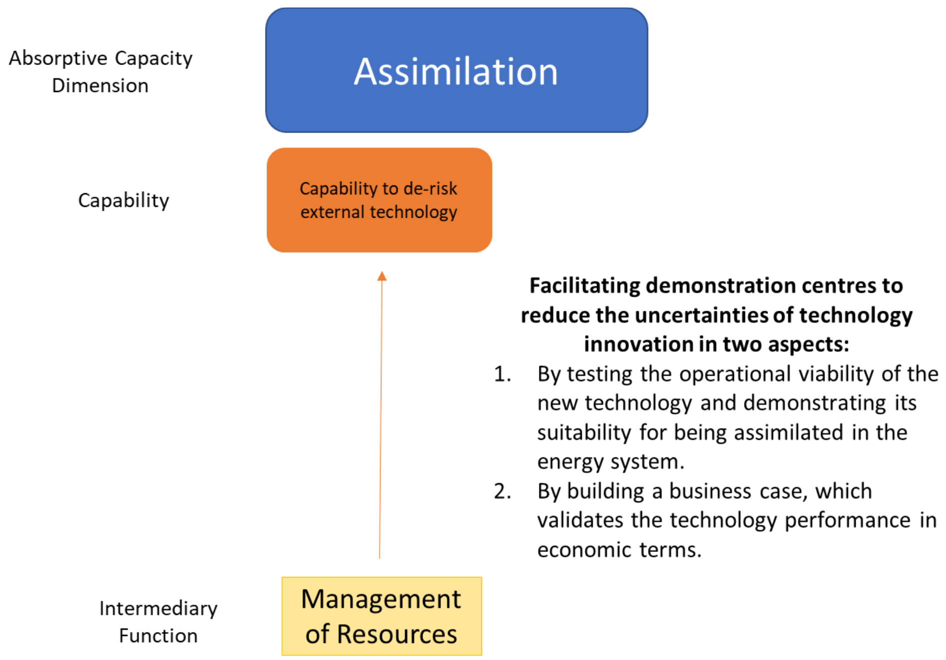

Figure 5.3 Intermediary function to develop the capability to de-risk external technology

5.2.2 Capability to create technological roadmaps for the assimilated knowledge

The energy transition is a topic of great relevance to utility firms, according to interviews. They are constantly considering routes the industry could take for decarbonising energy supply, each with its particular trade-off. To proceed with this analysis, incumbent firms – such as Scottish Power, Centrica, and EDF, to name a few– have a "future team" in charge of creating scenarios for the energy transition. Such corporate departments evaluate the volume of energy that would be needed in the future and the net zero options from which it would be produced. To conduct these investigations, future teams elaborate projections based on different public reports, combined with stakeholder engagement and market research. The proposed scenarios attempt to portray a credible range of outcomes and inform the annual planning and operability of incumbent firms, including investment decisions, policy development and a general understanding of the way the country will supply and consume energy between now and 2050. "*A lot of these companies have future teams. They develop their own pathway that is shared to see what innovation is needed*", Intermediary Innovator Support (INT 12) has confirmed.

Consequently, utility firms create reasonable scenarios for the short term and are well prepared to expand the current technologies that have demonstrated positive behaviour within the incumbents' business operations. Nevertheless, they are less prepared for the longer term. Incumbent Innovation Manager (INC 5) has mentioned that the corporate plans in his company are concentrated on enhancing innovation around wind farms. He has explained that developing a wind farm project requires at least two years. During this time, wind turbine technology can change. Accordingly, the development team is constantly monitoring the latest technologies to be sure they are working with expected deliveries in this technology field. For this reason, they have the proper information to construct a technological roadmap in the short term, helping them to analyse the trends that would affect the deployment of new projects.

On the other hand, long-term roadmaps are not particularly well-developed by incumbent firms. "*We have a good understanding of the upcoming technology in that field for 2025. Beyond that, we do not have a clear long-run map*", Incumbent Innovation Manager (INC 5) has acknowledged. Thus, the data obtained through the interviews have suggested that the capability to create technology roadmaps in incumbent firms is concentrated on expanding the current energy supply system capacity by adopting incremental innovation in known trajectories. From this perspective, energy companies tend to be conservative in the way they propose technology scenarios and accordingly act, as Incumbent Former Renewable Manager (INC 11) has explained: "*In general, those companies assimilate technologies that fit into the stable supply of energy*". This makes it difficult to look at innovation as a separate class from the current business. This leaves little room for utilities to coherently organise complex factors and design long-term technological roadmaps.

In this case, the neutral position of transition intermediaries enables them to connect with a wide variety of actors in the energy technology innovation system and collect diverse information that serves the purpose of promoting innovation in multiple transition scenarios for the long term. As they are not exclusively focused on one issue of the energy transition, transition intermediaries can detect and organise the complementariness of actors and information through the function of **Articulation of Transition by Knowledge Exchange**. This allows it to enlarge the generation of technology roadmaps to longer periods, extending the time of the initial short-term roadmaps considered by the incumbent firms.

One mechanism that intermediaries utilise to develop long-term strategies for the energy transition is to establish multi-disciplinary boards. Interviewees have highlighted that strategic boards in transition intermediaries are composed of diverse actors from the energy TIS. Commonly, intermediaries invite utility firms to integrate these boards to bring the industrial perspective, which in combination with the presence of innovation producers enriches the discussion about the future pathways for the energy supply towards the net zero target. Incumbent Head of Innovation (INC 4) has stated that the opportunity to be included in intermediary strategic boards has provided him with access to new ideas that can be applied to the long-term future of the energy supply: "*We find this collaboration a great way to share priorities and resources […] and helps us to do the spread of innovation in terms we cannot by our own*".

The dialogue at those meetings varies according to the possibility of inserting the innovation into an existing energy infrastructure. For instance, if there is an opportunity to add new technology to a wind farm, the incumbent firm will be looking for high equipment development. The assimilation of new technology into the prevailing infrastructure provides the chance for the innovation to become commercially viable. This addresses on one hand the short-term aspects of the roadmap for net zero transition. On the other hand, if the technology is not yet mature, the transition intermediary is committed to finding the expertise capable of moving the technology to an upper level of development. In this case, transition intermediaries capture and process data from R&D activities to understand the development of technology and support the generation of long-term roadmaps.

Intermediary Chief Technology Officer (INT 1) has explained how transition intermediaries undertake the modelling of transition scenarios at national, local and building scales. Serving as an important input of information to expand the forecasting of incumbent firms based on centralised energy supply systems into multiple levels of analysis. "*The transition analysis for particular areas reveals new opportunities for bringing innovation to the supply chain controlled by incumbent supplier firms*", Intermediary Chief Technology Officer (INT 1) has commented. Thus, the intermediaries' modelling of technological roadmaps creates insights that can be used by the energy supply firms to forecast different scenarios and elevate long-term priorities. Case Study E presents an instance of this transition intermediary function of Articulation of Transition by Knowledge Exchange.

Case Study E – The Carbon Trust
Intermediary function of Articulation of Transition by Knowledge Exchange

The Carbon Trust is an independent organisation set up by the UK Government in 2001 to drive energy innovation and accelerate the transition to a low-carbon economy. Part of its role is discerning how the future energy system will evolve. An information later transmitted to raise "*awareness and action on Net Zero by drawing on the Carbon Trust's 20 years' experience of working with businesses, governments and financial institutions globally*" (Carbon Trust, 2021).

The organisation has engaged with UK distribution network companies to visualise and integrate coming innovation by: "*identified five system-wide enabling conditions that can unlock progress on Net Zero: awareness and ambition, governance, finance, technology and innovation, and a just transition*" (Carbon Trust, 2021).

Incumbent Innovation Manager (INC 5) has commented that his firm is a member of an industrial board with the Carbon Trust, in which they are sitting with the biggest offshore wind developers. During board meetings, they discuss technology development and explore the possibility to adopt an innovation, creating long-term technological roadmaps for assimilating new concepts. "*Carbon Trust gives us additional information to talk about the future opportunities that we think are coming*", he has said.

This considers options beyond just improving wind turbine performance, but the integration of new value propositions which might disrupt energy markets. Therefore, the Carbon Trust keeps "*a keen eye on sector-wide developments in order to inform our work in developing strategic outlooks*" (Carbon Trust, 2021).

Additionally, transition intermediaries facilitate the exchange of information between actors in the energy supply sector by taking the lead in the implementation of technology roadmaps and bringing to life innovation development. For this reason, the analysis showed that transition intermediaries deploy a second function. This consists of **Technology Forecasting**, whereby transition intermediaries support the elaboration of technological roadmaps. Particularly around long-term innovation development, in which they elevate priority areas of research and generate open contests for emerging technologies to demonstrate their advancement. By committing to such activities, transition intermediaries gather proof that some socio-technical niches have a prominent role to play in the future energy supply system. Furthermore, the intermediary offers the winning prototype the concrete possibility of being assimilated by the energy industry. Intermediary R&D Director (INT 10) explained this activity developed by intermediaries. First, they frame industrial challenges to which start-up firms or academic departments can develop a solution. "*Then we do a selection process and choose the winner who will have the chance to demonstrate the prototype in an R&D testing facility*", has added. Case Study F provides more details of similar instances promoted by transition intermediaries through its function of Technology Forecasting.

Case Study F – Power Networks Demonstration Centre (PNDC)
Intermediary function of Technology Forecasting

PNDC, the transition intermediary previously described in Case Study C, announced a competition for funding projects that can develop a range of innovative low-carbon hydrogen supply solutions (PNDC, 2021). The contest is organised by DBEIS and divided in two phases (DBEIS, 2021b).

The first stage will support the feasibility studies; and, the second phase selects projects for testing in demonstration centres. PNDC can be used as one of the testing facilities and confirm the new technology development. Such an intervention helps to forecast the introduction of new solutions into the market. This, in turn, enables the development of long-term technological roadmaps around innovation that currently does not exist in the energy supply industry.

In summary, transition intermediaries assist in the identification of technology development for the long term and help to integrate innovation through industrial roadmaps. Figure 5.4 illustrates that transition intermediaries support the development of the capability to create technological roadmaps by deploying two functions. Articulation of Transition by Knowledge Exchange –at the left side of Figure 5.4–configures multi-disciplinary groups in transition intermediary strategic boards, conformed by diverse actors of the energy TIS, such as technology producers, academics and incumbent firms. In these instances, utilities can have access to new technology concepts that can be added for elaborating long-term roadmaps. Technology Forecasting –at the right side of Figure 5.4– helps to demonstrate innovation developments in the following way. First, transition intermediaries elevate priority areas on the long-term targets for the net zero goal. Second, they organise competitions for selecting technologies produced by niches addressing the issues identified in the first step. Third and finally, transition intermediaries support the validation of these new technologies in demonstration facilities.

Using both functions, transition intermediaries support the assimilation of technology innovation beyond the incremental solutions that fit in the incumbent firms' known trajectories. It also includes the possibility to identify radical technology located in niches, with the potential to influence the energy transition in the long term. As a result, it can be said that incumbent firms are in a better position to assimilate technology information that makes it possible to create long-term roadmaps.

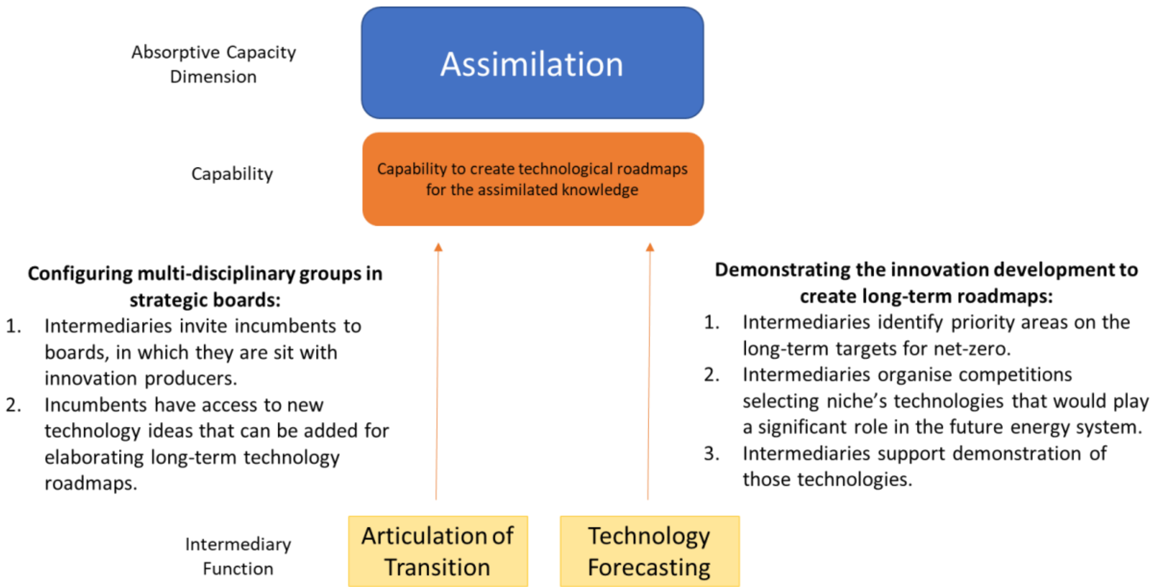

Figure 5.4 Intermediary functions to develop the capability for creating technological roadmaps for the assimilated knowledge

5.3 Transformation

5.3.1 Capability to overlap the knowledge acquired with the firm's internal knowledge

The capability to overlap external knowledge on the firm's technological base has been developed by utility companies in order to expand the capacity of the current energy supply system. According to the interviewees, incumbent firms have carried out this activity with extreme caution to not disrupt any service associated with the energy supply. When consulted about the plans on absorbing new technologies and transforming them into innovation outputs, Incumbent Head of M&A (INC 2) has explained that organisational goals are focused to be achieved "*in our space*", which he has defined as the increase of volume in the wind energy generation: "*In offshore wind, we have strategic targets that we announce to the market […] and are expressed in terms of gigawatts*". The statement reveals the preferable area where some of the incumbent firms plan to develop additional infrastructure and overlap suitable innovation for obtaining a larger capacity to supply energy.

Thus, the configuration of engineering resources to produce a higher volume of power can be interpreted as the pertinent sector in which incumbent firms will seek to overlap complementary knowledge. It is an area of corporate growth where they have a good command of the partnership model to connect with larger equipment manufacturers and access technology that increases the capacity for energy supply. The basis for sustaining relationships with such technology providers is supported by standard contract agreements. In these, the technology supplier slightly adapts the elements to be purchased by the UK energy companies to the local market necessities and regulations. Utilities prefer this option because the overlap of new technologies is offered by reliable providers. Moreover, the new technology does not demand extensive modification in the energy supply system for integration. "*Energy firms just want an adequate solution that fits into their current business which makes it easier to attend their massive customer bases*", Intermediary Senior Manager (INT 5) has commented.

Nonetheless, the net zero target has presented different challenges that are not going to be solved by incremental innovation, according to Incumbent Former Change Lead (INC 11): "*So, you look at hydrogen, renewable generation besides wind, new trading models. These are the forces to focus the industrial attention which not necessarily fit in known trajectories*". To achieve this goal, transition intermediaries implement the **Articulation of Transition by Knowledge Exchange** function. They unfold this function for collecting information that serves to localise nodes in the energy supply system. With such data, intermediaries overlap in those points the external technology innovation without altering the existing infrastructure of energy supply.

Transition intermediaries have detected that such nodes are related to the concept of "flexibility". This term refers to the extent to which the energy supply system can modify generation or consumption patterns in response to any variability, either in supply or demand, according to Intermediary Integration Manager (INT 7). In such a scheme, transition intermediaries gather relevant data to assess how and where different technologies can overlap in nodes inside of the energy supply system. Intermediary Integration Manager (INT 7) has said that these experiments gauge the maturity of the innovation and how the convergence of new technology in the node provides the sought flexibility: "*We are testing the impact the technology might have in the network and how the current assets can be used searching for flexibility to effectively integrate external innovation*".

Later the intermediary analyses if that flexibility is enough to impact the network on different scales for meeting net zero goals. In this regard, Intermediary Innovator Support (INT 12) has commented that most utility companies are interested in the innovation that could provide flexibility at the distribution level: "*Having a look at technologies that, for example, will connect homes with vehicles*".

Another technology field in which the energy industry is gradually reaching a meaningful portion of flexibility for the energy transition is digitalisation. Incumbent Former Change Lead (INC 11) has detailed that digital technologies deliver critical features of flexibility to smartly administer the variation of supply from renewable energy sources. Digitalisation concedes a cost-effective form to optimise the energy infrastructure and operations through the utilisation of data and control technologies without significantly altering the energy supply system. "*We are moving towards a net zero future in which utility firms have to concentrate on digitalisation as part of a new strategy*", Incumbent Former Change Lead (INC 11) has considered. Case Study G presents an illustration of the transition intermediary's function of Articulation of Transition by Knowledge Exchange.

Case Study G – Catapult Centre of Energy Systems (ES)
Intermediary function of Articulation of Transition by Knowledge Exchange

ES aims to accelerate the transformation of the energy system and "*ensure UK businesses and consumers capture the opportunities of clean growth*" (ES, 2017). This intermediary considers the digitalisation strategy as crucial for a cost-effective net zero transition. They predict that the adoption of new technologies by consumers can balance the intermittency of renewable energy and make it a source of power more prevalent in the near future (ES, 2021).

With this goal on the horizon, ES is working with socio-technical niches and incumbent firms to understand the potential of demand-side response technology through the FRED project (Flexibly Responsive Energy Delivery). This trial has tested a digital platform, developed by the niche's start-up Evergreen Smart Power, which integrates and manages energy technologies in real time. It also reacts to grid conditions and makes it easier for the energy system to be flexible according to the customers' consumption (Evergreen Smart Power, 2022). Additionally, the digital platform works with an electric vehicle charger that can be fed from homes' solar panels to later provide power to cars. Therefore, ES is gathering insights about consumers' expectations and the responses that consumers are offering to different commercial offers from utilities (ES, 2021).

Thus, the intermediary function of Articulation of Transition by Knowledge Exchange allows it to collect information about supply odes in the energy supply system that are capable of transforming external technologies into innovation outputs. Moreover, the intermediaries' attention to digitalisation, a technology field that does not demand a considerable modification on the energy infrastructure and provides flexibility to power supply and demand, offers the opportunity to overlap different niche technologies within the energy supply system for the net zero transition. "*The digital tracing platform has a lot of interest in the energy supply industry because it provides flexibility where other technologies can converge, such as EV chargers, heat pumps, and solar panels*", Intermediary Integration Manager (INT 7) has commented.

In summary, the intermediary function of Articulation of Transition by Knowledge Exchange procures to find nodes in the energy supply system. These offer the opportunity to overlap external technologies without affecting the security of power provision. Figure 5.5 exhibits this function unfolded in three stages by transition intermediaries. First, they detect nodes in the energy supply systems where technology innovation can be overlapped. Second, they arrange for the technology innovation to fit in these nodes and have the option to be transformed by the recipient organisation. Third, the capability to overlap external technology innovation is enhanced by transition intermediaries searching for solutions that can offer flexibility to the energy suppliers. This action balances the technology demand of incumbent firms from energy security-oriented solutions towards innovation that can contribute to the net zero goal, such as digital technologies.

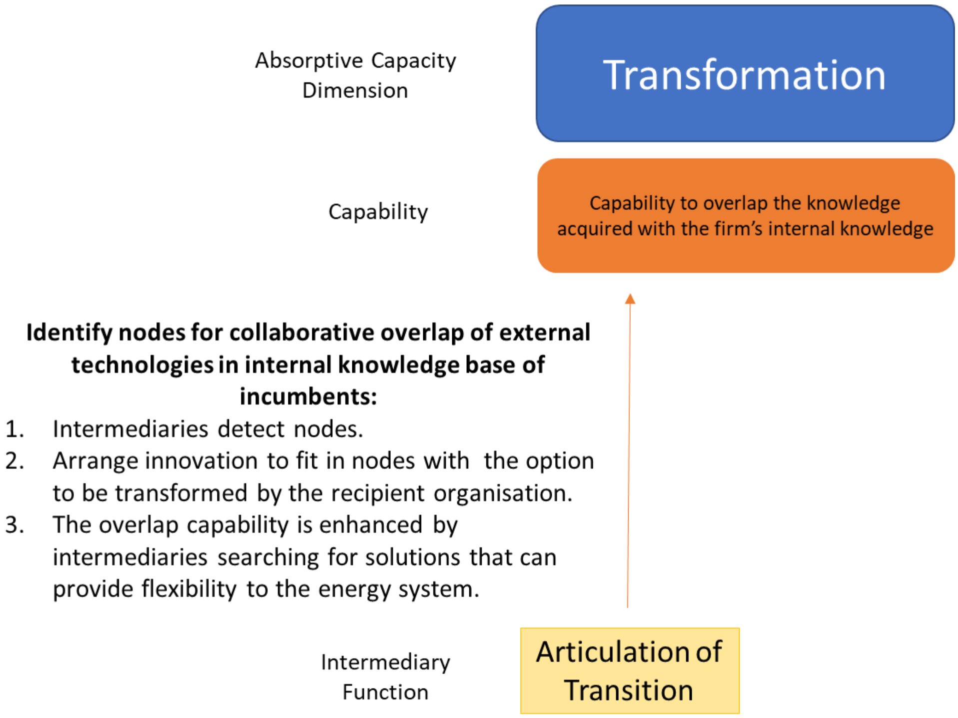

Figure 5.5 Intermediary function to develop the capability for overlapping the technology knowledge acquired with the firm's internal knowledge

5.3.2 Capability to separate the knowledge source between sender and receiver

Interviewees have discussed the situation where collaboration in technology transfer involves the transmission of confidential information that the innovation producer has not secured yet under the registration of intellectual property rights (IPRs). The most common form to prepare the spreading of the information under such conditions is by signing an *ex-ante* non-disclosure agreement (NDA). This document offers legal support to protect confidential information made available through the nature of the collaboration. It also recognises the source of innovation by defining which intellectual property pieces belong to each party. It is an important collaborative document that shows a relevant development in the capability to separate knowledge sources.

Both incumbent firms and socio-technical niches use their own NDAs to prevent the intellectual property from being replicated or disseminated without consent. Nevertheless, this process has organisational barriers in incumbent firms that make it difficult to sign this type of document. Niche Founder (NIC 8) has recounted that he was contacted by an incumbent energy company regarding a new technology in possession of his start-up company, which was related to a similar application field in the recipient end. The first round of meetings consisted of the niche company providing information at the request of the incumbent firm to evaluate the possibility of implementing the new technology within the utility company. The discussion entered a point at which sensible information would be disclosed and the niche enterprise asked to sign an NDA that the incumbent refused. "*Because we were working on very similar fields, they worried that by signing an NDA we will reveal information to them that would contaminate their technology process*", Niche Founder (NIC 8) has said. The example shows utility firms have an over-protecting approach for in-house technology, whose development is restricted by their scarce capability to add external information.

A similar reaction is obtained when socio-technical niche projects request sensible information for the incumbent firms to be shared with them. Incumbent Former Change Lead (INC 10) has recalled that signing NDAs was a difficult task to achieve in utility firms. According to her experience, it is not a common process for the utility's legal department to negotiate confidential information with small innovation projects. Incumbent firms are well prepared to sign NDAs with an established supplier of technology, in which the context of the arrangement presents an absolute certainty for both parties that the result of the collaboration will be optimal. These types of contracts are already consolidated in the legal processes of the incumbent firms, including hundreds of millions of pounds on indemnity in their favour. However, this legal structure of collaboration does not work favourably for socio-technical niches, in which the uncertainties are extremely high compared, for instance, to purchasing a standard wind turbine from a reputable provider. "*The utility company I was working for did not understand that an innovation project usually is about a pilot. That little* *company cannot sign up an indemnity over £100 million*", Incumbent Former Change Lead (INC 10) has explained.

The function that transition intermediaries deploy to improve these circumstances is framed within **Relationship Building**. In particular, the transition intermediaries can take a mediation role in which they contribute to the flow of confidential information by strengthening the relationship of the actors in the technology transfer process. Intermediary IP Director (INT 13) has explained that negotiations on intellectual property terms often present an unbalanced relationship in which the incumbent firm is in a position of power: "*Sometimes, the recipient company would be the only route for the start-up to commercialise the new technology*". Thus, such a possibility puts the socio-technical niche in an unequal position to negotiate, in which the smaller player is frequently forced to accept the incumbent firm's terms.

In this context, transition intermediaries have educated socio-technical niches about how to avoid signing those kinds of contracts. Generally, they are forced to disclose and hand most of the new IP generated to the large party, according to Intermediary IP Director (INT 13): "*It has been a long process of educating innovation actors about the importance of IPRs, where intermediaries include the IPRs item in the checklist of both sides of the technology transfer process*". According to this opinion, incumbent firms have realised that they must be flexible in negotiating such terms with socio-technical niches. At the same time, transition intermediaries have guided this collaboration not to overprotect the IPRs derived from the alliance between socio-technical niches and incumbent firms. Case Study H presents an instance of the transition intermediary function of Relationship Building, in which the support is concentrated on offering scenarios for the technology transfer to happen and educating the actors in IPRs.

Case Study H – UK Intellectual Property Office (UKIPO)
Intermediary function of Relationship Building

In 2002, the UK Government commissioned Richard Lambert to an independent report of the industry and university collaboration (Eggington et al., 2013). A year later, Lambert presented his review of business-university collaboration to the Chancellor (HM Treasury, 2003). The report recommended measures to boost industry and academia interaction, including improving intellectual property negotiations. This suggestion by the Lambert Report provided template agreements for business-university R&D collaboration (Wilson, 2012).

The document was rebranded as the Lambert Toolkit and has been regularly updated by the UK Intellectual Property Office (UKIPO, 2016). The toolkit offers multiple scenarios in which technology transfer can happen. The document includes a decision guide, with a number of model agreements for each context of collaboration. The aim of this document is to reduce the time to market, resources and efforts, required to secure the most suitable agreement for both ends of technology transfer. It also provides examples of best practices and other applicable resources as NDAs, confidentiality notices and licensing guidance, to name a few (UKIPO, 2016).

In summary, transition intermediary function of Relationship Building educates incumbent firms and socio-technical niches about the importance of intellectual property in the technology transfer process. Figure 5.6 illustrates the main two actions that transition intermediaries deploy through the function of Relationship Building. First, intermediaries seek to create a flexible approach for both parties enabling them to sign an NDA. Second, as a result of the first action, this generates a proper environment in which the appropriation of IPRs is assigned, enhancing the capability to separate the knowledge between sender and receiver during the joint technology development.

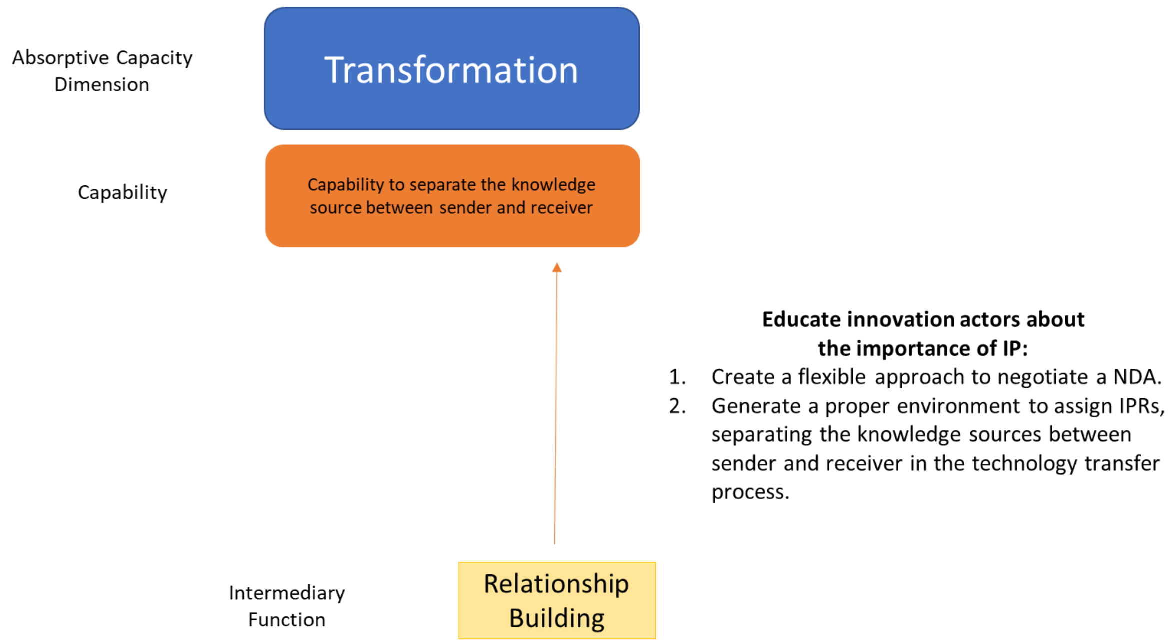

Figure 5.6 Intermediary function to develop the capability for overlapping the technology knowledge acquired with the firm's internal knowledge

5.4 Exploitation

5.4.1 Capability to Speed to market

According to participants of this research, the incumbent firms aim to operate in stable conditions with steady revenues. Incumbent Director (INC 7) has said that utilities need to deal with two main aspects in such regard. First, they conduct business activities within an infrastructure that follows a trajectory around a centralised energy supply system. This means that any new low-carbon technology must adapt to the existing infrastructure –and not vice versa– for being absorbed by utility companies. Second, the price cap regulation, calculated by Ofgem on the costs that energy suppliers face and by which utilities cannot charge more that the limit imposed by this regulation. This denotes that incumbent firms must handle the rates of return for stakeholders under such conditions. Innovation is also assessed under the same terms, whether it can obtain above-average returns compared to the price cap and without compromising the centralised energy supply system. "*If both conditions are met, the project is presented around corporate boards with real confidence that the new product is* *going to be in the market for the long run and making a good income*", Incumbent Director (INC 7) has stated.

Therefore, the utility firm requires a solid capability to scale the innovation until it reaches this point of commercial and technical certainty. Nonetheless, such a process is a risky activity that utility firms prefer to delegate to the innovation producer. The latter must demonstrate that the risk has been significantly reduced by constructing an appealing business case. In such an instance, it will show that the new technology fits with the incumbent firm's requirements. "*We (utility firms) are not R&D companies. So, to take front-technologies and put them on the market, we have to feel very comfortable with the technology choice and also how the business case is presented*", Incumbent Head of New Technology (INC 3) has explained.

This quote can be interpreted as the incumbent firms being extremely selective in choosing the innovation that they will be launched to the market. Mainly, picking new technologies that can be profitable under the current business model. In the words of Incumbent Head of Regulation (INC 6) when an innovation does not meet these requirements, the incumbent firm hesitates. As a result, this context diminishes the incumbent's capability to speed to market: "*In our sector, we literally say 'how do we get to the end of the year?' (…) So, thinking two years ahead is often out the window. We are just thinking about getting to the end of the present year*".

Another important aspect mentioned by Incumbent Former Renewable Manager (INC 11) is that utility companies should be able to configure a new market segment in concordance with the innovation to be commercialised. However, incumbent firms have difficulties identifying new markets who are willing to pay a premium price for greener energy and derived services: "*The energy industry has been quite slow to understand the customer side. The main focus has been in finding the cheaper price. But not in understanding exactly what people want from the energy supply*". Hence, the incumbent firms' orientation to efficiency through the reduction of operational costs has also constrained the capability to speed to market.

Having accepted the previous evaluation about the return on investment and identified the main client, the utility firm finally decides they will introduce a new product based on external technology. Arrived at this point, Intermediary Manager for Energy (INT 11) has explained that the utility company does not have the capacity to manufacture the final product. They rather delegate such activity again to the innovation producer. This is another issue that restricts the incumbents' capability to speed to market. "*The energy firm says to the smaller company: 'Please, can you deliver one million of this new product in the next few days?' But the larger companies need to understand that they are not going to get it that way*", Intermediary Senior Manager (INT 11) has described.

It can be stated that utility firms have limited capability to adapt business operations to launch new technologies. According to the findings, it is likely that the centralised energy supply system has influenced the mode in which they innovate. Niche Consultant (NIC 4) has further explained this situation. In his opinion, such a context produced utilities lacking the flexibility to adapt their operations when they launch low-carbon innovations: "*Even when companies are aware of these new things, they are still too comfortable on delivering the current business. By then, it is too late and they fall apart*".

Based on this analysis, incumbent firms have three main issues that reduce the velocity by which they can launch innovation to the market. These are: (i) revenue stream, (ii) identification of the customer segment, and (iii) manufacturing capacity. To solve these, transition intermediaries focus their support on deploying multiple functions.

On the first element about revenue stream, Niche Head of Commercialisation (NIC 2) has detailed that intermediaries, such as ES Catapult, act as a broker among the various market players. Under this role, ES Catapult detects which components of the current regulation could be lifted to facilitate the exploitation of a particular innovation. It is a similar activity previously described in 5.1.2, but in this case, it is related to monitoring the innovation's economic performance without price cap restrictions. In this instance, the incumbent firm can commercialise the new technology and evaluate the return on the investment in a real market context without the imposition of regulation. Consequently, transition intermediaries deploy the function of **Regulatory Change** to recommend the framework for new regulation. This will share the economic benefit of the technological offering around the whole market, helping the utilities to balance the right price. In turn, this allows it to demonstrate the return on investment for incumbent firms. Besides, utilities discover an affordable price to be paid by consumers. Thus, the benefits of low-carbon technology can be spread around the majority of the market's actors during the net zero transition. Niche Head of Commercialisation (NIC 2) presented an example of a new heating service that his start-up company has developed, in which the financial benefits could only have accrued to the network operator: "*The intermediary helps the regulator and private companies to unpick that. So, the financial benefits can be shared across all the participants, including consumers, network operators, energy retailers and so on*". Case Study I depicts the transition intermediary's function of Regulatory Change in this case.

Case Study I – Energy Technologies Institute (ETI)
Intermediary function of Regulatory Change

The Consumers, Vehicle and Energy Integration (CVEI) was a project launched in 2016 by ETI, in collaboration with the Transport Research Laboratory and ES Catapult. It also counted on the support of the utility firm EDF Energy. The project aimed to understand the consumers' behaviour towards the integration of electric vehicles (EVs) with the energy network. The CVEI analysed the obstacles and motivations of drivers using EVs compared to conventional petrol cars. Thus, the project forecasted the necessary changes to the existing infrastructure according to the consumer response. CVEI gathered in-depth data from vehicles and charging points for 584,000 miles of journey and more than 15,000 vehicle charge episodes, while surveys were undertaken to collect data on drivers' attitudes (ES, 2021a).

The main findings of the project, published in the report "Smart Charging - A UK Transition to Low Carbon Vehicles" (Haslett, 2021), pointed out that green vehicles cost is the same as current petrol cars over a 4-year period, including recharging. It also stated that mass charging at home through off-peak tariffs can have serious consequences for the network infrastructure.

Based on this analysis, the report expressed the public's concern between the charging services that drivers will need and the plans of the wide range of stakeholders – including utility firms – needed for progressing on electric transport. Finally, it suggested that if this gap is addressed through a series of collaborative actions, there will be fewer drivers' concerns about the cost of charging. This information provided strong evidence for utility companies to take decisions about EVs, increasing their speed to market on vehicle electrification.

The second element about the identification of the customer segment that will use the new technology is addressed by transition intermediaries by collecting and analysing data in order to recognise emerging markets during the energy transition. Intermediary Chief Technology Officer (INT 1) has explained that they provide a considerable volume of information to support corporate strategies, encouraging incumbent firms to shift their attention towards innovation niches and seek alternative solutions for meeting demand from new customer segments. In this case, transition intermediaries enhance the speed to market in incumbent firms through the function of **Articulation of Transition by Knowledge Exchange.** This helps incumbents to find markets that can be receptive to a new product in the energy sector. Consequently, transition intermediaries aid the identification of market segments that incumbent firms have previously overlooked. "*Making that data available has pushed incumbents to search in different directions where effectively they can contribute to net zero using innovation*", Intermediary Chief Technology Officer (INT 1) has indicated. Case Study J illustrates the transition intermediary function of Articulation of Transition by Knowledge Exchange. In this instance, the intermediation support has sought to generate a shift in the way utility companies understand the consumers' needs around sustainable transport and heating. Then intermediaries suggest actions that incumbent firms can take to engage with end-users' requirements.

Case Study J – Catapult Centre of Energy Systems (ES)
Intermediary function of Articulation of Transition by Knowledge Exchange

ES has released important data to orientate the energy sector for addressing new market segments. The report "Rethinking Electricity Markets" (ES, 2021c) concluded that the centralised approach of the energy system for developing innovation was the right choice during the last decade of the 2010s. This successfully increased the share of renewables in electricity generation from 14% in 2013 to 47% in 2020.

The report proposed that as the incremental stake of renewables will be constantly growing, equal efforts should be put now to decentralise the supply of energy. For this purpose, ES encourages smaller energy firms to unlock the demand-side flexibility. This aims to connect renewable generation with the consumption of electricity in new appliances, such as EVs and heat pumps. Both technologies are considered critical by ES to achieving the net zero transition.

The report has called for developing technology innovation to harness the combination of renewable sources with emerging applications. For instance, it has proposed management technologies for demand-side response and micro-storage, combined with technologies in securing the supply of energy. This will enable a larger flexibility in homes' consumption of electric heating and smart charging of EVs and open a new market for utility companies.

Finally, the third element of manufacturing capacity is tackled by transition intermediaries by suggesting incumbent firms consider alternatives when they ask a small company to produce a large number of the final product. Participants of this research have mentioned that utility firms should consider running a "*put-plan*" for working with start-up companies. "*Maybe the large firm needs to put some money from its pocket. For example, via licensing-in from the start-up firm, giving the option to manufacturing the units needed*", Intermediary Senior Manager (INT 11) has recommended. However, most utility firms do not have this in-house infrastructure to manufacture the final product. In these cases, transition intermediaries have links with other organisations that are capable of filling such gaps. An example that interviewees have mentioned is the "innovation laboratories", where energy companies can manufacture specific components of new technology in large volumes. In this instance, transition intermediaries deploy the function of **Management of Resources** to support incumbent firms in manufacturing a final product from which the utility firm is not familiar. Case Study K illustrates this intermediary function.

Case Study K – The Digital Manufacturing Innovation Hub (DMIW)
Intermediary function of Management of Resources

DMIW is a non-profit organisation located in Bridgend (Wales) that supports innovation through manufacturing assistance (DMIW, 2019). The intermediary organisation KTN can connect energy firms, searching for help to develop production lines with the support of DMIW (KTN, 2021).

For example, DMIW made it possible to carry out the electronic board design for a new type of smart meter. After designing the production line, the innovation lab can manufacture the amount needed for commercialisation (KTN, 2021). Even more, KTN can be the bidder to get the volumes for commercial exploitation and fill the lack of manufacturing capacity from utility companies. Particularly, fabricating a final product from which the incumbent firms have no previous experience in manufacturing.

In summary, transition intermediaries develop the capability of speed to market in incumbent firms by deploying three intermediary functions. Figure 5.7 presents from left to right the simultaneous mechanisms that intermediaries apply to address three main issues.

First, transition intermediaries support energy firms in forecasting steady revenue streams by conducting experiments through the function of Regulatory Change. These trials consist of lifting regulations for the new technologies in order to be tested in real market conditions. This allows the incumbent firms to assess the technology innovation in technical as well as economic terms. These mechanisms enable the incumbent firm to find the right balance between cost and price, obtaining relevant information to evaluate the possibility of generating a steady revenue stream in a potential new market. Moreover, using the information collected in such trials, transition intermediaries spread the value of the tested technology innovation across the market by suggesting the implementation of new policies for this purpose.

Second, transition intermediaries help incumbent firms identify emerging markets through the function of Articulation of Transition by Knowledge Exchange. In this case, transition intermediaries provide relevant data about emerging markets. This informs the utility companies of new consumers' needs, guiding the commercial strategy for addressing those demands.

Third, transition intermediaries utilise the function of Management of Resources to support incumbent firms in manufacturing a final product. In such efforts, intermediaries connect utilities with innovation laboratories that have manufacturing capacity. In there, the incumbent firms can manufacture the number of units necessary to launch the new product. This offers the opportunity for launching the new product faster into the market.

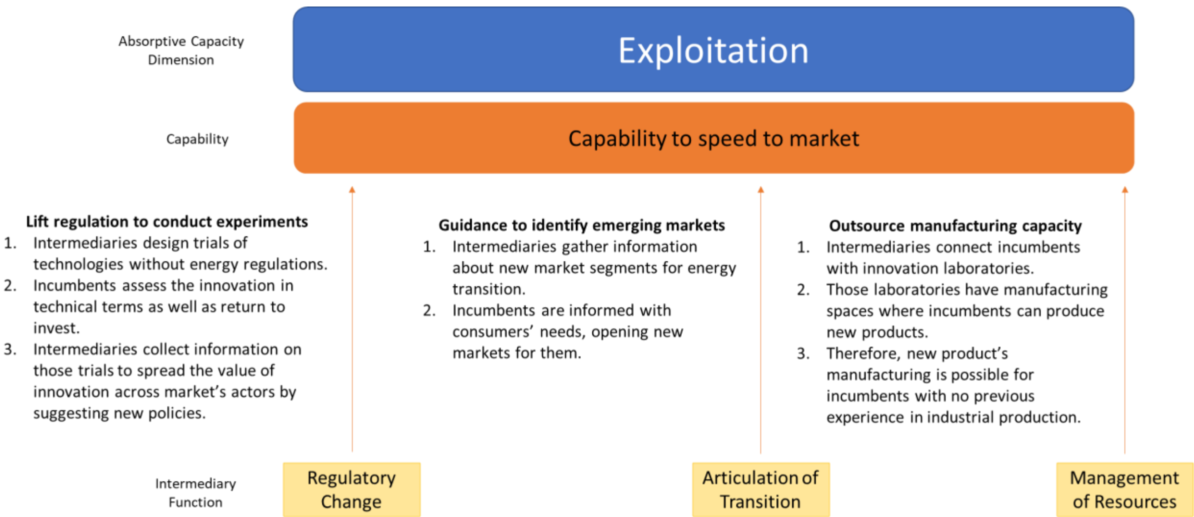

Figure 5.7 Intermediary functions to develop the capability to speed to market

5.5 Analysis recap

The analysis of the information obtained from primary and secondary sources shows that transition intermediaries perform a range of functions to cultivate capabilities in utility incumbent firms. Table 5.1 summarises the transition intermediary functions deployed for enhancing the capabilities of each dimension of the absorptive capacity. Every function included in this table contains intermediation mechanisms which are briefly described in the table below.

Table 5.1 Summary of transition intermediary functions assigned to each capability of absorptive capacity's dimensions

Acquisition	Assimilation	Transformation	Exploitation
Identification of new technology opportunities *Relationship Building*, connecting with radical technologies.	**De-risk external technology** *Management of Resources*, providing dedicated facilities to reduce the risk of unproven technology in technical and economic terms.	**Overlap external knowledge with internal tech base** *Articulation of Transition*, arranging the overlap of external innovation into nodes of the energy system, without altering the existing infrastructure.	**Speed to market** *Regulatory Change*, lifting regulations that enable the launch of innovation into the market. *Articulation of Transition*, accumulating relevant data to identify market niches by incumbents. *Management of Resources*, connecting the incumbent's manufacturing demand with the proper infrastructure for production.
Connect with R&D community *Articulation of Transition*, intermediaries collect info on the interaction incumbents-niches and reduce regulations for acquiring new technologies.	**Create technological roadmaps** *Articulation of Transition*, providing info to generate long-term roadmaps. *Technology Forecasting*, elevating R&D areas.	**Separate knowledge source and assign ownership to knowledge created** *Relationship Building*, guiding incumbents to reflect on their own capacity to exploit the new technology.	

Some functions contribute to strengthening more than one capability. Significantly, Articulation of Transition by Knowledge Exchange supports the development of four capabilities. Relationship Building and Management of Resources influence two capabilities each. Other functions, such as Technology Forecasting and Regulatory Change, enhance one capability. While the R&D Coordination does not play any supporting role in fostering capabilities in incumbent firms. These results are summarised in Table 5.2, which showcases the transition intermediary functions that enhance the specific capabilities of absorptive capacity. These are marked with a yellow circle, accompanied by the respective case study identified for that instance.

Table 5.2 Summary of transition intermediary case studies deploying a function assigned to each capability of absorptive capacity dimensions

Absorptive Capacity Dimension	Acquisition		Assimilation		Transformation		Exploitation
Capability / Intermediary Function	Identify tech opportunities	Connect with R&D community	De-risk external techs	Create tech roadmaps	Overlap tech acquired with firm's internal knowledge	Separate knowledge sources	Speed to market
Relationship Building	Knowledge Transfer Network					UK Intellectual Property Office	
Management of Resources			PNDC ORE Catapult				Digital Manufacturing Innovation Hub
Articulation of Transition		Innovate UK		Carbon Trust	ES Catapult		ES Catapult
Technology Forecasting				PNDC			
R&D Coordination							
Regulatory Change							Energy Technologies Institute

Lastly, Figure 5.8 summarises the transition intermediary functions that enhance each capability, located within the dimensions of absorptive capacity. Accordingly, arrows connect the intermediary's function with a specific capability. This figure corresponds to the top part of the conceptual framework presented in Chapter 3.

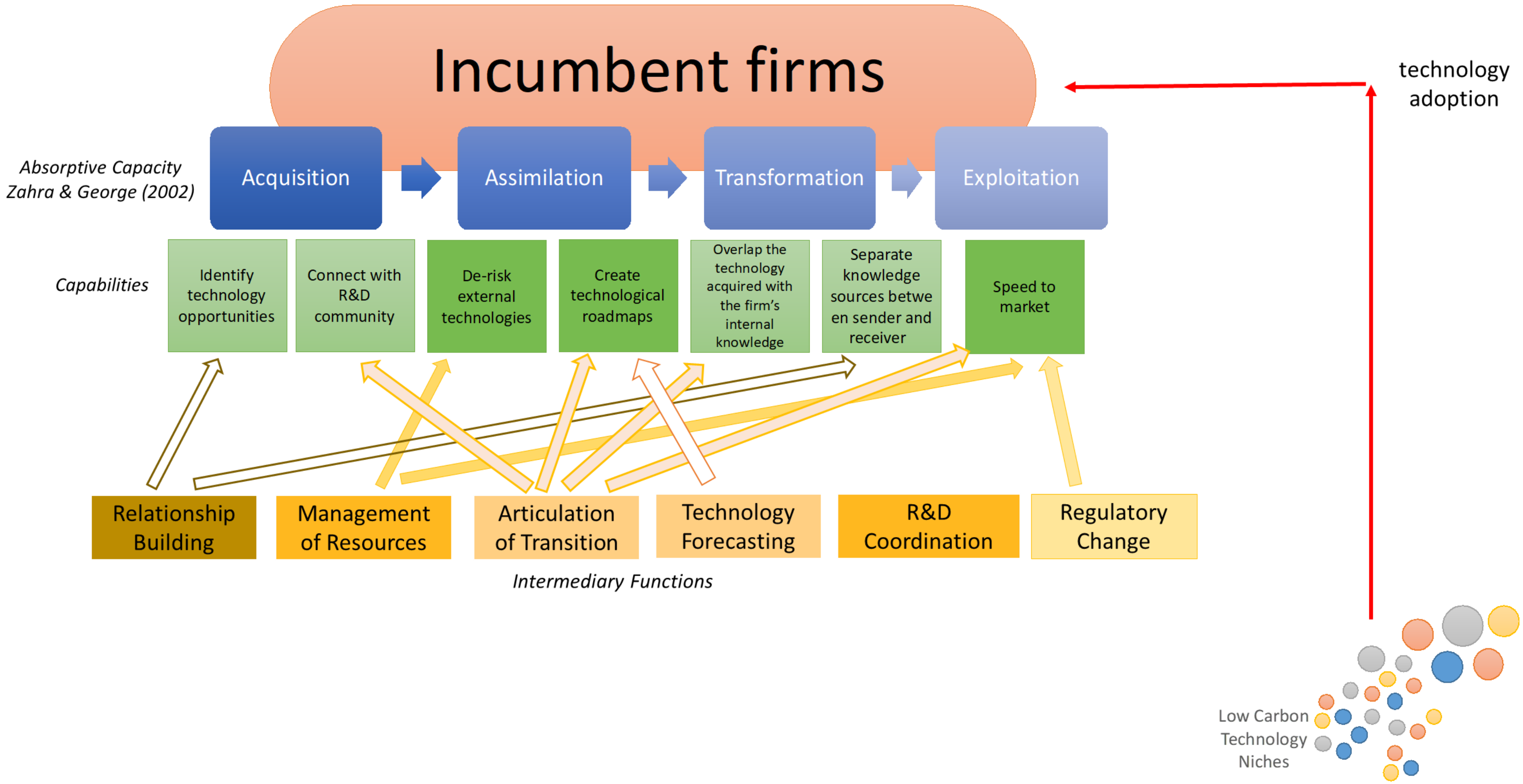

Figure 5.8 Summary of transition Intermediary functions developing capabilities for enhancing absorptive capacity in utility energy incumbents

5.6 Chapter Summary

This chapter presented the qualitative analysis related to how transition intermediaries develop capabilities for enhancing absorptive capacity in incumbent firms of the UK energy supply sector. The investigation outlined the mechanisms that transition intermediaries unfold to support the development of each specific capability associated with absorptive capacity's dimensions. Accordingly, Section 5.1 covered Acquisition; Section 5.2 discussed Assimilation; Section 5.3 investigated Transformation; and Section 5.4 explored Exploitation.

The interpretation of primary data obtained through interviews provided a first layer of findings that were later compared with case studies, presented in the format of vignettes. This approach helped to contrast the information provided by the participants of this research and identify common factors between both sets of data. This analytical operation allowed us to address Research Question A by showing how transition intermediary functions are critical for developing capabilities that facilitate the absorption of technology innovation in energy incumbent firms for the net zero goal.

The following chapter will continue the analysis of transition intermediary functions. This time, it investigates how they support the development of desorptive capacity in socio-technical niches.

6 The development of desorptive capacity in socio-technical niches by transition intermediaries

This chapter presents the qualitative analysis of the development of capabilities that socio-technical niches have nurtured with the support of transition intermediaries to desorb technology innovation. The main purpose of this chapter is to address Research Question B (see p. 4 on Chapter 1). This will be answered using the conceptual framework (Chapter 3), explaining how transition intermediary functions enhance the development of capabilities in both dimensions of desorptive capacity.

The analysis is presented according to the steps previously explained for mobilising the conceptual framework (Section 4.3). Accordingly, the analysis is separated into two dimensions of desorptive capacity: Section 6.1 Identification; and Section 6.2 Transfer. These dimensions hold a specific set of capabilities, according to the conceptual framework (Figure 3.1). This guides us to structure the analysis in the following way: sub-section 6.1.1 examines the capability to understand the technology base in the recipient; sub-section 6.1.2 explores the capability of technology marketing; sub-section 6.2.1 discusses the capability to transform pre-existing processes in the recipient; and sub-section 6.2.2 investigates the capability to manufacture prototypes. Each of these sub-sections is accompanied by case studies presented in a vignette format, following the methodological suggestions made in sub-section 4.3.5.

The same referencing system described in the introduction of Chapter 5 is used again, helping to anonymously identify the statements made by the participants of this research. A list of the reference codes used for each interviewee can be found in Appendix A.

6.1 Identification

6.1.1 Capability to understand the technology base in the recipient

Compared to utility companies, socio-technical niches are less preoccupied with the current regulation in the energy supply sector. Instead, they are concentrated on developing the technology concept without taking into much consideration the industry requisites for integration, related to stability, efficiency and cost. This approach has led socio-technical niches to produce uncompleted innovation outputs without adequate external validation. Niche Researcher (NIC 1) participated in the early development of a technology project with such traits. He produced a simulating tool for storing electricity through wind turbine generation from a technical point of view. In his opinion, the technology solution was still incomplete because he did not have all the information to insert the technology innovation into the business operation of a utility firm: "*In my role as an academic researcher, I am not really close to the industry to know what business requirements are needed to bring this technical solution to the market*".

According to the opinion of Niche Consultant (NIC 4), such a situation is recurrent. This can be explained as most of the new technologies for the energy transition are developed by engineers and researchers with little understanding of the energy market context. Thus, the origins of net zero innovations have little connection with the business aspect of potential industrial adopters, such as utility companies. Instead, technology development tends to be initiated by the curiosity of inventors in socio-technical niches, which often have no connections with the incumbent firms' concerns about their business operations. In his opinion, this creates little chance to break into the energy sector: "*It's difficult to sell when there is not a strategy for commercialisation, with no clear customer need and neither having scanned the regulation to implement the idea into the market*".

This denotes a divergent perception of the transition priorities, in which the technical aspect appears as the most important feature for socio-technical niches. While incumbents would prefer to receive proposals with defined business approaches in terms of saving cost, regulation and speed to market. This issue has generated a barrier that socio-technical niches must address in their aim to collaborate with incumbent firms. "*The problem is that they* *speak different languages. Energy suppliers do not react quickly enough to innovation. And innovators are ill-prepared to discuss the new venture in the business terms that utilities would like to hear*", Niche Senior Manager (NIC 3) has confirmed.

This is a critical point that transition intermediaries have focused on resolving, aiming to increase the commercial and technology awareness of niches. Regarding the capability to understand the recipient technology base, transition intermediaries are attentive that innovation projects require assistance to increase their business skills until they are accepted by the incumbent firms. Thanks to their work at the heart of the energy industry, transition intermediaries have accumulated relevant contacts with different innovation actors that are avid to pass to the socio-technical niches. Most of these contacts are among corporate managers in the utility sector, who can support the validation of the technology concept and identify the potential customer segment. This can solve some of the problems earlier described about the lack of awareness from niches to commercialise the technology innovation. "*We give them access to talk with informed actors about the problem they are trying to solve. In particular about the business aspect. Through this action they (socio-technical niches) get the right feedback and validation*", Intermediary Technology Director (INT 2) has stated. He has detailed that when projects have been accepted for this intermediation support, the socio-technical niches go out for testing the new technology through a market validation phase, having a series of interviews with key informants.

As socio-technical niches are conducting these conversations facilitated by transition intermediaries, they begin to consider the early elements of a business model. This allows them to connect not only with the technology base of the recipient but importantly with the commercial aspect as well. Transition intermediaries become even more involved in this process by discussing with socio-technical niches the findings of these conversations. Later intermediaries suggest improvements in the technology and business aspects, based on the collected evidence. This triangulation of analysis leads the socio-technical niches to acknowledge the expectations that incumbent firms have in the integration of innovation into the energy supply system.

These mainly consist of reducing carbon emissions in the current infrastructure, complying with the regulation and preferably at a lower cost, according to Intermediary SME Manager (INT 9). Having that information at hand, socio-technical niches are more prepared to edit the technology and business proposition increasing the chances to fit the innovation into the recipient firm. "*If the innovation project has understood these elements, it will have a greater chance of integration*", Intermediary SME Manager (INT 9) has confirmed.

Thus, intermediaries execute the function of **Relationship Building** connecting socio-technical niches with key informants in utility companies. These can guide the innovation in moving closer to validation and enabling the socio-technical niches to adapt the initial proposal for a better fit in the incumbent firms' technology base. In the voice of participants, with no transition intermediaries' support in this matter, it would take a longer time for socio-technical niches to actually obtain and process all the necessary information. According to Intermediary Technology Director (INT 2): "*It could take anywhere up to five years for them to do that on their own*". Consequently, the transition intermediary function of Relationship Building accelerates the process of validation on the innovation project, providing the links to collect information and properly understand the incumbent firms' technology and business base. This critical information increases the chances for socio-technical niches to adequately fit their proposals to the recipient's needs. Case Study L illustrates the transition intermediary function of Relationship Building.

Case Study L – Sustainable Ventures
Intermediary function of Relationship Building

Sustainable Ventures is a risk capital firm founded in 2011 that provides multiple services to green entrepreneurs. It has founded 10 companies, invested in other 30 and supported the development of over 250 more (Sustainable Ventures, 2020). The organisation helps entrepreneurs for raising funds to develop new business ideas that address climate change and resource scarcity.

In such a process, Sustainable Ventures leverage its network to support the customer validation of new technologies. For meeting this purpose, the incubated companies will have a dozen interviews already set up for them to speak with key informants, collecting critical data for testing the initial assumptions of the new venture. This allows them to build a value proposition that is consistent with the needs of the energy market and accordingly has better opportunities to raise funds for commercial deployment.

In 2021, five companies have received public investment through the help of Sustainable Ventures. Those are Guru Systems, Powervault, Sunswap, Verv and Airex. Each company will receive grants to demonstrate new technologies in the fields of energy efficiency, power generation, heat generation and energy storage (Sustainable Ventures, 2021a). Moreover, Sustainable Ventures has initiated a partnership with Schneider Electrics to discover and develop new technologies to build an open energy sector (Sustainable Ventures, 2021b).

When the socio-technical niches have accumulated sufficient evidence to proceed in these aspects, they come back to transition intermediaries for further analysis of the information. In this instance, transition intermediaries influence the desorptive capabilities through the function of **Management of Resources.** This allowed them to act as consultants and propose suggestions to change relevant aspects of the technology innovation concept using their experience to evaluate this market data. Thanks to such an extra effort from transition intermediaries, socio-technical niches can verify the previous analysis. Moreover, they can confirm the expectations that incumbent firms have about integrating new technology into their operations.

This collective work is corroborated by impartial evaluators who assess the support provided by transition intermediaries. This confirms that these efforts point in the right direction towards the energy transition. "*All the work we do is independently verified. (…) We seek opinions from several independent verifiers and unbiased sources showing what we are doing* *goes in the right direction*", Intermediary Project Manager (INT 6) has explained. Case Study M portrays the transition intermediary's function of Management of Resources.

Case Study M – The Energy Innovation Centre (EIC)
Intermediary function of Management of Resources

The EIC was established in 2008 as a non-profit organisation with the purpose to facilitate technological innovation for improving the utility systems in the UK. It works in partnership with more than ten gas, electricity and water utility firms, aiming to bridge the gap between industry and innovators.

EIC provides a platform to facilitate innovation projects (EIC, 2019). For this purpose, EIC formulates calls for innovation every year, in which the identification of an industrial need is suggested by incumbent firms. Innovators reply to these by proposing new technology solutions to those requirements.

After projects have been selected by EIC, these are put in contact with industrial players to test their technical and business assumptions. Then, innovators in collaboration with EIC assess the information to edit the original technology proposal until it finally fits into the energy supply system (EIC, 2018).

This support seeks to develop a solution in which the benefits are visible to EIC stakeholders, including incumbent firms and socio-technical niches. Moreover, the intermediary focuses that the new technology that complies with existing regulations in the specific area of the energy supply system where aims to be implemented.

In summary, the capability to understand the technology base in the recipient is affected by two functions of transition intermediaries, shown below in Figure 6.1.

First, Relationship Building contributes to establishing links between socio-technical niches and industrial informants. The latest actors provide relevant information to validate the initial technology proposal from niches. This supports niches to identify business aspects they did not initially consider, which later serves to edit the technology project improving the chances of being adopted by incumbent firms.

Second, Management of Resources supports the analysis of this set of information. Transition intermediaries act as consultants offering recommendations to edit aspects of the technology proposal. This triangulation of information enables socio-technical niches to understand better the expectations of incumbent firms when they integrate new technology into their business operations. Thereby, transition intermediaries teach business skills to socio-technical niches to tailor the proposal to a specific group of recipient firms. This work is assessed by impartial evaluators who confirm that the efforts from transition intermediaries point correctly at the energy transition.

It is important to notice that socio-technical niches not only receive information to understand better the technology base of the intended recipient companies. It is also about business aspects that can facilitate the diffusion of technology innovation in incumbent firms. Through this mechanism, transition intermediaries go beyond the conceptual definition of the capability to understand the technology base in the recipient, which originally was framed under technical terms. In this case, the transition intermediaries offer critical business information that enables the new technology to be introduced into utility firms.

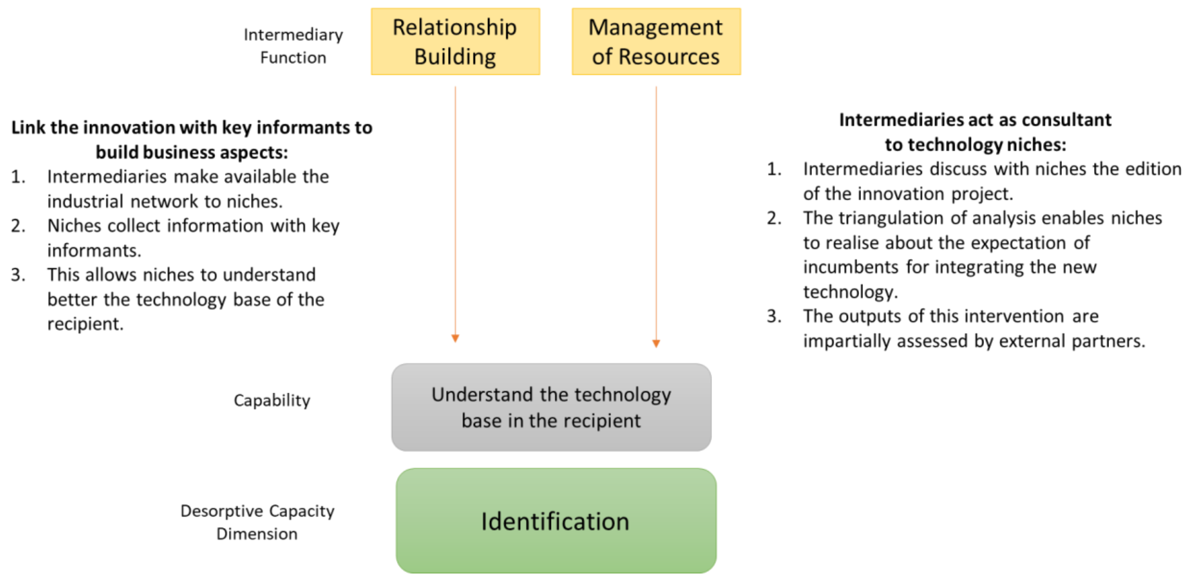

Figure 6.1 Intermediary functions developing the capability to understand the technology base in the recipient

6.1.2 Capability of technology marketing

The innovation sender must possess a minimum of market knowledge advising the way the technology functionality will satisfy the end-user's need. However, niches rarely initiate the development of a new technology motivated by an unmet demand in the energy market. It rather starts with a technical problem that the researcher or inventor considers intellectually stimulating, as was discussed in the previous sub-section 6.1.1. Since the original approach of the technology concept is not traced from a customer need, it is problematic to commercially scale the innovation and later transfer it to an incumbent firm. According to Niche Senior Manager (NIC 3), such a situation is typical on niche's innovation projects: "*So, we up having a bunch of suppose innovations that don't serve the market and are difficult to transfer to an industrial partner*".

Moreover, technology development involves a significant degree of unpredictability that is inherent to the innovation process (see Section 2.2). In the opinion of Niche Chief Financial Officer (NIC 7), such a situation becomes even more problematic when the socio-technical niche assigns the project development exclusively to the technical staff: "*We had our 'mad inventor' in one of our co-founders and he had twenty different ideas every day. The latest idea was the best and we had to go full speed ahead and pursue that idea and forget the others. This made it difficult to get a disciplined business process and generate any type of sales*".

Another issue blocking socio-technical niches from cultivating the technology marketing capability is the slow pace of innovation development. Reaching maturity for a new technology takes considerable time in the energy industry. This can range from a couple of years to more than a decade for its functionality to be acceptable by early adopters. Under such circumstances, the preferences of the market can change. Accordingly, the original application must adapt to a new demand that is more promising on commercial terms compared to the previous one. This situation was explained by the Niche Head of Commercialisation (NIC 2) who commented that the technology development by his start-up company needed eight years of testing to complete the innovation. During that period the market was evolving in different ways: "*Utility firms came to us, really interested in our product but for a different application. (…) We had to take a new market orientation in a space where we did not have all the insights or experience*".

Based on this information, it can be said that an important aspect of the capability of technology marketing is anticipating the future demand that will affect technology development. For such a reason, participants have commented that under the energy transition is important to innovate ahead of the current market, proposing a distinguished technology platform that will allow addressing more than one demand in the future. "*Innovation is about building the technology in advance before a commercial opportunity is being presented*", Niche Founder (NIC 6) has said. Thus, the enhancement of this capability signals that socio-technical niches should develop a stronger awareness of future markets. Otherwise, it has the risk of building a new technology with no real interest from industrial players when it finally is completed.

Transition intermediaries support socio-technical niches in this journey by concentrating efforts on integrating innovation into the energy supply system. Rarely, transition intermediaries handle specific pieces of technology to solve in isolation a technical aspect of the transition, according to Intermediary SME Manager (INT 9). In this sense, she has commented that transition intermediaries encourage niches to develop technologies whose greatest feature is the integration into the energy supply system: "*I really do not care about how efficient your new solar cell is, or any other stand-alone device works. I care about how you can integrate that into the energy network to improve stability, reduce carbon emissions and deliver a desirable output for the consumer*".

Consequently, the analysis of data allowed us to interpret that transition intermediaries implement a hybrid function of **R&D Coordination** combined with **Technology Forecasting** to support niches for enhancing the capability of technology marketing.

The function of R&D Coordination pushes niches to adapt the initial technology development to address specific market demands. To reinforce this position, transition intermediaries provide insights about consumer preferences, regulations and particularly the form of generating an economic benefit for the end-user. Based on the opinion of participants, this support is provided by transition intermediaries through consulting the expertise of multiple actors in the energy sector. According to Intermediary Operational Director (INT 4), transition intermediaries help new technologies to become commercially viable in this way by working through the whole energy supply chain: "*From SMEs coming out from universities to large energy suppliers. We leverage that expertise from different levels to bear the development of new technologies*". Then, the innovation has a better chance to offer value to the energy supply sector and become a target for incumbent firms' acquisition.

Niche Researcher (NIC 1) has recalled that transition intermediaries have guided part of the innovation process in his project by detailing the regulations that he needed to consider for reaching the market. Additionally, transition intermediaries offered inputs to calculate the entry costs for being integrated into the operation of an incumbent firm. "*Definitively, they drove my technical expertise to produce something useful for the utility firms*", he has mentioned. Case Study N illustrates in more detail the intermediary function of R&D Coordination.

Case Study N – The European Marine Energy Centre (EMEC)
Intermediary function of R&D Coordination

EMEC was established in 2003 as a facility for demonstrating wave and tidal energy converters in the North Sea. EMEC attracts technology developers to test prototypes to get real sea experience in less challenging conditions (EMEC, 2019).

In 2017, EMEC developed the world's first tidal-powered hydrogen at Fall of Warness tidal test site, located in the Orkney Islands, Scotland. The energy start-up firms, Orbital and Tocardo have been testing hydrogen devices on EMEC's site (EMEC, 2018). The hydrogen technology can then be used locally in a variety of applications (e.g., fuel, power and heat).

For example, EMEC operates a 75 W fuel cell housed at Kirkwall Pier in the Orkney Islands. This facility can convert hydrogen back to electricity to 'cold iron' the local ferries while berthed overnight at the pier, in a real market application of this technology innovation.

EMEC has a number of partners, including the utility firm E.ON which invested in the wave power technology Pelamis in 2009. The marine innovation was developed with the help of EMEC but went into administration in 2014.

Through the function of Technology Forecasting, intermediaries disseminate pertinent information about the legal and economic context facilitating the adoption of the technology innovation on future markets relevant to the energy transition. This is a difficult terrain for socio-technical niches because they have little capability to anticipate when those dimensions will be connected and generate new market opportunities. On the other hand, transition intermediaries promote the alignment of such aspects in favour of the net zero goal, enabling commercial prospects to become available for socio-technical niches. For example, the demand side is a potential space where the links between incipient technologies like blockchain, artificial intelligence and machine learning could converge towards the broad area of “smart grid”. Intermediary Integration Manager (INT 7) has explained that transition intermediaries do not evaluate new technologies in isolation for future technology markets like these. On the contrary, it is more about how they can fit together and make the system emerge in an organised form. To move in that direction, intermediaries facilitate demonstrations of different technologies in real environments to design the future energy supply system and unlock innovation. “*We develop pilot projects to test combinations in different scales, looking in domestic properties and see if it works to aggregate another number of houses for scaling-up*”, Intermediary Integration Manager (INT 7) has added.

Transition intermediaries recognise, nonetheless, that often these efforts do not fully work. According to participants, the alignment of such elements can occur in a different application sector. For such a reason, transition intermediaries recommend socio-technical niches to have a flexible approach addressing future market opportunities beyond their initial application sector. “*We see a tendency around local energy* supply *systems, for example. But the market is not quite there yet, because players are still trying to align with each other. In this case, they need to act with flexibility to alter course when new opportunities arise in different areas*”, Intermediary Innovator Support (INT 12) has explained.

For these reasons, transition intermediaries suggest socio-technical niches consider broad market possibilities for new technologies even beyond the energy industry. Intermediary Senior Manager (INT 3) has asserted that intermediaries’ agnostic position to technology enables them to search potential demand in different industries, apart from those initially thought by socio-technical niches. This is possible through the network of partnerships that transition intermediaries have built. This allows scoping diverse possibilities to move into new opportunities for the energy transition. “*A small company producing robotics in the renewable sector could serve in another sector, such as telecommunication, with the same technology. […] So, we are trying to identify those sectors with universities, R&D centres and energy companies. Even when there is no apparent current market for a specific product*”, Intermediary Senior Manager (INT 3) has mentioned.

According to the analysis of information, the intermediary function of **Technology Forecasting** offers important guidance to socio-technical niches for developing the capability of technology marketing. This function provides sufficient flexibility to adapt the technology design when different business opportunities emerge. Often, these chances are facilitated by transition intermediaries by proposing technology trials. Case Study O portrays how this situation can be enabled by the transition intermediary's function of Technology Forecasting.

Case Study O – Scottish Enterprise
Intermediary function of Technology Forecasting

Scottish Enterprise is Scotland's national economic development agency founded in 1991. Scotland has set a net zero target to be achieved in 2045, five years earlier compared to the rest of the UK. Scottish Enterprise contributes to this goal by developing a series of interventions in the technology innovation system.

In 2022, Scottish Enterprise announced the programme HeatSource, seeking to reduce carbon emissions from heating at an affordable cost for consumers (SE, 2022). HeatSource works closely with local authorities and trade bodies to collect data for identifying business opportunities to deliver low-carbon heating solutions across Scotland. Blar Mhor Air Source Heat Pump and Heat Battery Project is one of these projects developed by HeatSource. This seeks to demonstrate that new heating technologies can be integrated with store batteries in the Blar Mhor housing development located in Fort William (Heat Source, 2022).

In this case, combining storage battery with heat pump will reduce user costs by switching the electricity consumption to off-peak tariffs. The Blar Mhor project will reduce the running costs for 117 householders by between 40-60% compared with the fossil alternative of the liquid gas system. If these tests are positive, then the project will expand to 250 homes.

For Sunamp, the start-up firm developer of energy storage systems, this project represents an instance of diversification. The company has a technology platform ranging from multi-megawatt industrial applications to smaller batteries for electric cars (Sunamp, 2022). Thus, moving to thermal storage for heating offers an opportunity to apply the same technology concept to a different commercial application.

In summary, socio-technical niches can expand the capability of technology marketing through the guidance they receive from two functions of transition intermediaries, as Figure 6.2 presents below.

First, R&D Coordination provides information about market preferences, regulations and the form to generate an economic benefit for the end-user. Intermediaries pass this information to niches when the technology innovation is still in the early stage of development. This information helps the socio-technical niches to redirect their R&D efforts and produce an innovation with better chances to find a market when it is launched to the market.

Second, Technology Forecasting can support the socio-technical niche's decisions in this regard by offering additional insights about the market preferences in future energy supply systems. With this information at hand, the transition intermediaries recommend the socio-technical niches exploring different commercial applications of the same technology development. Niches have obtained sufficient flexibility thanks to the previous transition intermediary function of R&D Coordination, which allows them to modify the technology design when these business opportunities arise. Frequently, such commercial instances are promoted by transition intermediaries with demonstration projects.

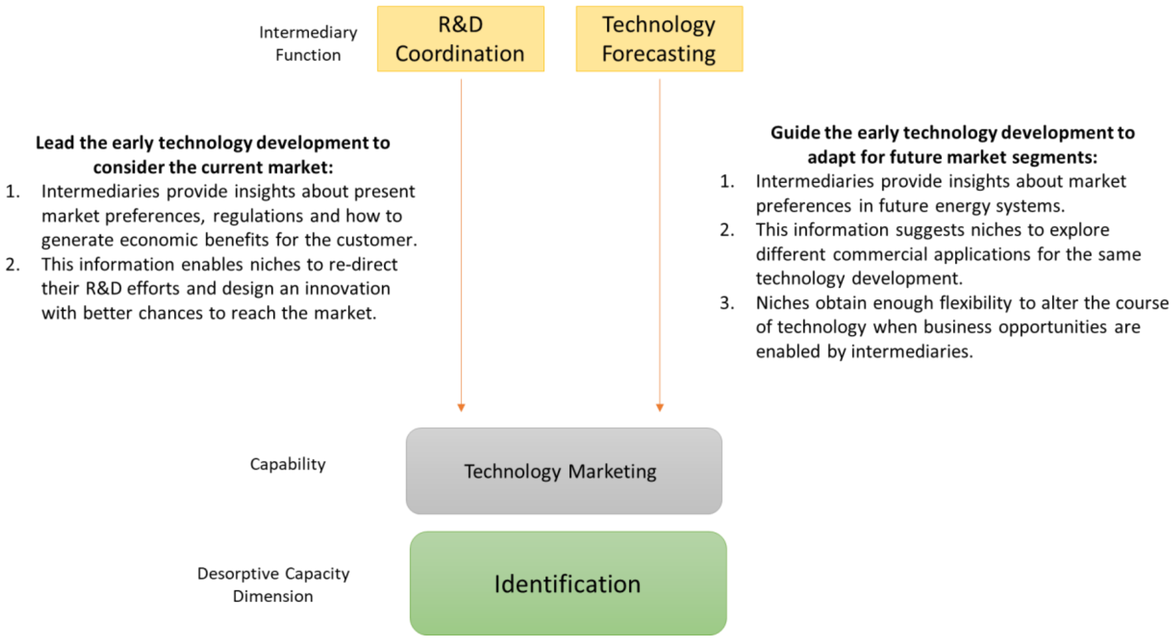

Figure 6.2 Intermediary functions developing the capability of technology marketing

6.2 Transfer

6.2.1 Capability to transform pre-existing processes in the recipient

A critical finding in this capability pointed out that socio-technical niches do not transfer a large portion of the innovation processes to incumbent firms. On the contrary, it is the dominant energy infrastructure that dictates the operational processes that socio-technical niches must follow to insert the innovation. According to participants of this research, the orientation to efficiency in the current energy supply system has created a stagnant situation. Incumbent firms have little tolerance to absorb an external innovation that requires the transformation of existing infrastructure and processes in incumbent firms. In the opinion of Niche Corporate Technology Officer (NIC 5), the energy supply sector is a top-down regulated industry, in which existing processes and the know-how to secure the supply of energy must be preserved. In his opinion, it is very difficult to innovate in this context. "*Because this situation is not coherent with the concept of change and it has a very limited capacity to tolerate transformative innovation*", Niche Corporate Technology Officer (NIC 5) has said.

Consequently, socio-technical niches want to transform an industry with no flexibility for adapting existing processes to absorb external technology innovation. To deal with this challenging environment, socio-technical niches have had to adapt their strategies to diffuse innovation. This means that niches must make efforts to develop new technology with an adequate set of processes that can rapidly connect with the internal practices of incumbent firms. In this case, the approach consists of elaborating flexible processes that can scale along with technological innovation. Thus, niches will have the possibility to transfer a consistent product or service with clear and orderly processes to serve the large market segment that incumbents usually target. In the opinion of Niche Founder (NIC 6), ensuring that customer service is properly delivered for a great number of clients through consistent processes is a very difficult task for smaller organisations: "*Customer management is an ongoing activity and small tech companies do not have the internal capability to keep going back to the same customer and getting things right as the number of clients grows*".

The socio-technical niche's inability to scale business processes as the technology increases traction among users creates a problem when the innovation attempts to be transferred to incumbent firms. Because these processes are not ready for the large number of customers required by utility firms to have a viable business. In this context, Niche Founder (NIC 6) has said that "*start-ups fail in exactly the opposite way to large energy suppliers fail when are doing innovation*". As the niches have inconclusive processes, the possibility of transferring these to the incumbent firms to facilitate the technology adoption at the recipient is low.

Transition intermediaries intercede by deploying the function of **Management of Resources**. This provides training and sharing experience to foster a disciplined approach to define, maintain and improve business processes in socio-technical niches. These can be later transferred to recipient firms facilitating the technology adoption. Intermediary Advisor (INT C) has explained that in his role he identifies areas of possible process adjustments by proposing a plan to improve operations in innovation projects. The intermediary's support begins by framing the value proposition of the technology innovation and later through the execution of key processes to strategically deliver it. These are monitored systematically by the transition intermediary to verify whether it has improved efficiency in putting the innovation in the hands of a larger number of customers.

Intermediary Advisor (INT C) has detailed that his support aims to reduce the expenses involved in a particular process that previously was not carefully organised by socio-technical niches demanding more time and resources to be carried out. Later, the niche tests the reorganisation of processes –based on the advice that the transition intermediary has provided– allowing them to reach a consistent result every time. In this way, the socio-technical niche masters business processes and possibly can teach it to another organisation, such as an incumbent firm when the new technology has been acquired. "*In my own experience, most of the critical steps are already there in the start-up firm. I just take care of organising those and explain the importance of having systematic processes. In the end, the final product is almost incidental*", Intermediary Advisor (INT C) has described.

As a result, socio-technical niches have confirmed that the rigorous approach of the transition intermediaries contributes to defining critical processes in business operations. According to participants, transition intermediaries' actions have made a difference in the socio-technical niches' ability to engage with partners for transferring the new technology. Importantly, this capability improved by providing processes to reach millions of customers, supporting the incumbents to initiate the commercialisation phase. "*This helps to demonstrate the technology's scale up and communicate to utilities what processes they need to implement after we have improved those in our own business*", Niche Chief Financial Officer (NIC 7) has commented.

Achieving such a milestone is extremely important in the opinion of Intermediary Consultant (INT 8). In his words, the adaptation of processes involved in the new technology operation is particularly tensional: "*All large energy companies that I know do not have a strategy to acquire new technologies and as a result neither the skill to adapt existing processes to adopt* *the innovation. So, for a large company to get interested, the start-up must demonstrate that the new technology is perfect in all those aspects*".

Therefore, the innovation project must be prepared beforehand to facilitate the adoption of the innovation in the recipient firm. According to Niche Chief Executive Officer (NIC 9), the support of intermediaries was critical in his case allowing him to improve the technology proposition through the generation of consistent processes: "*I did not have the experience to create processes as the business was growing. So, the support of intermediaries was important to show us the way to regularly deliver the same value proposition to customers*". Case Study P exhibits the transition intermediary's function of Management of Resources by creating a partnership with different actors and helping the innovation project to obtain standard processes for manufacturing a new product.

Case Study P – The High Value Manufacturing Catapult Centre (HVMC)
Intermediary function of Management of Resources

HVMC was established in 2011 by Innovate UK with the goal to bridge the gap between business and academia. To deliver this goal, HVMC provides access to specialist knowledge, expertise and equipment to manage innovation challenges (HVMC, 2014a). HVMC delivers these resources through partnerships with seven centres of industrial innovation. Each offers different assets to innovation projects, from provision of raw materials to product assembly processes (HVMC, 2014b).

To make these connections possible, HVMC applies for public funding on behalf of its associates. For example, HVMC helped to develop a lightweight EV for urban transport, which would potentially be used to delivering online shopping (HVMC, 2017). HMVC provided funding to the design firm Astheimer to develop the prototype, which has a larger interior space for transporting parcels. Whilst the WMG (the R&D centre for manufacturing of the University of Warwick and one of the seven partners of HVMC) created a light battery system that makes the whole vehicle lightweight. The automobile reduces pollution and energy consumption during the start-stop of deliveries.

HVMC has been working on improving the manufacturing processes of this EV by upgrading the battery for longer ranges and faster charging (HVMC, 2017). Thus, through the HMVC's guidance for implementing lean manufacturing practices, it has reduced the time to market on the introduction of this vehicle that contributes to the energy transition (HVMC, 2017). Consequently, these manufacturing processes can be standardised and transferred to the car and electric manufacturing companies.

In summary, Management of Resources supports defining and scaling processes related to technology innovation in niches. Figure 6.3 draws on the main mechanisms that transition intermediaries unfold in this case. First, the transition intermediary checks the (non)existing process of the socio-technical niche. Second, it proposes a plan to improve existing processes; this might include creating new ones. Third, the adopted processes are monitored by the transition intermediary to verify efficiency. Fourth, the socio-technical niche gets closer to reaching a consistent result every time processes are completed. Fifth, the socio-technical niche masters the processes and can teach these to the recipient firm when the new technology is acquired.

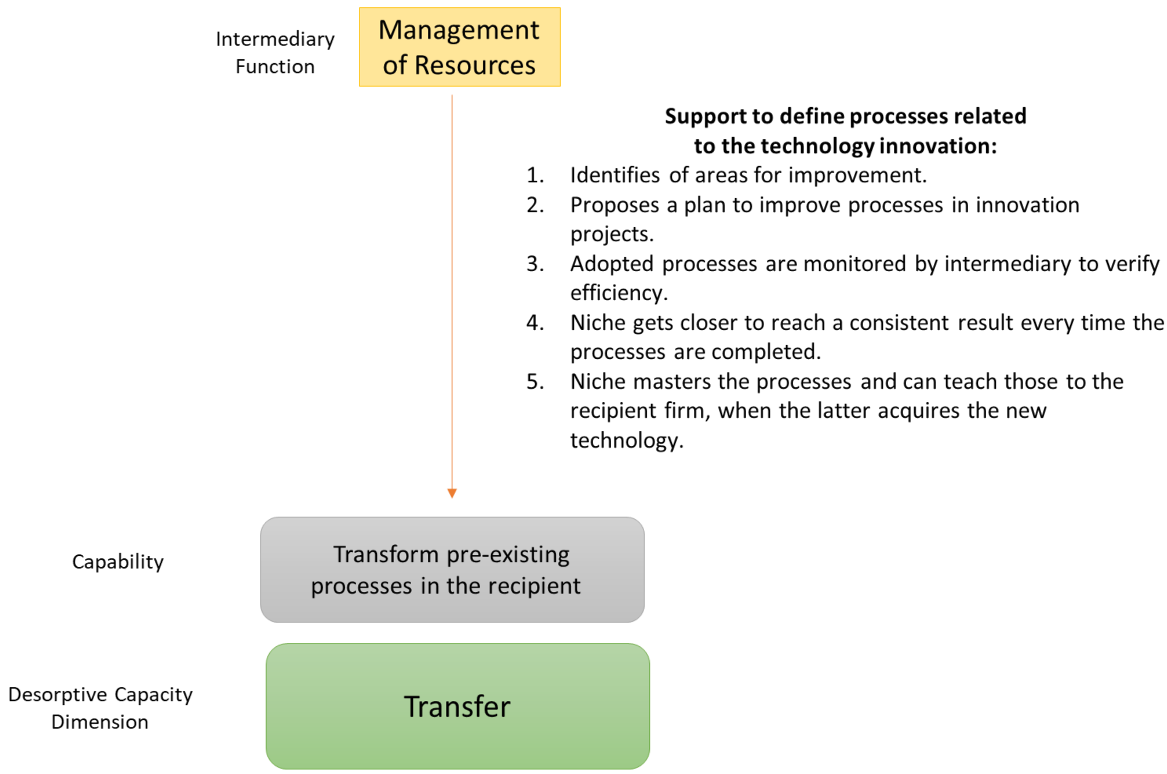

Figure 6.3 Intermediary function developing the capability of technology marketing

6.2.2 Capability to manufacture prototypes

In the words of participants, the manufacturing of a prototype is an important activity for demonstrating the early technology concept and exhibiting the innovation functionality to stakeholders. According to Niche Head of Commercialisation (NIC 2), prototyping serves to evaluate the form in which the technology fits into the energy supply system and the requirements it must have to facilitate the adoption by incumbent firms. However, this involves a substantial amount of investment. "*We spend about a million pounds per year in materials and engineering for R&D. Probably we invest more than that, to be honest*", Niche Head of Commercialisation (NIC 2) has said.

Participants have recognised that developing new technology is a costly activity that often comes at the expense of the niches' pocket. Niche Chief Executive Officer (NIC 9) has recalled the investment needed for building the early version of his technology prototype: "*I put £150,000 of my own money to fund my start-up and have a minimum product*". In such circumstances, socio-technical niches encounter the first problem for manufacturing prototypes. This relates to the access to financial resources necessary to hire engineers, buy materials and access proper designing facilities. This financial commitment creates a gap in this capability because not all innovation projects have the leverage to invest during the early stages. Intermediary R&D Director (INT 10) has said that socio-technical niches normally have a financial constraint in everything they want to do. This situation particularly is reflected in the poor state of manufacturing prototypes whose result tends to be premature and incomplete. "*Hence, they seek for technical support to understand what they can do next*", has added.

Transition intermediaries get involved by providing critical skills and resources for manufacturing the first version of a prototype by deploying the function of **Management of Resources**. For example, business incubators and accelerators can feed the necessary elements to design and exhibit the essential features of the prototype by providing support for lean manufacturing. This includes workshop space, training on technology design and access to real customers for testing the early version of the innovation. "*We help young companies that do not have the expertise for prototyping a new technology, comply with the requirements of energy suppliers and then insert the innovation into the power network*", Intermediary Innovator Support (INT 12) has mentioned.

Case Study Q presents further details about the intermediary's function of **Management of Resources** enhancing the capability to manufacture prototypes.

Case Study Q – The Michelin Scotland Innovation Parc (MISP)
Intermediary function of Management of Resources

MSIP is a joint venture between the French tyre manufacturing company Michelin, Dundee City Council and Scottish Enterprise, created to support the development of green technologies for a net zero future (MSIP, 2020).

MSIP offers a business accelerator programme supporting early-stage firms to develop new solutions for decarbonising goals. In the call of September 2021, the programme selected a group of companies that received funding to demonstrate the viability of zero-emission technologies. This includes a range of options related to hydrogen fuel cells, battery power, solar thermal, heat capture and hydroelectric energy. The funding aimed to support a cohort of start-up firms to conduct prototyping, among other activities (MSIP, 2021a).

To provide those services, MSIP has established the Skills Academy, an accessible ecosystem to address industry needs for achieving net zero. The MSIP Skills Academy brings knowledge and expertise from academia as well as industry to deliver new technologies. Some of the training offered is about manufacturing through to high end technical and digital skills.

This provides essential capabilities to start-up companies about manufacturing prototypes for addressing the opportunities that the energy transition has created (MSIP, 2021b). For instance, the Skills Academy highlighted the growing opportunities in the electric battery industry that requires to put together low volume of battery prototypes (MSIP, 2021b).

Once the prototype has been built, it needs to demonstrate the key functional aspects. To achieve this goal, the socio-technical niche seeks to test the prototype in an environment that simulates the real energy supply system where it intends to operate. Such a demonstration is critical for assessing the limitations of the prototype and later improving its design. Consequently, the capability to manufacture prototypes is also influenced by the option to test them in real conditions. Nonetheless, according to participants of this research finding the right environment to assess the prototype creates another gap, in which the niche technology must recreate the system in which the prototype will be integrated. Niche Business Manager (NIC 10) has recounted that the innovation project she was working on took almost a decade to find the right conditions for testing. In this case, the complexity of trialling the prototype in a real energy supply system led the socio-technical niche to build a pilot plant simulating the actual operation site. "*This demanded a lot of effort and resources* *that took a long time to achieve. Almost a decade in our case. The difficulty to demonstrate the prototype in a real environment is a huge bottleneck for innovations in the energy supply sector*", she has said.

Transition intermediaries have recognised this difficulty and have created conditions to test the prototypes in a controlled environment. In this context, intermediaries reinforce the function of Management of Resources by accelerating the assessment of prototypes on real conditions. Living laboratories –or the abbreviation "living labs"– have been an option developed by transition intermediaries to solve these issues. Living labs pursue validating complex solutions in multiple and evolving real-world test environments where new technologies can be evaluated, according to Intermediary Chief Technology Officer (INT 1): "*Living labs has been highly instrumental for testing new ideas effectively and understand consumer's willingness in particular situations*".

Such an opportunity offers to rapidly assess the integration of new technologies in application fields, such as smart meters, heating devices and vehicle chargers, to name a few. In such regard, Niche Head of Commercialisation (NIC 2) has recalled that through the intermediaries' support, his innovation project was allowed to demonstrate functionality in a living lab: "*We have a solution for storing electricity inside of buildings. The intermediary set the stage for testing the supply of hot water in 360 flats. In this way, we could demonstrate the innovation to a large utility company*". This intervention effectively took the prototype demonstration into a deeper commercial relationship with the incumbent firm, confirming the opportunity to manufacture the innovation at a larger scale, as Niche Head of Commercialisation (NIC 2) has recalled.

Case Study R offers more details about the intermediary's function of Management of Resources, creating proper conditions to test low-carbon technologies in real-world environments or living labs.

Case Study R – Catapult Centre of Energy Systems (ES)
Intermediary function of Management of Resources

The Living Lab initiative by ES offers a quick and affordable real-world trial environment to test technology innovations, contributing to the net zero transition. Established in 2017, Living Lab runs trials directly with consumers in their homes by trying green technologies.

ES describes Living Lab as a digitally open, interoperable and scalable platform connecting 500 homes across England, Scotland and Wales (ES, 2018). With a variety of tenures, property types and demographics, innovative businesses can rapidly design, market-test and launch new energy products, services and business models (ES, 2018).

In 2022, ES has called low carbon energy innovators in Scotland to test their new technologies in real homes with energy network operators. The aim was to decarbonise aspects of domestic heating and transport. The idea facilitated the Living Lab initiative to innovators willing to participate by offering real interactions between homes, energy networks and policy frameworks to be tested across different future energy scenarios (ES, 2022). In this way, the transition intermediary's action will open the possibility for niches to work with real energy consumers. Supporting trials prototypes in heating, EV charging and storage technologies in a living lab of 300 homes across Scotland.

In summary, the capability to manufacture prototypes has been enhanced by the transition intermediary's function of Management of Resources. Figure 6.4 illustrates the two main actions that transition intermediaries unfold in this regard. First, the skill to produce functional prototypes has been increased by training socio-technical niches in lean manufacturing. Second, transition intermediaries organise demonstration trials in living labs allowing niches to test their prototypes in real-world environments.

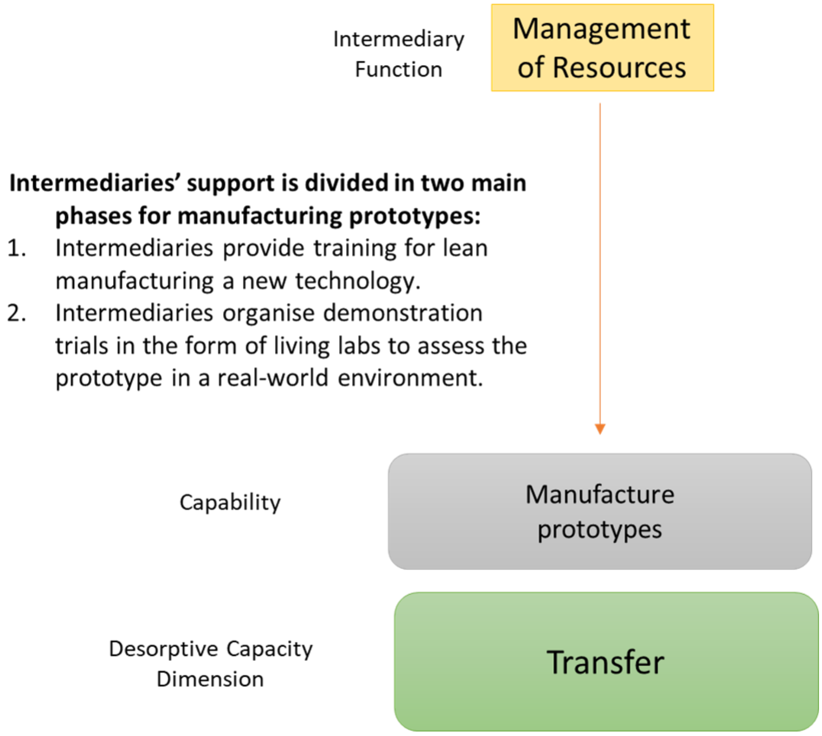

Figure 6.4 Intermediary function developing the capability to manufacture prototypes

6.3 Analysis recap

The analysis of the collected information from primary and secondary sources showed that transition intermediaries deploy a diversity of functions to enhance desorptive capacity in socio-technical niches. Table 6.1 summarises the transition intermediaries' support for the development of capabilities in each dimension of the desorptive capacity conceptualisation. Every function presents a mechanism that is succinctly described in the same table below.

Table 6.1 Summary of transition intermediary functions assigned to each capability of absorptive capacity dimensions

Identification	Transfer
Understand technology base in the recipient *Relationship building*, connecting niches with industrial actors who validate technology proposal. *Management of resources*, intermediaries act as consultants recommending edit technology proposal. This facilitates the approach to incumbents.	**Transform pre-existing processes in the recipient** *Management of resources*, providing training and sharing experience to foster a disciplined approach that designs, maintains and improves processes on niches. To then, transferring those processes to the recipient firm.
Technology marketing *R&D coordination*, provides information about market preferences and regulations. This helps niches to redirect R&D efforts and produce an innovation with better chances to meet market's demands. *Technology forecasting*, suggesting market preferences in future energy systems. Intermediaries recommend niches exploring different commercial applications for the same technology development.	**Manufacture prototypes** *Management of resources*, providing resources and training to niches in lean manufacturing. This allows to produce a larger amount of product units. Later, the prototypes are tested in real-world environments.

Some functions influence the development of more than one capability. Most significantly, Management of Resources contributes to the strengthening of three capabilities. Relationship Building, Technology Forecasting and R&D Coordination affect one capability each. On the other hand, Articulation of Transition and Regulatory Change do not influence any capability. Table 6.2 presents the transition intermediary functions that enhance each specific capability of desorptive capacity. Those are represented with a yellow circle, accompanied next by the case study identified for this instance.

Table 6.2 Summary of transition intermediary case studies deploying a function assigned to each capability of desorptive capacity's dimensions

Desorptive Capacity Dimension	Identification		Transfer	
Capability / Intermediary Function	Understand technology base in the recipient	Technology marketing	Transform pre-existing processes in the recipient	Manufacture prototypes
Relationship Building	Sustainable Ventures			
Management of Resources	Energy Innovation Centre		HVM Catapult	Michelin Scotland Innovation Parc
Articulation of Transition				
Technology Forecasting		Scottish Enterprise		
R&D Coordination		European Marine Energy Centre		
Regulatory Change				

Lastly, Figure 6.5 illustrates the transition intermediary functions that influence the development of each capability of the desorptive capacity's dimensions. Accordingly, arrows connect the intermediary's function with a specific capability. This figure represents the bottom part of the conceptual framework described in Chapter 3.

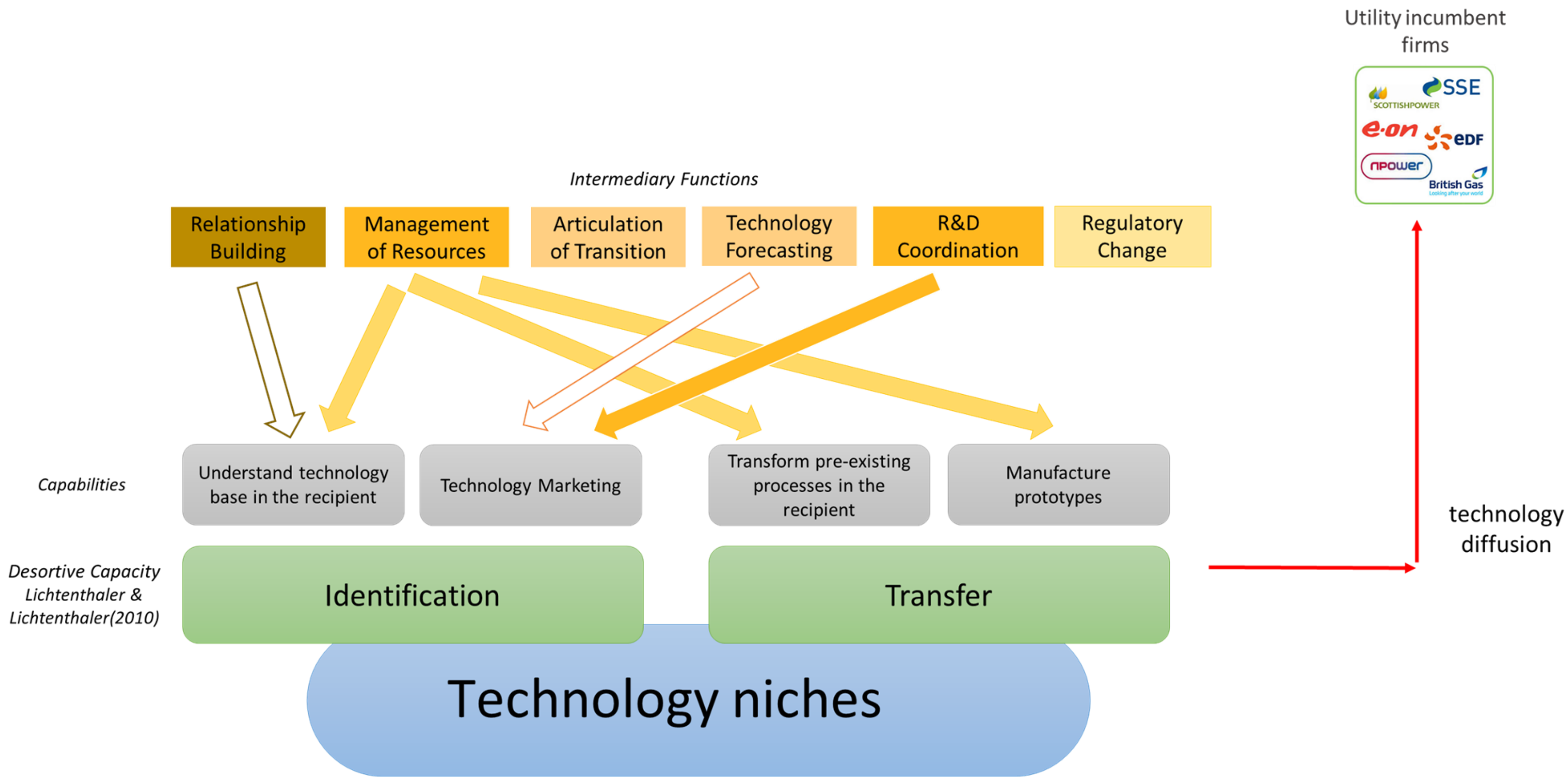

Figure 6.5 Summary of transition Intermediary functions developing capabilities for enhancing desorptive capacity in socio-technical niches

6.4 Chapter Summary

This chapter presented the qualitative analysis of the empirical investigation related to how transition intermediaries develop capabilities for enhancing desorptive capacity in socio-technical niches of the UK energy supply sector. The analysis described the main mechanisms that transition intermediaries deploy to strengthen the development of each capability associated with desorptive capacity's dimensions. Therefore, Section 6.1 investigated Identification; and Section 6.2 explored Transfer.

The interpretation of primary data collected through interviews offered a first layer of results that was contrasted with case studies, presented in vignettes. This approach supported comparisons between the information offered by the participants with the secondary data found in corporate reports. This helped to establish similar findings between both groups of information. Such analytical operation enabled us to address Research Question B by exhibiting how transition intermediary functions are key for cultivating capabilities to desorb sustainable innovation by socio-technical niches.

7 Discussion

This chapter builds upon the research findings of the two sections of analysis (Chapters 5 and 6) to discuss the main contributions to theory and practice. This present chapter is divided into three sections, each underlining the contributions this thesis has made to the three core bodies of knowledge where it aims to position: absorptive capacity in incumbent firms (Section 7.1); desorptive capacity in socio-technical niches (Section 7.2); and the role of transition intermediaries mediating between absorptive and desorptive capacities during a socio-technical transition (Section 7.3). Then, this chapter will assess the conceptual framework (Section 7.4). Finally, the overall results will be used to reflect on the implications to practice, divided into managerial suggestions and policy recommendations (Section 7.5).

7.1 Contribution to absorptive capacity literature in incumbent firms

This section is divided into three different sub-sections. Each of them discusses the contributions this research has made to the literature on absorptive capacity in incumbent firms (Cohen and Levinthal, 1990; Zahra and George, 2002).

First, *previous experience* is an important concept in absorptive capacity literature because it constitutes the knowledge base of the firm, conditioning the direction where it integrates new technologies (Duchek, 2013). Previous experience is configurated by R&D (Cohen and Levinthal, 1990) and the progressive development of capabilities by repeating innovation activities (Zahra and George, 2002). This thesis contributes to the absorptive capacity literature by discovering a third type of previous experience that in UK energy incumbent firms are shaped through operational routines. This idea will be explained in sub-section 7.1.1.

Second, *capabilities* are relevant drivers that support the integration of technology innovation in incumbent firms. To proceed in this discussion, it is important to remember the differences between capacity and capability[8]. Capacity is the quantitative measure that allows the firm to contain resources. Whist capability is a collaborative process deployed by individual or organisational skills to a specific activity of the firm. In such regard, this thesis has found that UK energy incumbent firms' capabilities to integrate technology innovation have become rigid with little tolerance for absorbing innovation. Sub-section 7.1.2 will cover this in more detail.

Third and finally, this research has determined the important contributions that the external environment plays in developing absorptive capacity. This topic has not been fully explored by the absorptive capacity literature and this research fills such a gap by analysing the context in which incumbent firms integrate technology innovation in the UK energy supply sector. This issue will be discussed in sub-section 7.1.3.

7.1.1 Previous experience

One of the basic principles of absorptive capacity is that the prior stock of knowledge held by the firm supports further integration of external technologies (King and Lakhani, 2011). The main driver for this mechanism lies in corporate R&D (Cohen and Levinthal, 1990), which the absorptive capacity literature has referred to as "previous experience" (Todorova and Durisin, 2007). Zahra and George (2002) have argued that previous experience can be developed through capabilities that are fed by innovation experiments. This last idea led Lane et al. (2006) to conclude that R&D efforts are a critical but insufficient condition for investigating absorptive capacity. Consequently, R&D must be combined with capabilities to explore how both configure previous experience and develop absorptive capacity in the firm (Duchek, 2013).

By applying the conceptual framework (Chapter 3) as a lens to investigate previous experience, the results showed that UK energy incumbent firms do not have a sufficient accumulation of learning to insert radical innovation into their processes and routines. Sub-section 5.2.1 supports this by presenting that incumbent firms prefer maintaining a secure energy supply system. This

[8] Although these were defined in the Introduction (sub-section 1.2.3) and the Literature Review (sub-section 2.3.1), it is important to remind the reader about their fundamental differences.

offers characteristics in supply and demand that make the operation of energy utilities consistent and predictable. This means that UK energy incumbent firms tend to look for incremental innovation that fits these priorities, but at the cost of marginally absorbing radical innovation to reach the 2050 net zero goal. Consequently, it's more incremental versus radical innovations when they absorb new technologies. This was corroborated by further analysis (sub-section 5.3.1) that exhibited how incremental innovation was possible to be integrated into incumbent firms' operations. The evidence shows that this type of innovation does not demand modifications to the reliable characteristics of the energy supply system. In contrast, the inertia to acquire radical innovation can be explained due to the possibility of disrupting the current energy supply system (sub-section 5.1.2).

For these reasons, this research has found that the centralised energy supply system constitutes the most influential factor for configuring the previous experience of UK energy incumbent firms and shaping their absorptive capacity. As incumbent firms do not substantially invest in R&D and have had little experimentation in promoting their capabilities to integrate new technologies (see Table 1.1 and Figure 1.7 in sub-section 1.1.4), they have rather used routines for managing the centralised energy supply system as the main source to generate previous experience. Nevertheless, the knowledge base produced by operational experience only allows the UK energy incumbent firms to absorb incremental innovation that supports a greater degree of efficiency in managing the energy supply system. Therefore, the innovation outputs in this process support further efficiency in the incumbent energy supply system, as Figure 7.1 shows.

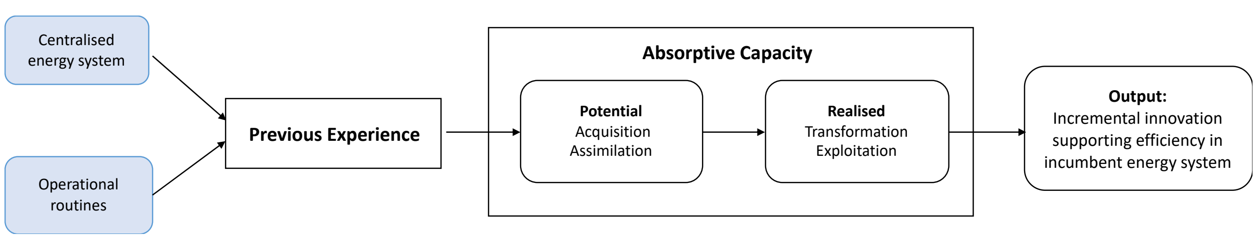

Figure 7.1 Configuration of previous experience in UK energy incumbent firms

This type of previous experience based on operational experience offers serious limitations for absorbing radical innovation. The RBV literature has described such mechanisms as relatively passive experiential processes of learning that gear towards the routine of the firm associated with established practices (Zollo and Winter, 2002). These are insufficient to develop dynamic capabilities that enable organisational change and thus dramatically reconfigure the resource base of the firm through socio-technical evolution (Zahra and George, 2002). These findings explain the motives that most incumbent firms react slowly to innovation opportunities, with little mobilisation of resources to integrate new technologies not aligned with existing routines (sub-section 5.2.1). Significantly, this constitutes a barrier to adopting radical innovation that can transform the energy supply system into a net zero structure.

These results make an important contribution to the absorptive capacity literature (King and Lakhani, 2011) by improving our understanding of how incumbent firms –with little investment in R&D and scarce experimentation in innovation activities– develop a previous experience. Importantly, this research has found that UK energy incumbent firms use operational routines to build a previous experience. Consequently, this corporate decision has a strong influence on the development of absorptive capacity that allows it to integrate only knowledge complementing the operational management of the energy supply system.

These findings are relevant for the absorptive capacity literature because they offer an additional standpoint to the previous conceptualisations of developing previous experience either by R&D (Cohen and Levinthal, 1990) or a combination of R&D with innovation experiments (Zahra and George, 2002). Both offer explanations of how learning can be internalised in the organisational memory, but neither perspective is supported by this research. Instead, it suggests a new type of previous experience in the UK energy incumbent firms that is shaped through operational routines.

7.1.2 Capabilities

The previous sub-section 7.1.1 exposed the configuration of previous experience in UK energy incumbent firms. Now, this sub-section 7.1.2 will discuss the development of capabilities in large energy suppliers. They are different in the following way. Previous experience is the accumulation of knowledge –usually through internal R&D and innovation experiments– that increases the capacity to add new information to the firm (Jansen et al., 2005). While capabilities are the specific processes of the firm that help to manage resources (Amit and Schoemaker, 1993). The latest concept is important because it offers the opportunity to understand how UK energy incumbent firms have generated skills to administrate new technologies that allow them to confront a socio-technical transition (Turnheim and Sovacool, 2020).

The conceptual framework (Chapter 3) was fundamental to address this question by investigating the development of capabilities associated with the absorptive capacity dimensions defined by Zahra and George (2002). This qualitative approach helped us to reveal the evolution of capabilities in the UK energy incumbent firms when faced with new challenges, such as the integration of technology innovation responding to external pressure (e.g., climate change). This is an important contribution to the absorptive capacity literature that has, to date, neglected the qualitative investigation about the development of capabilities (Duchek, 2013). Instead, it has mostly analysed the state of absorptive capacity during a specific period, usually in quantitative terms correlating the prior investment in R&D with the later production of a patent portfolio or the intensity of launching new products (Fabrizio, 2009).

The results of this thesis indicate that UK energy incumbent firms have developed capabilities to integrate new technologies in the past, but these have become less open to adopting technology innovation to meet the 2050 net zero target (sub-section 5.1.2). In this regard, when the conceptual framework was applied to UK energy incumbent firms to explain how these capabilities have been endogenously constructed before the transition intermediary intervention, the findings showed a rigid nature. This means that capabilities became inflexible due to the successful previous integration of resources that have improved the security of the energy supply system. Consequently, UK energy incumbent firms continue to perform those capabilities in a similar way for reducing carbon emissions.

This shows limited signs of learning about the absorption of new technologies responding to different challenges. This was manifested through the analysis of the development of the capability to overlap the knowledge acquired with the firm's internal knowledge (sub-section 5.3.1). Here, the UK energy incumbent firms demonstrated a lack of flexibility to edit established processes to absorb external innovation. As was the case of adapting NDAs to reduce the level of indemnity in incumbent firms' favour (sub-section 5.3.2).

These findings obtained through the application of the conceptual framework were supported by the general sustainability overlook of the UK energy supply sector presented in sub-section 1.1.4. This denoted how the development of capabilities in UK energy incumbent firms allowed them to integrate renewable energy in the last 20 years. However, the findings generated through the application of the conceptual framework in Chapter 5 showed that they have not modified these capabilities fast enough to absorb new technologies in the last couple of years. Transforming these capabilities to face a new challenge is not an easy matter –as this thesis has shown– due to the attachment that the UK's incumbent energy firms have with the security component of power supply (sub-sections 5.1.1, 5.2.1 and 5.3.1).

These results contribute to explaining why incumbent firms have difficulties in absorbing technological innovation, complementing previous research with inconclusive results (Kattirtzi et al., 2021). It is not only about accessing external resources but the adaptation of technology-related capabilities that allow incumbent firms to transform and exploit the innovation for commercial purposes. Thus, the evolution of capabilities is critical for crossing the boundaries between potential and realised dimensions in absorptive capacity, according to the framework proposed by Zahra and George (2002)[9], as Figure 7.2 illustrates.

[9] See sub-section 2.3.3 for more details about the potential and realised dimensions in absorptive capacity.

Figure 7.2 Capabilities supporting to cross from potential to realised absorptive capacity

Consequently, this thesis has contributed to exhibiting the reasons behind the slow adaptation of capabilities to absorb technology innovation responding to new challenges in the energy sector. This adds to the motives explaining the carbon lock-in (Unruh, 2002) by applying an absorptive capacity perspective (Escribano et al., 2009; Flatten et al., 2011; Vanhaverbeke et al., 2008).

Additionally, these findings are aligned with an extended view of the MLP (Geels, 2014), which underlines the rigidness of incumbent firms to integrate external knowledge (van Mossel et al., 2018). This thesis has shown how the endogenously development of capabilities by UK energy incumbent firms is insufficient to address the complexity of a socio-technical transition. Consequently, the state of capabilities in incumbent firms makes it difficult for them to integrate niche technologies. Particularly, when the external innovation puts at risk the stability of the energy supply system. This reflects the deep commitment that incumbent firms have to traditional practices that characterise the socio-technical regime and how this circumstance moulds capabilities in incumbent firms to exclusively manage incremental innovation. In summary, the capability approach can explain why some incumbent firms in the UK energy supply sector have difficulties moving away from “business as usual”.

7.1.3 External environment

An important factor that the absorptive capacity literature has not paid sufficient attention to is the influence that the external environment plays in developing firm’s capabilities. This topic has been slightly addressed by Camison and Fores (2010), relating to the adaptations that firms might take to face changes in the competitive landscape. Consequently, few studies have investigated the influence that the external environment has on the development of absorptive capacity.

To proceed with that analysis, this thesis argues that a stronger integration between absorptive capacity with the MLP (Geels, 2002) can help to explain the influence of the external environment. The MLP proposes that incumbents' approach to innovation is profoundly influenced by the rules of the socio-technical regime (Geels and Schot, 2007). These norms act as a filter to select the adoption of new knowledge, which is typically incremental (Fuenfschilling and Truffer, 2014). Such an incumbency approach has been labelled as a resistant behaviour to transitions (Geels, 2014). However, recent literature has proposed a nuanced description of incumbent firms (Turnheim and Sovacool, 2020). This line of investigation has reflected on the influence that the external environment plays in driving incumbent firms to accept the entry of radical technologies into the regime (van Mossel et al., 2018). Even to the point where incumbents absorb these for sustainable purposes (Hansen and Coenen, 2017).

This thesis contributes to such a debate by considering the broad context of the external environment and how it affects the absorptive capacity of incumbent firms by applying MLP principles. Specifically, around the influence that important dimensions of the regime have in integrating new technologies in incumbent firms. In this case, the analysis showed that the centralised energy supply system plays a big role in shaping the absorptive capacity of UK energy incumbent firms.

For example, incumbent firms seek incremental technology innovation to augment the energy supply capacity by leveraging existing infrastructure, as was analysed in sub-section 5.1.1. In this example, incumbent firms have developed a cautious approach to external technology because this brings the possibility of destabilising the core regime's function of security in the energy supply. This thesis found that knowledge absorption is related to incremental innovation, which primarily aims to improve efficiencies within the existing energy supply system rather than transform it. On the contrary, incumbent firms are reluctant to integrate radical innovation that might disrupt the energy supply system. Therefore, the energy supply system works as an important external factor that conditions the behaviour of incumbent firms towards technology innovation.

Figure 7.3 depicts these powerful factors that influence the generation of a previous experience, which subsequently affects the type of innovation to be integrated by the absorptive capacity of the incumbent firms to finally produce incremental innovation. Consequently, it can be said that external factors associated with industrial infrastructure act as the most influential element shaping absorptive capacity in UK energy incumbent firms. This contributes to add external factors into the Zahra and George's framework[10] as Figure 7.3 suggests below.

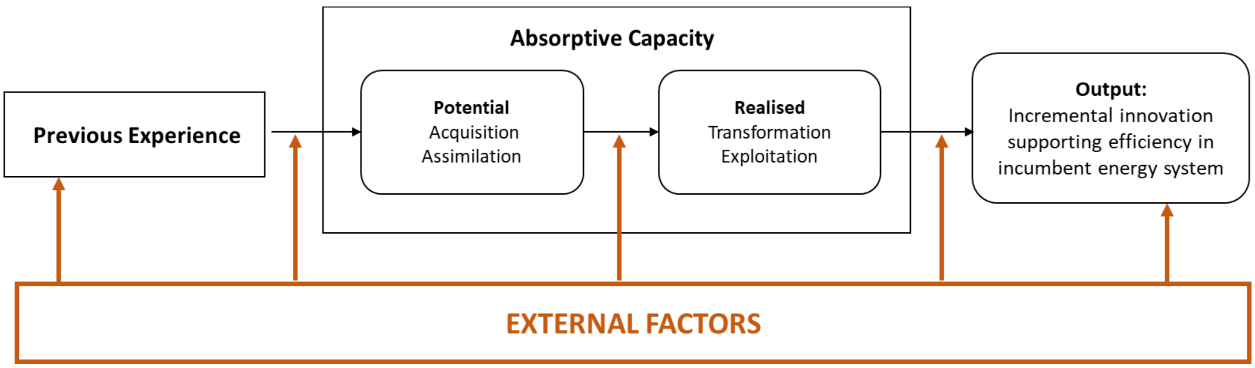

Figure 7.3 External factors influencing absorptive capacity in incumbent firms

These results are consistent with the description of incumbent firms provided by part of the MLP literature, which defines them as established companies that follow regime rules (Penna and Geels, 2015). Furthermore, incumbents maintain and defend the socio-technical regime where they belong with their strategic decisions (Geels et al., 2017; Pinkse and Groot, 2015; Smink et al., 2015). These results are aligned with the recent findings published by Geels and Turnheim (2022) indicating that utility firms marginally innovate by following the dominant regime's rules of security in the UK energy supply system.

On the other hand, by confirming that incumbent firms absorb technology innovation based on outside factors to the firm (i.e., the energy supply system), this thesis has shown that the external environment plays a big role in shaping absorptive capacity. Moreover, it has provided in-depth insights into the constraints that UK energy incumbent firms face in integrating new technologies that cannot be easily merged into the energy supply system. This shows that the energy supply system acts as a dominant filter for selecting the entry of new knowledge. Other studies have

[10] See Figure 2.4 for reviewing the original framework from Zahra and George (2002).

arrived at similar conclusions when have investigated different industrial sectors where a centralised system provides security of operations but with little tolerance for adding new technologies, such as heating systems (Hanmer and Abram, 2017) and water treatment (Quezada et al., 2016). In other words, this thesis offers further confirmation that the UK energy supply industry follows the pattern of other "centralised systems" sectors. Therefore, this research has revealed that incumbent firms operating within a centralised system face an important layer of entrenched rules that guide their innovation behaviour and deeply affect their performance on absorptive capacity.

7.2 Contributions to desorptive capacity literature in socio-technical niches

This second section now considers the two contributions this research has made to the literature on desorptive capacity in socio-technical niches (Lichtenthaler and Lichtenthaler, 2010).

First, this thesis offers a *new understanding* of the conceptualisation of desorptive capacity as a stand-alone framework separated from absorptive capacity as it was originally proposed by Lichtenthaler and Lichtenthaler (2009 and 2010). The results obtained through the conceptual framework (Chapter 3) showed that desorptive capacity is a multifaceted notion that involves a set of capabilities deployed in a non-linear fashion that reduces the inherent risk in technology innovation development. This will be covered in sub-section 7.2.1.

Second, *learning* is an important component of desorptive capacity that helps to improve the efficiency of technology transfer. However, previous studies in desorptive capacity (Bianchi and Lejarraga, 2016) have had difficulty in explaining how learning is produced in socio-technical niches. The present research contributes to understanding this process by linking learning with the development of capabilities. This will be discussed in sub-section 7.2.2.

7.2.1 New understanding of desorptive capacity

The literature on desorptive capacity has described this concept as complementary to absorptive capacity (Dell'Anno and Del Giudice, 2015). Firms with sufficient absorption of external knowledge can produce further R&D results and later these outputs can be diffused to the technology market through desorptive capacity (Muller-Seitz, 2012). This thesis took a different approach to examining desorptive capacity by isolating it from its initial definition. This meant that desorptive capacity was analysed separately from the other elements mentioned in the model proposed by Lichtenthaler and Lichtenthaler (2009 and 2010). This research followed such an option because it provided the opportunity to explore in depth the management practices and capabilities of socio-technical niches to diffuse innovation in the UK energy supply sector. This presents a twofold importance.

Firstly, it establishes a theoretic value by displaying a group of specific capabilities associated with the desorptive capacity's dimensions of identification and transfer[11]. This was proposed using the conceptual framework (Chapter 3), allowing the researcher to explore the particular heuristics of outward technology transfer in niches of the UK energy supply sector. By taking such an approach, this investigation concentrated on the diffusion process of technology innovation, enabling us to understand how socio-technical niches develop capabilities for this purpose. Such a standpoint disaggregates desorptive capacity as a derivative function of absorptive capacity and analyses it on its merit. This new approach responds to the calls made by Ahn et al. (2016) who suggested exploring desorptive capacity beyond its complementary function of absorptive capacity.

Secondly, it offers empirical value by examining the development of capabilities for diffusing innovation in socio-technical niches. This constituted a contrast with the approach proposed by Lichtenthaler and Lichtenthaler (2009 and 2010), who covered large and established technology firms in more dynamic industrial sectors, such as Lucent Technologies in telecommunications equipment, IBM in information technology, and Procter & Gamble in the consumer health sector.

[11] These capabilities are defined in sub-section 2.3.4 of the Literature Review chapter. See Table 2.7 for more details.

It is an important difference because it was previously understood that desorptive capacity was only possible in large firms, with significant resources to constantly absorb knowledge, convert it into technology innovation and later desorb it. However, this thesis selected socio-technical niches in the UK energy sector with less experience in deploying that process. This allowed us to explore how smaller actors develop capabilities for diffusing technology innovation without using a great number of resources for external knowledge exploitation.

Under this new approach to investigating desorptive capacity, this research was able to establish two key differences compared with the original term coined by Lichtenthaler and Lichtenthaler (2009 and 2010).

First, the initial definition of desorptive capacity –as complementary to absorptive capacity– has been presented as an out-licensing mechanism. This suggests a reductionist point of view that minimises the complexity of technology transfer to a legal transaction, in which IPRs move smoothly from one business to another. It also assumes that both ends have the same level of information and competencies to proceed with the licensing agreement.

This research has expanded desorptive capacity as a multifaceted framework that involves three mechanisms for disseminating a new technology in the UK energy supply sector. These include: (i) testing the technology innovation in a controlled environment to assess its integration into the energy supply system; (ii) complementing the new technology in the existing infrastructure of the energy supply system; and (iii) validating the technology innovation in technical and economic terms to be inserted in the processes and routines of incumbent firms.

This approach is synthesised in Figure 7.4, which made it possible to allocate mechanisms in the dimensions of desorptive capacity (Lichtenthaler and Lichtenthaler, 2009 and 2010), according to the results obtained from Chapter 6. Sub-section 6.1.2 described how socio-technical niches diffuse innovation for testing innovation in experiments with the energy supply system, addressing mechanism (i) in the dimension of identification in desorptive capacity. Sub-section 6.2.1 determined the efforts that socio-technical niches make for creating processes that complement the adoption of technology innovation into the recipient firms, mentioned in (ii). Sub-section 6.2.2 provided insights about the validation of technology innovation when niches participate in living lab projects, as mechanism (iii) has proposed. The mechanism (i) can be placed in the potential dimension of desorptive capacity, while the other two mechanisms (ii) and (iii) are placed in the dimension of transfer. The three mechanisms support the iteration of the technological innovation multiple times until it meets the social, economic and industrial conditions in which it is rooted, facilitating its diffusion to incumbent firms.

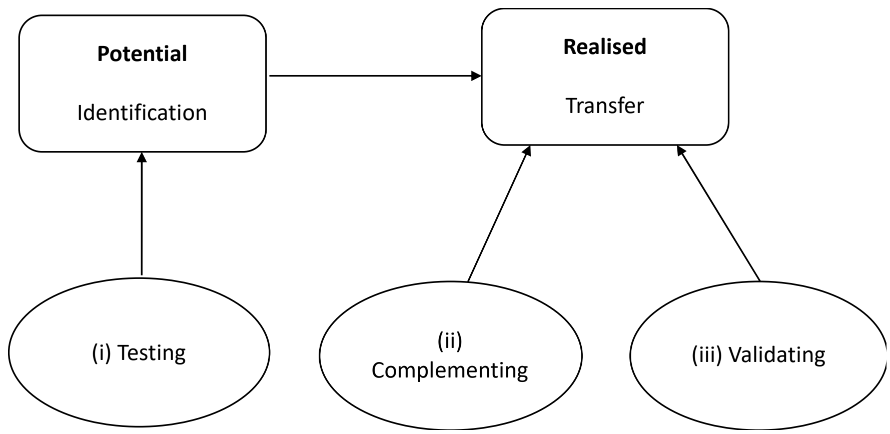

Figure 7.4 Mechanisms of desorptive capacity

Second, Lichtenthaler and Lichtenthaler (2010) considered that companies possessing large technology portfolios will be reluctant to transfer core technologies ("crown jewels") to firms in the same industry due to the possibility of creating a future competitor. This idea deems that firms are selective about which technologies they transfer to potential partners, limiting desorptive capacity and reducing even further the scarce efficiency of technological markets (Aliasghar and Haar, 2021). However, this thesis did not observe such an approach from socio-technical niches in the UK energy supply sector. On the contrary, the results showed the inclination to generate a collaborative environment where a variety of actors promote the diffusion of low-carbon technologies (sub-sections 6.1.1, 6.1.2 and 6.2.1). This helps the technology innovation to be validated by incumbent firms and achieve significant progress. Through the secondary sources of information, this research has identified such elements of cooperation in Case Studies M, N and R.

To illustrate this point, Case Study R described how the living lab initiative promoted by ES Catapult Centre organises trials of niche technologies with the support of energy utilities. Such real-world tests aim to demonstrate the technology concept with real customers, obtaining feedback that allows the innovation to get closer to the incumbent firms' operations. In such cases, socio-technical niches are open to demonstrating their core technologies with industrial players. Because they have understood –through the intervention of intermediaries– that this approach can help them to later transfer the technology innovation to large utility companies as part of their commercial strategy.

This is a modest sample obtained by this research in the particular context of the UK energy supply industry; and, probably, it does not allow it to generalise results. Nonetheless, it indicates a strong tendency in the UK energy supply industry to seek collaboration when socio-technical niches develop an innovation. This evidence is contrary to the previous assumption of the desorptive capacity literature that was less inclined to consider the transfer of new technology due to the possibility of creating a potential competitor (Hu et al., 2015).

In summary, this research offers a new understanding of desorptive capacity as a group of capabilities that progressively reduce the inherent risk of technology development. This new conceptualisation differs from the standard definition proposed by Lichtenthaler and Lichtenthaler (2009 and 2010) as a complementary function of absorptive capacity, only performing activities of out-licensing. Instead, this research has taken into consideration the development of technological innovation in the UK energy supply industry, proposing a new notion of desorptive capacity. This consists of a group of capabilities that support socio-technical niches in reducing the risk during the translation process from invention to innovation with the support of transition intermediaries and larger industrial partners, regardless of the possibility of creating a future competitor.

7.2.2 Development of capabilities through learning

The importance of learning has been discussed in the desorptive capacity literature in terms of accumulating skills that upgrade the efficiency of executing out-licensing agreements (Bianchi et al., 2014; Roldan Bravo et al., 2019). This means that firms can improve the management of technology transfer if they constantly repeat licensing agreements. These learnings reduce the transaction cost of outwardly transferring a technology innovation and improve the efficiency of the process (Ziegler et al., 2013). However, such learning effects are difficult to observe due to the multifaceted development of capabilities that depend on the integration of new knowledge into the routines and practices of the organisation (Bianchi and Lejarraga, 2016).

This thesis attempted to address this issue by reconceptualising Lichtenthaler and Lichtenthaler's (2010) framework of desorptive capacity, previously explained in sub-section 7.2.1. This made it possible to analyse the feedback loop for learning exploitative capabilities. The results obtained in this investigation showed that socio-technical niches rely on external actors, such as incumbent firms and transition intermediaries, to generate an environment of learning and develop the capabilities required for enhancing desorptive capacity.

The findings suggest that these learning processes start when socio-technical niches strengthen the ties with an industrial network thanks to the intervention of transition intermediaries. There, niches collect information from industrial actors (including incumbent firms) that guide the technology design towards the demands of the energy supply sector (sub-section 6.1.1). This generates important insights for niches offering the opportunity to edit the technology development. The modification of the new technology is carried out by socio-technical niches with the support of transition intermediaries. This collaborative approach accelerates the usual slow pace of technology development in the energy supply sector (sub-section 6.1.2). An important result of this relationship consists in the learning that socio-technical niches obtain for pivoting the technology that has failed in the energy supply sector and moving it to different industrial applications, as Case Study O has shown.

These insights clarify important aspects of learning that have not fully been investigated by the desorptive capacity literature. Dell'Anno and Del Giudice (2015) explored organisational networks that collaboratively exchange critical resources to facilitate learning in the technology producer. However, they offered few interpretations to explain how capabilities to diffuse technology innovation are developed in niches. Similarly, Bianchi and Lejarraga (2016) have framed the interaction of actors in technology licensing, using an approach that partially studied the mechanisms to organically develop capabilities. Finally, Bauer et al. (2018) examined the organisational capabilities to desorb new technologies and their effects on performance, but they neglected the question of how these capabilities are built. This last paper made the recommendation to analyse the processes involved in learning capabilities for outwardly diffusing new technologies.

Responding to Bauer et al.'s (2018) calls, this thesis has emphasised the importance of feedback loops for learning in desorptive capacity. Such feedbacks develop capabilities for diffusing technology innovation that occurs in niches through a series of iterations of the technology development. It is not only about the accumulation of experience in licensing activities as Bianchi and Lejarraga (2016) suggested. But the potential to learn from incumbent firms how they assess the new technology received from socio-technical niches and use them in their daily routines and processes. This feedback from incumbent firms allows niches to modify the technology development with the support of transition intermediaries. Case Study M showed that intermediaries propose innovation challenges in the UK energy supply industry that socio-technical niches address by presenting proposals. The transition intermediary selects some of these and put the niches in contact with industrial informants, who offered suggestions for improving the technology development. In this process, niches learn to edit the initial technology concept in order to comply with regulations, operational and commercial aspects until fits into the incumbent energy supply system. This learning process is summarised in Figure 7.5.

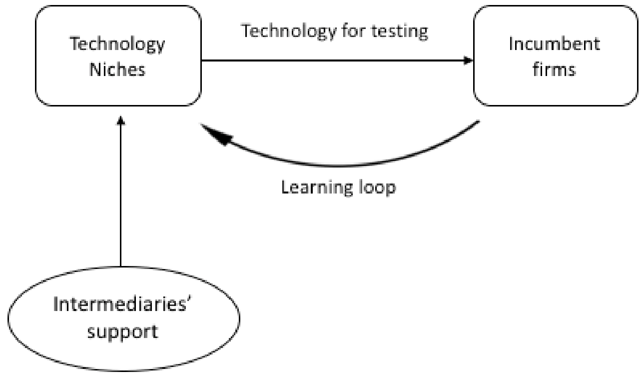

Figure 7.5 Socio-technical niches' learning process

Thus, these results contribute to the desorptive capacity literature by suggesting that socio-technical niches' efforts to develop capabilities for diffusing new technologies in the UK energy sector are essentially collaborative. It is not the consequence of repeating licensing transactions that generates experience, as prior studies have suggested (Bianchi et al., 2014; Sikimic et al., 2016; Ziegler et al., 2013).

This is an important contribution to the literature because it positions desorptive capacity as a set of capabilities that are progressively learned through the joint efforts of a network of actors. Such a network supports the technology diffusion of smaller but innovative actors (i.e., socio-technical niches) for achieving sustainable purposes. In this context, the role of transition intermediaries is fundamental to facilitating this learning environment. Their interventions reduce the enormous cost for a young organisation in the energy supply sector to execute several licensing agreements until they obtain sufficient desorptive capacity. Consequently, this offers the possibility to diffuse new technologies that can effectively support the net zero transition in the UK.

7.3 The role of transition intermediaries mediating between absorptive and desorptive capacities during socio-technical transition

This research investigated the critical role that transition intermediaries play in developing absorptive and desorptive capacities. Now, this section will discuss how intermediaries develop these by interacting with incumbent and niche actors in the technology innovation system of the UK energy supply sector. Particularly, by making dots that allow socio-technical niches to diffuse new technologies and the incumbent firms to adopt these. This section will present two key contributions to that topic.

First, it will discuss the form in which transition intermediaries provide critical resources to create a previous experience in absorptive and desorptive capacities. As was previously covered in sub-section 7.1.1, the concept of previous experience in absorptive capacity refers to the accumulation of a knowledge base that allows incumbent firms to integrate additional technology innovation. Whilst desorptive capacity literature uses a similar term of previous experience to describe the antecedents that influence the diffusion of technology innovation. The next sub-section 7.3.1 will address how transition intermediaries build previous experience in both absorptive and desorptive capacities by providing resources. An important factor that helps to establish connections between incumbent firms and socio-technical niches.

Second, this thesis proposed a typology of intermediary transition functions collected from different strands of the transition literature (summarised in the Table 2.5). This typology was implemented through the conceptual framework for analysing the role that intermediaries play during the sustainability transition. The results provided important lessons that allow us to compare with similar typologies from the literature. In turn, this generates a reflection on the role of intermediary functions interacting between niches and incumbents in the broader context of a socio-technical transition. This will be discussed in sub-section 7.3.2.

Third, the results show that intermediary functions proposed in sub-section 2.2.2.2 act in combination, configuring a meta-function. This gathers a group of individual functions that together provide a solution to various conflicts in the relationship between absorptive and desorptive capacities. These findings resonate well with the concept of “motors of innovation”, defined in sub-section 2.2.2 as the cooperation of multiple TIS functions (Suurs, 2009). This will be covered in sub-section 7.3.3.

7.3.1 Intermediaries as providers of critical resources for building absorptive and desorptive capacity

The literature has investigated the efforts of transition intermediaries to overcome shortcomings in the relationship between incumbents and niches (Kivimaa et al., 2019a). However, more insights are needed to establish intermediation mechanisms to connect both types of actors (Bergek, 2020). This research has addressed this issue by using the transition intermediary functions, proposed in sub-section 2.2.2.2, as a base for unveiling these mechanisms.

The results showed that transition intermediary functions are not only important to strengthen capabilities for diffusing and adopting technology innovation by changing perceptions and guiding actions in socio-technical niches and incumbent firms. They also provide critical resources for developing both absorptive and desorptive capacities. By following that approach, this thesis makes an important contribution by inserting the RBV theory into the transition literature. The next two sub-sections will discuss the type of resources that transition intermediaries offer to incumbent firms in sub-section 7.3.1.1, and to socio-technical niches in sub-section 7.3.1.2.

7.3.1.1 Intermediary resources provided to incumbent firms for developing absorptive capacity

The theory of absorptive capacity proposes that the firm requires internal resources to conduct R&D, such as laboratories, equipment, scientists and a dedicated budget (Cohen and Levinthal, 1990). The research outputs can be later tested through innovation experiments, which in turn enhances capabilities for integrating additional knowledge (Zahra and George, 2002). This creates an organisational memory or a knowledge base for absorbing external technologies (Lane et al., 2006). However, R&D and innovation experiments demands expensive resources that an important number of firms are not in position to invest due to different strategic choices.

Consequently, it can be expected that depending on the dynamism and environmental conditions of their industrial sector, incumbent firms consider unnecessary to have R&D departments and neither conduct innovation experiments. For this reason, some incumbents lack the necessary knowledge base to integrate new technologies (Volberda et al., 2010).

Sub-section 1.1.4 has detailed such a situation by showing the scarce investment that UK energy incumbent firms have made in corporate R&D[12]. This approach has been reinforced through the efficiency-oriented strategy that inhibits the investment in R&D, according to the analysis of primary information (sub-section 5.1.1). This has resulted in incumbent firms not having sufficient resources to conduct internal R&D and innovation experiments, reducing their chances of creating a knowledge base for absorbing clean technologies. This can represent an important setback for achieving the 2050 net zero target in the UK energy supply industry.

In such regard, one of the most important findings of this research is that transition intermediaries provide these critical resources related to R&D and innovation experiments, making it possible to enhance absorptive capacity in UK energy incumbent firms. In turn, the provision of R&D resources supports incumbent firms to link with the technology development generated by socio-technical niches. The analysis showed that transition intermediaries supply these resources by deploying functions. As the literature review explained in sub-section 2.2.2.2, these functions consist of mechanisms that intermediaries use to improve the innovation performance of TIS actors (Kanda et al., 2019; Lukkarinen et al., 2018).

To illustrate such a point, this thesis showed that the intermediary function of Management of Resources provides dedicated facilities to test new technologies (sub-section 5.2.1). When these innovations have been adequately validated, intermediaries then support the mass production of the new technology to be commercialised, deploying the same function of Management of Resources. Moreover, sub-section 5.4.1 described how transition intermediaries connect incumbent firms with innovation laboratories, where utility companies can manufacture specific components of new technology in large volumes (Case Study K). This is accompanied by the transition intermediary’s function of Articulation of Transition by Knowledge Exchange, which

[12] See Table 1.1 and Figure 1.7 for more details.

offers critical information to insert the technological innovation into the energy supply system without disrupting it (sub-section 5.3.1). Finally, the function of Articulation of Transition by Knowledge Exchange reduces the regulation that makes it difficult to test the new technology in real-world trials and observe the impact technological innovation has on the energy market (sub-section 5.4.1).

Through this process, transition intermediaries provide critical resources –such as demonstration facilities, manufacturing centres and specific technical information– that replace the internal R&D and innovation experiments at the firm level. Consequently, energy incumbent firms can increase their absorptive capacity. Additionally, the provision of resources by intermediaries influences the direction in which incumbent firms seek technological innovation, responding to the current pressure of reaching the 2050 net zero goal. This indicates that transition intermediaries are critical to updating the carbon technologies used by the UK energy incumbent firms.

Therefore, this thesis suggests that incumbent firms can develop absorptive capacity through the external resources provided by transition intermediaries that replace the costly investment of internal R&D and innovation experimentation. These findings contrast the prior assumption of the literature that considered R&D resources as a necessary internal investment of the firm to building absorptive capacity (Dyer and Singh, 1998; Lane and Lubatkin, 1998; Todorova and Durisin, 2007).

Table 7.1 summarises these findings by detailing the specific transition intermediary's function supporting the development of capabilities in each dimension of absorptive capacity. Likewise, it shows the intermediary resources provided and the intermediation examples presented in Chapter 5.

Table 7.1 Summary of intermediary functions and resources provided to incumbent firms for developing absorptive capacity

Absorptive Capacity	Innovation Intermediary Function Performed	Innovation Intermediary Resource Provided	Innovation Intermediary Example in brackets the case study code
Acquisition			
Capability to identify new technology opportunities	• Relationship Building	• Innovation network	• Knowledge Transfer Network (A)
Capability to connect with the R&D community	• Articulation of Transition	• Packages of Information	• Fusion Project by the Department of Business, Enterprise and Regulatory Reform (B)
Assimilation			
Capability to de-risk external technology	• Management of Resources	• Demonstration centres	• Power Networks Demonstration Centre (C) Offshore Renewable Catapult Centre (D)
Capability to create technological roadmaps	• Articulation of Transition • Technology Forecasting	• Technology roadmaps Demonstration contest	• The Carbon Trust (E) Power Networks Demonstration Centre (F)
Transformation			
Capability to overlap the knowledge acquired with the firm's internal knowledge	• Articulation of Transition	• Technology testing in nodes of the energy system	• Energy System Catapult Centre (G)
Capability to separate the knowledge source between sender and receiver	• Relationship Building	• Knowledge about intellectual property	• UK Intellectual Property Office (H)
Exploitation			
Speed to market	• Regulatory Change • Articulation of Transition • Management of Resources	• Real-world testing • Novel market information Manufacture capacity.	• Consumer, Vehicle and Energy Integration project by the Energy Technology Institute (I) • Energy System Catapult Centre (J) Digital Manufacturing Innovation Hub (K)

Thanks to the intermediation efforts shown in Table 7.1, the main resource provided to develop absorptive capacity in UK energy incumbent firms focuses on translating the technology information offered by socio-technical niches. This is possible to offer by establishing an innovation network as the main resource in the dimension of acquisition. This is supported by the interpretation of packages of information –another critical resource– from the R&D community, enabling incumbent firms to acquire new technology. The acquired technology innovation is then tested in demonstration centres (intermediary resources) showing incumbent firms that it is possible to integrate low-carbon technology into the energy supply system without disruption, in the assimilation dimension. Such a mechanism opens the possibility of developing a new energy supply system by designing technology roadmaps. This group of new technologies is further tested in nodes of the energy supply system, where the intermediaries help to define the intellectual property and assign it to the right parties, in the transformation dimension. Finally, in the exploitation dimension, the intermediaries offer resources to incumbent firms for scaling the new technologies trials with real-world customers. This is further supported by intermediaries through manufacturing resources allowing incumbents to produce the end product in larger numbers.

Throughout the analysis of data, this thesis has discovered that transition intermediary functions proposed in sub-section 2.2.2.2 are often deployed in combination with each other. Figure 7.6 illustrates how one function supports another to enhance each dimension of absorptive capacity in incumbent firms. This means that the intermediation functions go beyond knowledge brokerage, as Kilelu et al. (2011) suggested. The results note that intermediaries recognise the enormous effort needed to bring technology innovation that can be accessible to incumbent firms. Accordingly, they have taken a predominant role in which different intermediary functions are combined to address the problems found in the development of technology innovation (Section 2.1).

To illustrate this point, we take the dimension of exploitation in absorptive capacity in below Figure 7.6. This helps it to observe the combination of intermediary functions. For example, the complexity of exploiting the technology integrated by the incumbent firm has been an issue raised by the absorptive capacity literature (Mahmood and Mubarik, 2020). This thesis has found that transition intermediaries unfold three functions in combination to support this critical dimension in UK energy incumbent firms.

In summary, transition intermediary functions allow UK energy incumbent firms access to R&D activities and innovation experiments, summarised as mechanisms in Figure 7.6. These insights constitute an important difference from the previous conceptualisation of absorptive capacity that suggested the firm must internally invest in R&D and innovation experiments. Importantly, it can be concluded that the knowledge base of the firm might be created within an industry where external factors do not push companies to perform corporate R&D, such as the UK energy supply sector. Therefore, the presence of transition intermediaries is crucial to engage incumbent firms with R&D resources and innovation experiments, making it possible to renovate the outdated technology platform that generates carbon emissions.

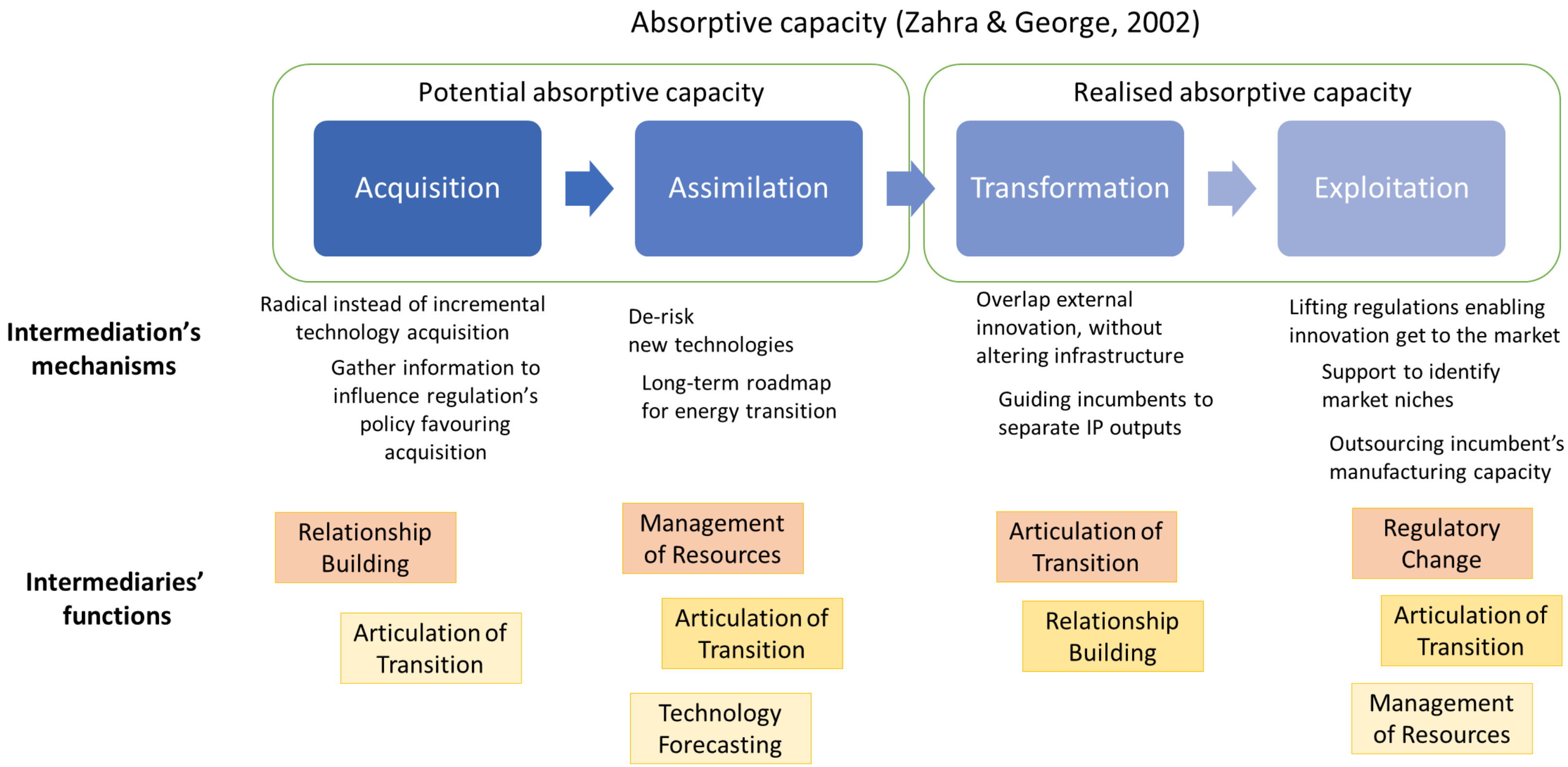

Figure 7.6 Summary of results of intermediary functions supporting the development of absorptive capacity in incumbent firms
Source: Own work based on Zahra and George (2002)

7.3.1.2 Intermediary resources provided to socio-technical niches for developing desorptive capacity

Desorptive capacity is also influenced by factors that shape a previous experience, similar to absorptive capacity. This conditions the development of capabilities for diffusing technology innovation (Bauer et al., 2018). According to the literature review (sub-section 2.3.4), the previous experience in desorptive capacity is moderated by two main factors: (i) a strong patent portfolio that increases the volume of opportunities for licensing; and (ii) prior experience conducting technology transfer that helps to improve further out-licensing agreements. If both conditions are met, then they reinforce management heuristics –associated with practices and routines– leading the organisation to repeat the prior successful experience and thus reducing the transactional cost of technology transfer (Dell'Anno and Del Giudice, 2015). However, such a previous experience is difficult to achieve because it demands a high level of investment to build a patent portfolio and learn how to manage it (Christensen, 1997). This is an issue that the desorptive capacity literature has addressed by using as the main sample of analysis large technology firms with significant inbound and outbound experience in technology transfer (Lichtenthaler and Lichtenthaler, 2010). Nonetheless, it says little about how smaller organisations with scarce resources can develop previous experience in desorptive capacity.

This thesis has contributed to filling such a gap by exploring the mechanisms through which socio-technical niches in the UK energy supply sector obtain previous experience with the assistance of transition intermediaries. In such regard, this study has found that the networks and learning processes facilitated by transition intermediary functions proposed in sub-section 2.2.2.2 can support the configuration of the previous experience in the two main factors (i) and (ii), previously mentioned in the paragraph above.

In factor (i) concerning a strong patent portfolio, sub-section 6.1.1 described the form by which transition intermediary functions of Relationship Building and Management of Resources connect socio-technical niches with industrial experts who recommend feasible commercial routes for technology innovation. By receiving this support, socio-technical niches can understand the industrial context where they search for partners to transfer technologies.

Moreover, by following these recommendations, socio-technical niches close ties with the technology innovation network. Significantly, this support is converted into a critical resource that reduces uncertainties during the technology development by going through a process of validation. This thesis considers that such an approach fits well with the nature of socio-technical niches in the UK energy supply industry. The literature review explained the complex process and the intensive resources needed for bringing new technologies (Section 2.1). Consequently, any support that can accelerate this journey is welcome by the technology innovation actors. In this case, transition intermediaries enable niches to conduct a narrow search of technology opportunities, instead of applying the volume approach suggested by the desorptive capacity literature (Bianchi and Lejarraga, 2016).

In factor (ii) regarding the building of previous experience in technology transfer, sub-section 6.2.2 found that the intermediary function of Management of Resources generates such an experience by training socio-technical niches on prototype manufacturing (Case Study P). The prototypes are later tested with the support of the same intermediary function of Management of Resources. These intermediation mechanisms bring the technology innovation producer (i.e., socio-technical niches) closer to the adopter (i.e., incumbent firm) by creating an environment of collaboration that can replace the licensing experience. Particularly, the living labs (sub-section 6.2.2) are important initiatives where the industrial adopter (incumbent firm) observes how the final customer responds to the new technology. While the innovation producer (socio-technical niche) obtains valuable insights that help it to edit the technology development. Consequently, this iteration provides important learning to socio-technical niches, generating an experience for transferring innovation that they can replicate in successive technology transfer opportunities.

Table 7.2 summarises these findings by specifying the transition intermediary's functions supporting the development of capabilities in both dimensions of desorptive capacity (identification and transfer). Table 7.2 also shows the critical resources provided by intermediaries and the intermediation examples presented in Chapter 6.

Table 7.2 Summary of intermediary functions and resources provided to socio-technical niches for developing desorptive capacity

Desorptive Capacity	Innovation Intermediary Function Performed	Innovation Intermediary Resource Provided	Innovation Intermediary Example in brackets the case study code
Identification			
Capability to Understand technology base in the recipient	• Relationship Building • Management of Resources	• Industrial network • Process of information	• Sustainable Ventures (L) • Energy Innovation Centre (M)
Capability to Technology marketing	• R&D Coordination • Technology Forecasting	• Market insights • Technology trials	• European Marine Energy Centre (N) • Scottish Enterprise (O)
Transfer			
Capability to Transform pre-existing processes in the recipient	• Management of Resources	• Professional advice	• High Value Manufacturing Catapult Centre (P)
Capability to Manufacture prototypes	• Management of Resources	• Training in lean manufacturing • Living lab facilities	• Michelin Scotland Innovation Parc (Q) • Catapult Centre of Energy System (R)

These intermediation functions and resources assist the development of capabilities in socio-technical niches, assigned to each of the desorptive capacity's dimensions. Thus, they help socio-technical niches to fit their innovation development within the practices of UK energy incumbent firms. According to the analysis, the resources offered by transition intermediaries are focused on promoting business skills in socio-technical niches (sub-sections 6.1.1 and 6.1.2). This is a critical capability that supports niches to diffuse technology innovation according to the specific routines, practices and operations of the incumbent firms.

These findings contribute to explaining how socio-technical niches develop capabilities to diffuse technology innovation via the utilisation of external resources from intermediaries. This idea expands the RBV literature which initially stated that the development of organisational capabilities is an internal process for learning how to manage new resources (Zollo and Winter, 2002). This thesis has found that external resources from intermediaries are essential to generate such learning instances that are so difficult to produce in the energy supply sector.

This research considers that such a connection to develop desorptive capacity is possible thanks to the transition intermediary functions. Figure 7.7 summarises how these are deployed by intermediaries to enhance desorptive capacity using the bottom part of the conceptual framework. In the case of the dimension of identification, intermediary functions are deployed in combination. However, the dimension of transfer is only influenced by the intermediary function of Management of Resources. This indicates that transition intermediaries have emphasised the provision of infrastructure, training and sharing experience to socio-technical niches in the UK energy supply industry. This finding is aligned with the assumption proposed by Aliasghar and Haar (2021), who suggested that the outbound technology transfer process has better opportunities for success when the new technology has demonstrated its value to potential recipient firms. Consequently, it is not rare to observe that transition intermediaries deploy a single function to strengthen capabilities in the transfer dimension. Similar results were obtained by the study of Matschoss and Heiskanen (2017), analysing how intermediaries aggregate learning on knowledge transfer between niche and regime actors. They have found that intermediaries provide stability in the scaling up of novel solutions by focusing on the later stages of commercialisation. In comparison, this thesis offers similar results in which the intermediaries focus on the lack of resources in niches during commercialisation. The main point of differentiation with the work of Matschoss and Heiskanen (2017) is that they investigated this phenomenon through three case studies (fed by semi-structured interviews) of local sustainability initiatives in Finland. While, this thesis used a wider range of qualitative sources, including interviews and case studies for exploring the overall intermediary approach at a national scale in the UK.

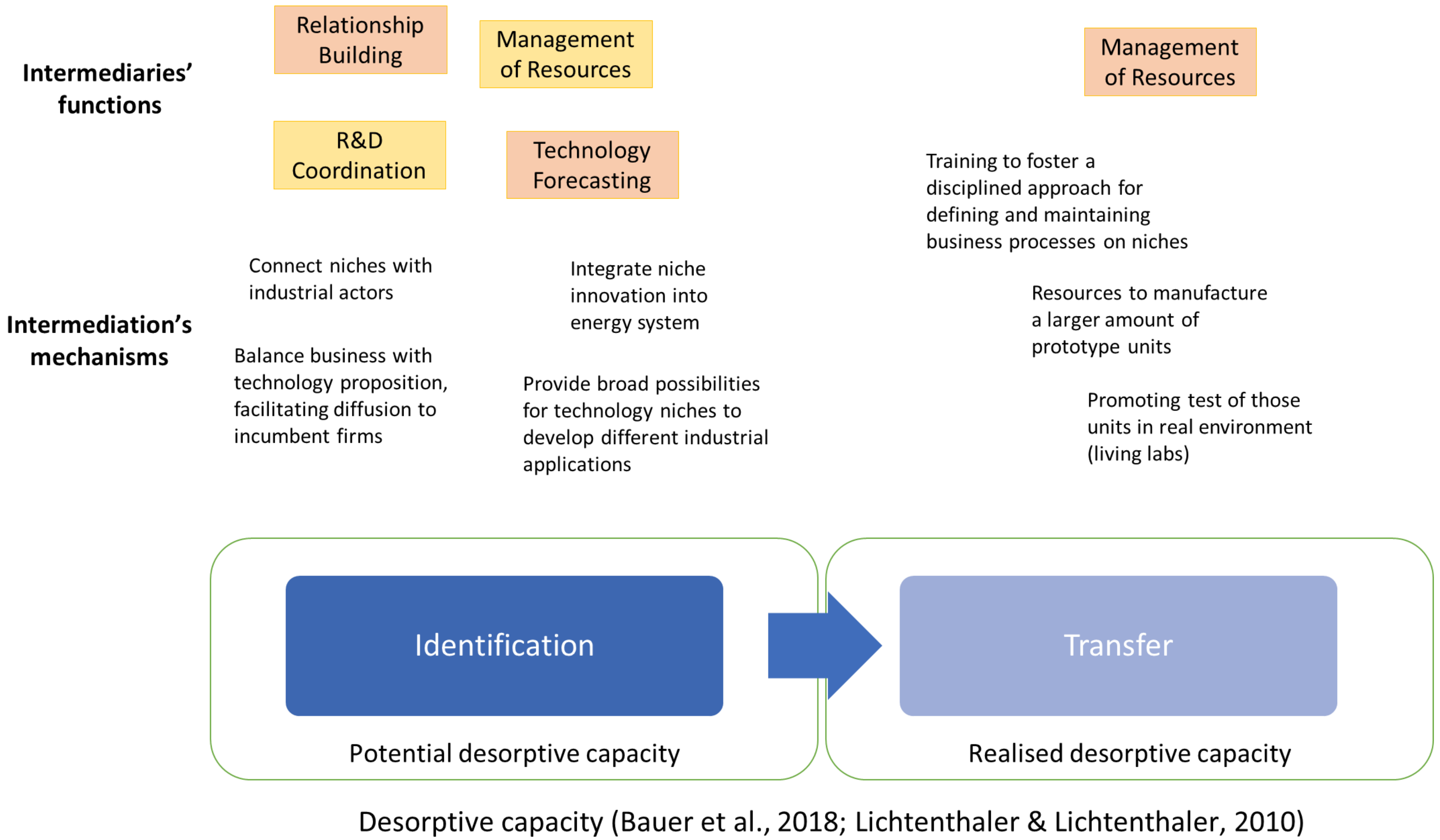

Figure 7.7 Summary of results of intermediary functions supporting the development of desorptive capacity in socio-technical niches
Source: Own work based on Bauer et al. (2018), Lichtenthaler and Lichtenthaler (2010)

The findings, summarised in Figure 7.7, demonstrate that transition intermediaries deliver critical resources focused on promoting the relationship between socio-technical niches and incumbent firms. The implications are significant because signal that desorptive capacity can be built through interaction with other actors. Such an approach offers better chances for learning the diffusion of technology innovation. This is contrary to the assumption made by the desorptive capacity literature, which suggests that such learning occurs through the development of a large patent portfolio. This means a costly investment in producing a variety of new technologies, which later are used by the firm to repeat licensing agreements until it masters the process of diffusing innovation (Bianchi and Lejarraga, 2016). This thesis has found that niches do not have this capacity and instead they usually develop a single technology that with the help of intermediaries can be diffused to the incumbent firms.

This is an important aspect in the UK energy supply industry where the interconnection of technological pieces affects the whole power system and thus the integration of technology innovation must be conducted collaboratively. It is different to other industrial sectors (e.g., pharmaceutical and software), where individual efforts can develop new technology and its eventual failures during the process do not have serious effects on society, as the energy supply does present. For this reason, the resources committed to technology testing are critical in the dynamics of bringing technological innovation to the energy supply system, as sub-section 6.2.2 has described. Therefore, socio-technical niches in the UK energy industry can save important resources by avoiding the construction of expensive patent portfolios, as the previous standpoint in desorptive capacity has considered. This can reduce the cost of generating previous experience in socio-technical niches, providing affordable opportunities to diffuse low-carbon technologies in the UK energy supply sector.

Overall, these results contribute to explaining how socio-technical niches develop desorptive capacity. A topic the literature has ignored by concentrating on explaining such a phenomenon exclusively in large firms. This thesis has contributed to filling this important gap by inserting the presence of transition intermediaries, which provide critical resources for outwardly diffusing technology innovation in the UK energy supply sector.

7.3.2 Intermediary functions mediating in the context of socio-technical transition

Now, this sub-section will discuss the intermediary functions proposed in sub-section 2.2.2.2 (see Table 2.5) by comparing this typology with other lists presented in the literature. This will help to reflect how intermediation functions mediate between niches and incumbents in the broader context in which sustainable transition happens.

The functions of intermediation in innovation processes have been extensively studied (Caloffi et al., 2023). However, the exploration of specific functions of intermediaries in transition is an emerging topic (Kivimaa et al., 2019a). This thesis has contributed to that field of study by proposing a list of intermediary functions following two main suggestions from the literature. First, the TIS field has made calls for developing conceptualisations linking the variety of intermediary forms with TIS functions (Kanda et al., 2019; Lukkarinen et al., 2018). Second, the RBV has been modest in exploring the role of external organisations (e.g., intermediaries) in developing absorptive and desorptive capacities by feedback functions. Thence, the RBV literature has suggested investigating this issue supporting the notion that firms of different sizes can improve their capabilities to diffuse and adopt technological innovation through the support of intermediaries in an open innovation fashion (Ahn et al., 2016; Hill and Rothaermel, 2003; Zobel, 2017). Therefore, the lens of intermediary functions can be applied to further study how middle bodies influence the evolution of innovation management capabilities to deal with the environmental pressures of a socio-technical transition.

Building on these recommendations, the focus was placed on identifying transition intermediary functions through the extensive volume of intermediation literature. This review started from a systemic perspective on middle organisations supporting the wide innovation process. Based on the work of Howells (2006), this thesis departs from the innovation study on intermediaries and then connects it to the transition literature of middle bodies (Kivimaa, 2014). This approach allows it to expand the typology of intermediary functions supporting particular innovation processes to the transition changes in fundamental sectors of society.

In principle, the intermediary functions were collected from a combination of both knowledge fields of innovation and transition literatures. Then, this theoretical approach progressively advanced to the idea that intermediaries can interplay between niche producers of innovation with incumbent firms during a socio-technical transition. Accordingly, this thesis gathered a typology of intermediary functions from a TIS perspective (Bergek et al., 2008; Hekkert et al., 2007), which was suitable to articulate the relationship between niches and incumbents. These functions also considered the broad context presented by the MLP (Geels, 2002), constituting a relevant guide to place intermediaries in between the different levels of niches and incumbents. Importantly, the RBV -through absorptive and desorptive capacities- helped us to explicitly propose the flow of technology resources from a bottom-up perspective with the assistance of intermediaries. The combination of these three theories (two transition frameworks and one management model) allows us to define a clearer role of intermediaries mediating between niches and incumbents. This conceptual elaboration contributes to reducing the ambiguity mentioned by Kivimaa et al. (2019a) about the position that intermediaries take in socio-technical transitions.

Our proposed typology attempted to show that although transition intermediaries fundamentally assist innovation processes, their focus is put on building lasting relationships between distant actors. This approach constitutes a stronger orientation for them to lead profound transformations necessary for achieving transitions. The results obtained by mobilising this typology with the conceptual framework (Chapter 3) exhibited that intermediaries promote organisational changes through specific capabilities that transcend the traditional functions of setting bilateral relations (Kilelu et al., 2011; Klerkx and Leeuwis, 2009) within the broad innovation process (Howells, 2006). Therefore, our list of functions complements other typologies (Kanda et al., 2019; Kivimaa, 2014; Lukkarinen et al., 2018; Sovacool et al., 2020) by including a multi-directionality of support that transition intermediary functions equally deliver to niche and incumbent actors. This adds to the work of Kivimaa and Kern (2016), by further analysing the mixed functions that transition intermediaries take to foster the skills of niches to create innovation outputs and reduce the resistant position of incumbents to integrate these.

7.3.3 Meta-function of transition intermediaries

Having discussed the intermediary functions during transitions in the previous sub-section 7.3.2, now we will explain how these cooperate with each other to develop capabilities in niches and incumbents. This conceptual elaboration contributes to the notion of "motors of innovation" (Suurs, 2009; Suurs and Hekkert, 2012), which has been not sufficiently explored by the TIS literature (Kohler et al., 2020).

The conceptual framework (Chapter 3) proposed that transition intermediaries have a central role in enhancing capabilities for diffusing and adopting new technologies. The findings showed that such an intermediary functions strengthens the network between both niche and incumbent actors for introducing low-carbon technologies into the UK energy supply system. Moreover, it can be said that pluralistic and organised intermediary support is crucial to address the complexity of decarbonising the energy supply system. Consequently, an important sense of coordinated intervention has been discovered by this thesis when transition intermediaries deploy functions in a combinative manner to tackle sustainable challenges, as it was explained in the previous sub-section 7.3.1 and 7.3.2. This expands the observations from intermediation research (Kilelu et al., 2011; Kanda et al., 2019; Kivimaa and Kern, 2016; Lukkarinen et al., 2018), which have considered intermediary functions as critical to addressing societal challenges but not necessarily acting in combination.

Building on the results of Chapters 5 and 6, this thesis proposes that the combinative manner in which transition intermediaries deploy their functions configures a meta-function[13] within the broad context of sustainability transition. This research found that this meta-function creates a bridge for crossing from the potential to the realised dimension in both absorptive (Zahra and George, 2002) and desorptive capacities (Lichtenthaler and Lichtenthaler, 2010). This meta-function substitutes the previous mechanisms described in both literatures, related to social integration in absorptive capacity (Figure 2.4 in p. 82) and large patent portfolio in desorptive capacity (Figure 2.5 in p. 91), presented in the Literature Review chapter. Moreover, this thesis

[13] A meta-function can be defined as a group of functions that in combination perform a multi-operation task that finds a consensual solution to multiple conflicts (Wulf, 1995).

proposes that the meta-function unfolds two mechanisms of validation related to technological and business aspects enhancing absorptive and desorptive capacities and helping to achieve a sustainable transition.

This discovery resonates with the concept of "motors of innovation" proposed by Suurs (2009). These form cumulative causation from the mutual relation between the functions of a TIS, generating a positive loop that is an important condition for innovation processes to flourish in addressing sustainability issues (Suurs and Hekkert, 2012). Sub-section 2.2.2 discussed that the dynamics of motors of innovation have been partially explored by the TIS literature (Kohler et al., 2020). Addressing such a gap, this thesis makes a relevant contribution to elucidating the means whereby motors of innovation are developed by transition intermediaries. While Suurs (2009) distinguished motors of innovation as stages in the development of a TIS, this thesis found that intermediaries simultaneously combine functions developing capabilities in transition actors to meet sustainability goals. Consequently, the meta-function improves our understanding of the underlying mechanisms that intermediaries employ to drive the diffusion and adoption of innovation in a dynamic relationship between niches and incumbents.

Figure 7.8 presents the meta-function through a simplified version of the conceptual framework (Chapter 3). This illustrates the allocation of two mechanisms of validation that the meta-function unfolds. These relate, on one hand, to technological aspects; and, on the other hand, to business elements. Both configure a strong influence that is drawn by two axes departing from the meta-function in below Figure 7.8.

Firstly, the vertical axis shows the influence that the meta-function has on crossing from the potential to the realised dimensions in both absorptive and desorptive capacities. This topic will be discussed in more detail in sub-section 7.3.3.1.

Secondly, the horizontal axis in dash format draws the meta-function performing technological and business validation, addressing important elements in the transition literature. Particularly, about the lack of flexibility indicated by MLP in incumbent (sub-section 2.2.3.1) and niche actors (sub-section 2.2.3.2) to address the challenge of a transition. This idea will be explained in sub-section 7.3.3.2. These mechanisms of the meta-function conceptually contribute to understanding the advancement of sustainability transitions by inserting the RBV literature in the following manner.

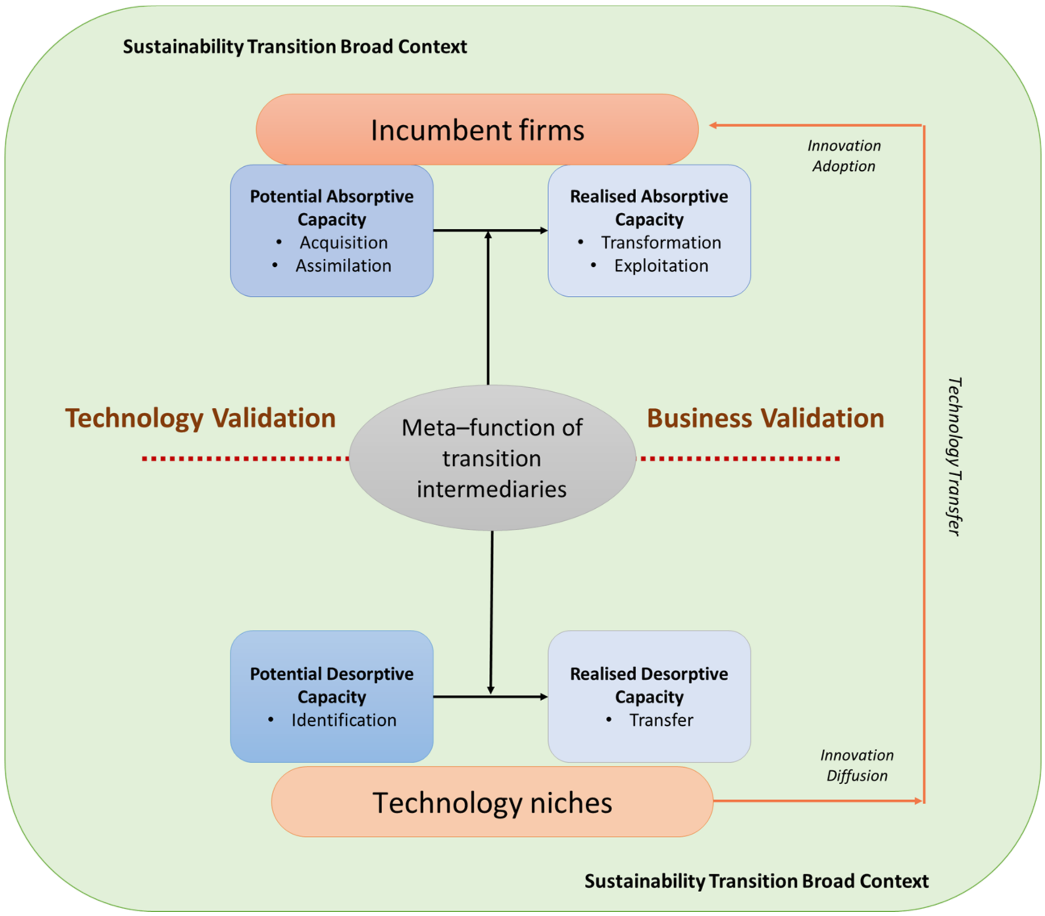

Figure 7.8 Meta-function of transition intermediaries

7.3.3.1 Intermediary moderation to cross from potential to realised dimension in absorptive and desorptive capacities

The literature described how internal mechanisms operate within the organisation to remove structural, cognitive and behavioural barriers that technological innovation presents to the firm (Lemon and Sahota, 2004). In absorptive capacity, Zahra and George (2002) have suggested that this consists of social mechanisms enabling the firm to cross from the potential dimension of acquiring and assimilating technology innovation to the realised dimension of transforming and exploiting it for commercial ends (sub-section 2.3.3). Similarly, the desorptive capacity literature has proposed a mechanism for crossing from potential to realised dimensions based on a large patent portfolio developed by the firm, in which technological outputs are outwardly transferred to industrial players (sub-section 2.3.4).

Nonetheless, this research has discovered that both mechanisms are not so relevant when transition actors (i.e., incumbent firms and socio-technical niches) attempt to exchange technology resources in the broad context of a socio-technical transition. Instead, transition intermediary functions (sub-section 2.2.2.2) act as a substitute for those mechanisms in both capacities. Moreover, this thesis raises the possibility that the transition intermediaries perform their functions in a combinative manner. This configures a meta-function that explains how intermediation clients cross from potential to realised dimensions in absorptive and desorptive capacities.

Such a finding is important to the literature on intermediaries in transition (Kivimaa et al., 2019a) because contributes to present the role of middle organisations in achieving socio-technical transition. This theoretical elaboration synthesises the intervention of transition intermediaries in a single function that influences both ends of the technology transfer process. Moreover, this idea expands the conceptualisation of intermediary functions developed by the innovation literature (Howells, 2006; Kilelu et al.; 2011; Klerkx and Leeuwis, 2009) and the transition literature (Kanda et al., 2019; Kivimaa, 2014; Lukkarinen et al., 2018; Sovacool et al., 2020; and van Lente et al., 2003), who described functions acting separately as brokers between the sender and the recipient of technological innovation. In this new proposition, the meta-function intervenes directly in the internal processes of both actors, strengthening the capabilities to diffuse and adopt technology innovation for sustainability purposes. Thus, the meta-function reduces the internal barriers of technology transfer, when the socio-technical niches have problems diffusing radical innovation to a recipient partner that has a lower absorptive capacity.

In sum, the meta-function bridges the potential with the realised dimension of absorptive and desorptive capacities when niches attempt to transfer technological resources that can transform the unsustainable practices of incumbents.

The following two subheadings will describe how the meta-function is deployed in each conceptualisation of absorptive and desorptive capacity.

Meta-function in absorptive capacity

The results have indicated that transition intermediary functions work in combination, developing the potential aspect of absorptive capacity in incumbent firms. Figure 7.9 summarises this proposal, where it can be observed different functions influencing each dimension of absorptive capacity. Essentially, different intermediary functions operate in the potential dimension of absorptive capacity helping incumbent firms to acquire and assimilate net zero technologies. In the following dimension of realised absorptive capacity, intermediary functions help the incumbent firms to transform and exploit these new technologies until the final stages of commercialisation.

Crossing from the potential to the realised dimension is critical because it offers the possibility for incumbent firms to obtain economic benefits from emerging opportunities during the energy transition. In this regard, the meta-function has a great impact in delivering positive experiences for incumbent firms in the commercialisation of new technologies, in which they previously had little involvement. Consequently, this research argues that the meta-function provides a concrete direction to incumbent firms for exploiting the outputs generated via absorptive capacity.

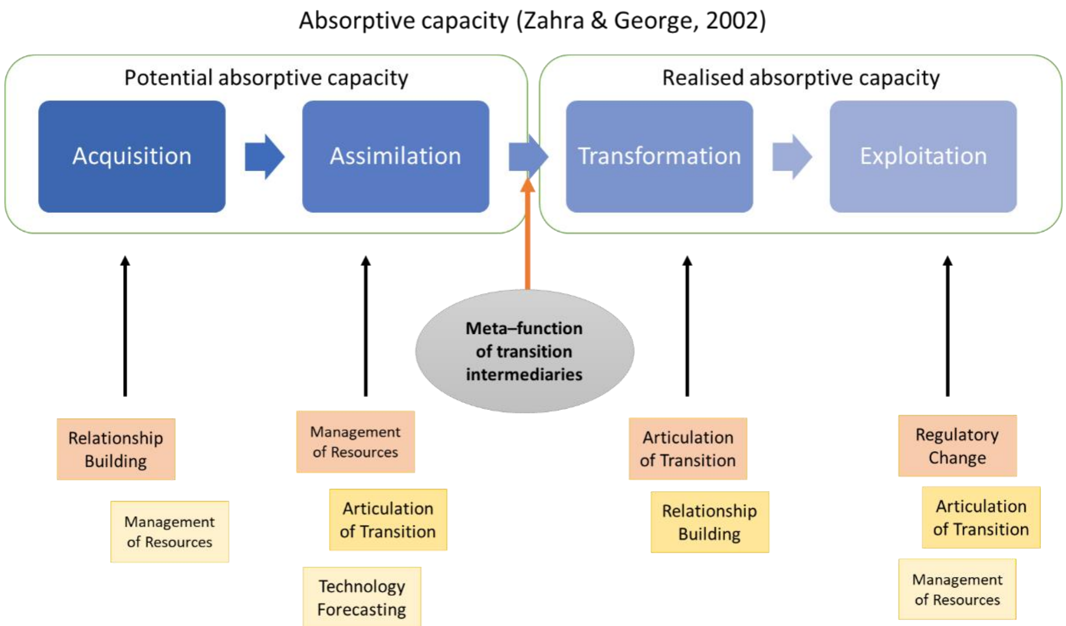

Figure 7.9 Intermediary meta-function in absorptive capacity
Source: Own work based on Zahra and George (2002)

This conceptual elaboration has an important implication for the theory of absorptive capacity. The intermediation meta-function replaces the social mechanisms to cross from potential to realised absorptive capacity, as Zahra and George (2002) have previously defined. Such social mechanisms consist of communication instances promoted by the senior management inside of the firm, encouraging the exchange of information between organisational divisions (Flatten et al., 2011). Nonetheless, according to the analysis of this thesis, the meta-function substitutes social mechanisms by deploying regular activities that go beyond the communicational aspect. The meta-function mobilises the technology innovation across the four dimensions of absorptive capacity (acquisition, assimilation, transformation and exploitation). Importantly, the meta-function coordinates capabilities in incumbent firms by helping them to build connectedness between different skills allocated in the four dimensions of absorptive capacity. As a result, the meta-function facilitates the integration of technology innovation into the business routines and processes of incumbent firms without a substantial modification of these.

This constitutes an important contribution to explaining how incumbent firms can specifically modify their attitude to sustainability transitions. Although MLP has progressively modified its initial perception of considering incumbents as resistant to change, it has limited elaboration on how these organisational transformations occur in large firms during transitions. Consequently, the theoretical proposition of meta-function contributes to revealing the proceedings of incumbents' transformations, addressing the issues of incumbency under-conceptualisation by the transition literature (van Mossel et al., 2018).

Meta-function in desorptive capacity

In desorptive capacity, the findings have shown a similar way in which intermediary functions act in combination to develop capabilities for diffusing new technologies. In the potential dimension of desorptive capacity, transition intermediaries deploy four functions in combination. On the realised dimension, intermediaries only unfold one function in a strong format as was explained in sub-section 7.3.1.2. According to such results, this thesis suggests that transition intermediaries configure a meta-function that supports crossing from potential to realised desorptive capacity. Figure 7.10 illustrates this proposition.

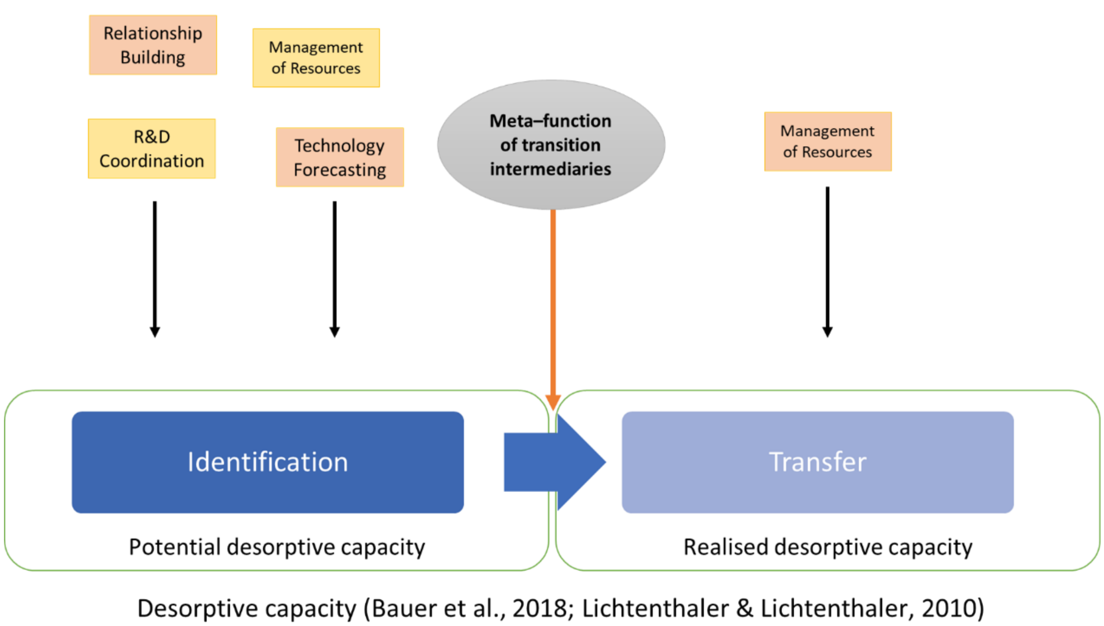

Figure 7.10 Intermediary meta-function in desorptive capacity
Source: Own work based on Bauer et al. (2018) and Lichtenthaler and Lichtenthaler (2010)

Likewise, this conceptual elaboration has repercussions for desorptive capacity theory. The meta-function is the main influence to cross from potential to realised desorptive capacity. This idea establishes an important separation from the previous literature that considered desorptive capacity as dependent on absorptive capacity (Muller-Seitz, 2012; Ziegler et al., 2013). Such a prior proposition suggested that it was necessary to have a strong inward technology transfer experience based on a volume approach of a large patent portfolio. This provides an experience that the organisation obtains by negotiating licensing agreements. As a result, the mutual relationship between absorptive and desorptive capacities creates a business intelligence in the firm that allows it to move from the potential to realised desorptive capacity (Bauer et al., 2018).

This thesis shows that the meta-function can replace the arduous process of building a business intelligence described above. Instead, desorptive capacity is enhanced by close inter-organisational learning between niches, incumbents and intermediaries. Fundamentally, the intermediary meta-function provides support to outwardly transfer the innovation produced by socio-technical niches to incumbent firms. This offers an important contribution to desorptive capacity theory by breaking the idea that must go in hand with absorptive capacity. Instead, this thesis suggests that such an interaction is possible between transition intermediaries and desorptive capacity, helping socio-technical niches to develop capabilities for outwardly diffusing technological innovation.

Additionally, the meta-function has implications for the MLP. Under this transition framework, niches develop technology innovation through learning processes and experiments (Schot and Geels, 2007). Accordingly, the niche with the most flexible approach will have better chances of diffusing the new technology and confronting the dominant design. The MLP literature has proposed that niches can be nurtured by intervention policies (Smith and Raven, 2012) that are executed by intermediary functions (Kivimaa et al., 2019a). In such a regard, this thesis contributes to describing how these interventions are deployed by the meta-function, consolidating the learning processes of niches. Consequently, the meta-function expands the evolutionary idea of niches (Smith and Raven, 2012) by identifying additional protection from intermediaries within the ”fit-and-conform” approach, covered in sub-section 2.2.3.2. This consists of supporting to move from potential to realised dimension in desorptive capacity, making niche innovation competitive without a radical change of the selection environment that favours incumbents.

7.3.3.2 Validation mechanisms in technical and business aspects

The literature review of socio-technical transitions (Section 2.2) showed the need for further research exploring the mechanisms that transition intermediaries deploy to connect actors. Regarding such an issue, this thesis makes an important contribution to the literature on transition intermediaries. In particular, by expanding the work of Kivimaa and Kern (2016) related to intermediary policy mix and analysing the role of transition intermediaries as a key bridge linking actors in the regime and niche levels. Moreover, this thesis indicates that intermediaries have a strong influence in developing low-carbon technologies that respond to the net zero challenge. This intervention ensures that new technologies are developed for being subsequently integrated without disrupting the energy supply system.

This thesis has elaborated on the concept of intermediary meta-function as a unifying role linking socio-technical niches with incumbent firms. The meta-function is displayed through mechanisms of validation in both technical and business aspects of the technology innovation development. The findings suggest that such mechanisms of validation moderate the high expectations of socio-technical niches and incumbent firms, contributing to explaining how the collaboration between regime and niche occurs under the TIS (Bergek et al., 2008; Hekkert et al., 2007) and MLP (Geels, 2002). Accordingly, the meta-function brings these distant positions closer as follows.

Incumbent firms expect to receive a fully functional product, which will be inserted without disruption in the energy supply system, as was analysed in Section 5.1. This contradicts the innovation literature (Dodgson et al., 2008; Pavitt, 2006) that has indicated that technology development is a laborious process with a high risk of failure usually taking decades to fully form (Section 2.1). From the perspective of socio-technical niches, the expectation is finding a recipient partner who will be open to making strong commitments to adopting an incomplete and risky new technology (Section 6.1). This involves adjustments of processes and routines in incumbent firms, accompanied by investment that will help to scale the new technology from early R&D

phases to the final stages of commercialisation (sub-section 6.1.1). However, the transition literature has explained that the behaviour of incumbent firms towards technology innovation presents a slow and often sceptical response (sub-section 2.2.3.1). Therefore, both expectations make it extremely difficult to conduct technology transfer in the energy supply sector. This is a critical breach that, according to the results of this thesis, transition intermediaries fill by deploying two types of validations.

First, the transition intermediaries demonstrated a purposeful aim to produce a technical validation of the new technology. This approach guides socio-technical niches and incumbent firms to meet in a common space organised by transition intermediaries. This consists of informal networks, which later can be converted into formal alliances (Case Studies A and B). These collaborative mechanisms are deployed by transition intermediaries through the function of Relationship Building. Moreover, they continue strengthening such links using the function of Management of Resources, where intermediaries provide demonstration centres elevating the technology development (sub-section 5.2.1). Consequently, the results indicate that a combination of these mechanisms configures the technical validation in the intermediary meta-function.

Second, transition intermediaries help to fit the technology innovation within existing business processes of incumbent firms through the function of Articulation of Transition by Knowledge Exchange. Here, intermediaries support the introduction of low-carbon technologies without disrupting the incumbent firms' priority of security in the energy supply (sub-sections 5.3.1 and 6.2.1). Then, transition intermediaries help to test the technology innovation with real customers by lifting regulations in the energy market through its functions of Management of Resources and Regulatory Change (sub-section 6.2.2). Therefore, the results suggest that the mixture of mechanisms sets up the second type of validation in the meta-function around business aspects.

As a whole, both types of validation contribute to existing theories of absorptive and desorptive capacities by proposing a meta-function in a horizontal line, portrayed in Figure 7.8. Accordingly, technology validation relates to the potential dimension of absorptive and desorptive capacities, while business validation shares a conceptual space with the realised dimension of both capacities. This contribution is relevant to the broad transition literature because it explains how different actors establish collaborative links to develop new technology. On the one hand, transition intermediaries reduce the incumbent's resistance to perceiving the potential of new technologies and integrating them with existing operations, as described by Bergek et al. (2013). On the other hand, transition intermediaries support the technology development to move out of the protective space provided by niches. This adds to the work of Smith and Raven (2012), explaining how technological innovation enters broader markets by progressively increasing the necessary validations in technical and business aspects. This convinces incumbent firms to adopt a competitive new technology that can assist the regime in moving towards sustainability goals.

Furthermore, this idea contributes to the transition literature by understanding how technology innovation can be conjunctly produced during socio-technical transformations through the support of transition intermediaries. This conceptualisation expands the role of transition intermediaries beyond individual levels of analysis and positions them as critical actors in technology development, supporting the work of Kivimaa et al. (2019a). Moreover, transition intermediaries strategically engage in building networks combined with learning processes that generate a meta-function, originally based on a variety of individual intermediation functions proposed by the literature (Howells, 2006; Kanda et al., 2019; Kilelu et al., 2011; Kivimaa, 2014; Kivimaa and Kern, 2016; Klerkx and Leeuwis, 2009; Lukkarinen et al., 2018; Sovacool et al., 2020; and van Lente et al., 2003). Accordingly, the meta-function provides a holistic perspective on the role of transition intermediaries during socio-technical transitions, performing a heterogeneity of mechanisms at multiple levels of the technology transfer process. In practice, the meta-function contributes to achieving important validations for technology development, which can resolve recurrent failures due to the uncertain and risky nature of innovation (Dodgson et al., 2014).

7.4 Assessment of the conceptual framework

The previous sections have outlined the main contributions to the bodies of knowledge that this research aims to position. Now this section will assess the conceptual framework (Chapter 3), which was an essential component in conducting the research by linking the theoretical constructs presented in the Literature Review (Chapter 2) with its application through the Method (Chapter 4) into the empirical context of this investigation (Section 1.1).

By mobilising the conceptual framework to analyse the diffusion and adoption of low-carbon technologies in the UK energy supply sector, this thesis attempted to decipher the role of transition intermediaries in enhancing capabilities at both innovation processes. In this regard, the conceptual framework considered the broad industrial context that technological innovation must overcome in the energy supply sector. Particularly, on security issues. Thus, the conceptual framework aimed to contribute to the growing transition literature focused on how to upgrade unsustainable locked-in systems without destabilising their fundamental function (Kohler et al., 2019).

To proceed in this analysis, the conceptual framework allocates transition intermediary functions (sub-section 2.2.2.2) in the middle as the central driver capable of approaching distant positions between incumbent firms and socio-technical niches. When it was applied to the empirical context of the UK energy supply industry, the conceptual framework provided important insights describing how transition intermediaries can support the development of capabilities among these actors. This was possible to obtain due to the conceptual framework being constructed on an extensive Literature Review (Chapter 2) that suggested a combination of three main theories –MLP, TIS and RBV–. These configured a first layer of analysis conferring the researcher with sufficient sensitivity to collect and analyse the initial set of data.

However, these preliminary insights were still inconclusive in understanding the deep roots impeding a fluid relationship for conducting technology transfer in the UK energy supply sector. In the iterative process of building the conceptual framework, the literature review offered additional theoretical pieces on absorptive (Zahra and George, 2002) and desorptive

(Lichtenthaler and Lichtenthaler, 2010) capacities. Both provided a second layer of analysis for investigating the diffusion and adoption of technology innovation by breaking both constructs of absorptive and desorptive capacities into multiple capabilities within their dimensions. This improved the directionality of the inquiry and allowed the researcher to explore how transition intermediary functions promote technology transfer between incumbents and niches by developing capabilities in both groups of actors.

The following sub-section 7.4.1 will discuss how the reflective cycles operation approach helped to develop the conceptual framework. Then, sub-sections 7.4.2 and 7.4.3 will debate how the empirical findings were supported to advance the conceptual model.

7.4.1 Reflection cycles operation approach

The reflective cycles operation (Blaikie and Priest, 2017) was fundamental to developing and applying the conceptual framework. This approach provided a series of interwoven activities to compare data and theory until achieving theoretical saturation (Saunders et al., 2018). This was particularly important due to, during the early stages of the investigation, the researcher found that using exclusively the dimensions of absorptive and desorptive capacities provided by the literature did not confer significant analytical depth. The initial results were insufficient for explaining how niches desorb technology innovation and neither clarifying how incumbents absorb these in the UK supply energy sector. These emphasised an unstructured nature of both absorptive and desorptive capacities in which the organisation supposedly can adopt or diffuse technology innovation simply by the intensity of previous experience based on R&D (Dell'Anno and Del Giudice, 2015).

To address these issues, the reflective cycles operation suggested going back to the literature and further exploring theoretical pieces that could provide the sought-after analytical depth (Blakie and Priest, 2017). This was found in the concept of capabilities, which were inserted into each dimension of absorptive and desorptive capacities. This approach allowed the conceptual framework to conduct a narrowed thematic analysis (Braun and Clarke, 2006), discovering hidden components that explained the formation of capabilities to diffuse and adopt technology innovation.

Based on this research experience, we can claim that innovation management capabilities is an area where the absorptive and desorptive capacity bodies of literature have a limited understanding. Therefore, by following the reflective cycles operation approach as a method for building theory in social science, this thesis contributed to developing a new conceptualisation of developing capabilities for diffusing and adopting technology innovation through the support of intermediaries. This was one of the fortes of the conceptual framework, which revealed the "black boxes" whereby capabilities are generated in both absorptive and desorptive capacities. Addressing an important gap in which both theories have been criticised (Lane et al., 2006; Ziegler et al., 2013).

7.4.2 The addition of transition intermediary functions

Supporting the analytical process, the addition of transition intermediary functions (sub-section 2.2.2.2) offered the opportunity to enrich the analysis in the conceptual framework. These solidified the intermediary role as orchestrators of innovation processes between two or more parties with little history working together. Moreover, the integration of intermediary functions made it possible to identify the mechanisms responsible for removing the organisational and structural barriers in the development of capabilities. By positioning transition intermediary functions at the heart of this investigation, the conceptual framework discovered that these mechanisms were transversal for spreading learning among actors and therefore enhancing their capabilities for managing innovation to meet transition targets.

Importantly, the conceptual framework contributed to delineating the role of intermediaries during socio-technical transitions, which has been a topic of debate in the literature (Kanda et al., 2019; Kivimaa et al., 2019a). Essentially, transition intermediaries have been positioned as enablers for actors to learn the best way to scale technology innovation for sustainable purposes (Raven et al., 2008). For this reason, the transition literature initially assumed that intermediaries favoured niche development (Schot and Geels, 2008; Smith and Raven, 2012). This idea was later complemented by the notion that transition intermediaries could erode the position of resistant incumbents and modify regime rules. Thus, giving space for niche innovation to scale and replace unsustainable practices from established companies (Kivimaa, 2014; Matschoss and Heiskanen, 2018).

Such points of view have positioned intermediaries as a contributor to niche creation and regime (de)stabilisation (Kivimaa and Kern, 2016). However, this approach has not produced sufficient investigation related to the cross-boundary role of transition intermediaries linking both actors. To address these issues, the conceptual framework added the RBV school of thought (Barney, 1991). This suggests that the exchange of key resources is possible through the cultivation of specific capabilities (Barney et al., 2001; Eisenhardt and Martin, 2000; Grant, 1991), which can evolve in a dynamic fashion thanks to organisational learning (Lawson and Samson, 2001; Schoemaker et al., 2018; Teece et al., 1997; Wang and Ahmed, 2007; Zollo and Winter, 2002). The middle position of intermediaries enabled the conceptual framework to consider the generation of capabilities across the whole board of actors, without taking a specific stand of favouring one or the other. Instead, the conceptual framework sought to establish links of collaboration between niches and incumbents through intermediation functions.

The conceptual framework found that intermediary functions act as positive feedback in various capabilities, providing details about how intermediation mechanisms in one organisational skill can affect another. For example, the general intermediation mechanism of testing new technologies, deployed through the function of Management of Resources, feeds different capabilities by demonstrating that technological innovation is beneficial for the whole energy supply system. This solves a major concern around innovation failure affecting energy security, expressed by the transition literature (Geels and Turnheim, 2022). The framework produced an important understanding of how intermediary mechanisms support the evolution of the energy supply system towards net zero. In such a regard, the conceptual framework was sufficiently flexible to connect diverse intermediary functions with absorptive and desorptive capacities, describing how different intermediation mechanisms remove deterring factors associated with the institutional lock-in of the energy supply industry. Consequently, the conceptual framework contributed to explaining how collaboration is achieved in this complex industrial sector and it becomes a key driver for mobilising the socio-technical transition.

7.4.3 Distinction between absorptive and desorptive capacities

The separation of roles between actors enabled the conceptual framework to differentiate incumbent firms and socio-technical niches. These either deploy diffusion or adoption of technology innovation in the UK energy supply sector. This approach is in line with the recommendations for analysing desorptive capacity as a distinguished function of the firm separated from the absorptive capacity (Ahn et al., 2016; Robertson et al., 2012). The conceptual framework followed this suggestion investigating both capacities as inter-organisational components of the technology transfer process, instead of being both intra-organisational capacities of a single firm as was proposed by Lichtenthaler and Lichtenthaler (2009 and 2010).

Drawing upon the empirical findings about the development of capabilities for adopting and diffusing technology innovation in both actors of the UK energy supply industry with the support of transition intermediaries, the results are shown in Figure 7.11. This illustrates the links whereby transition intermediary functions influence each capability of absorptive and desorptive capacities. This helps to represent connections in a synthetic way answering research questions (pp. 3-4 of the Introduction Chapter) and providing the reader with a general scheme of the main results from this research.

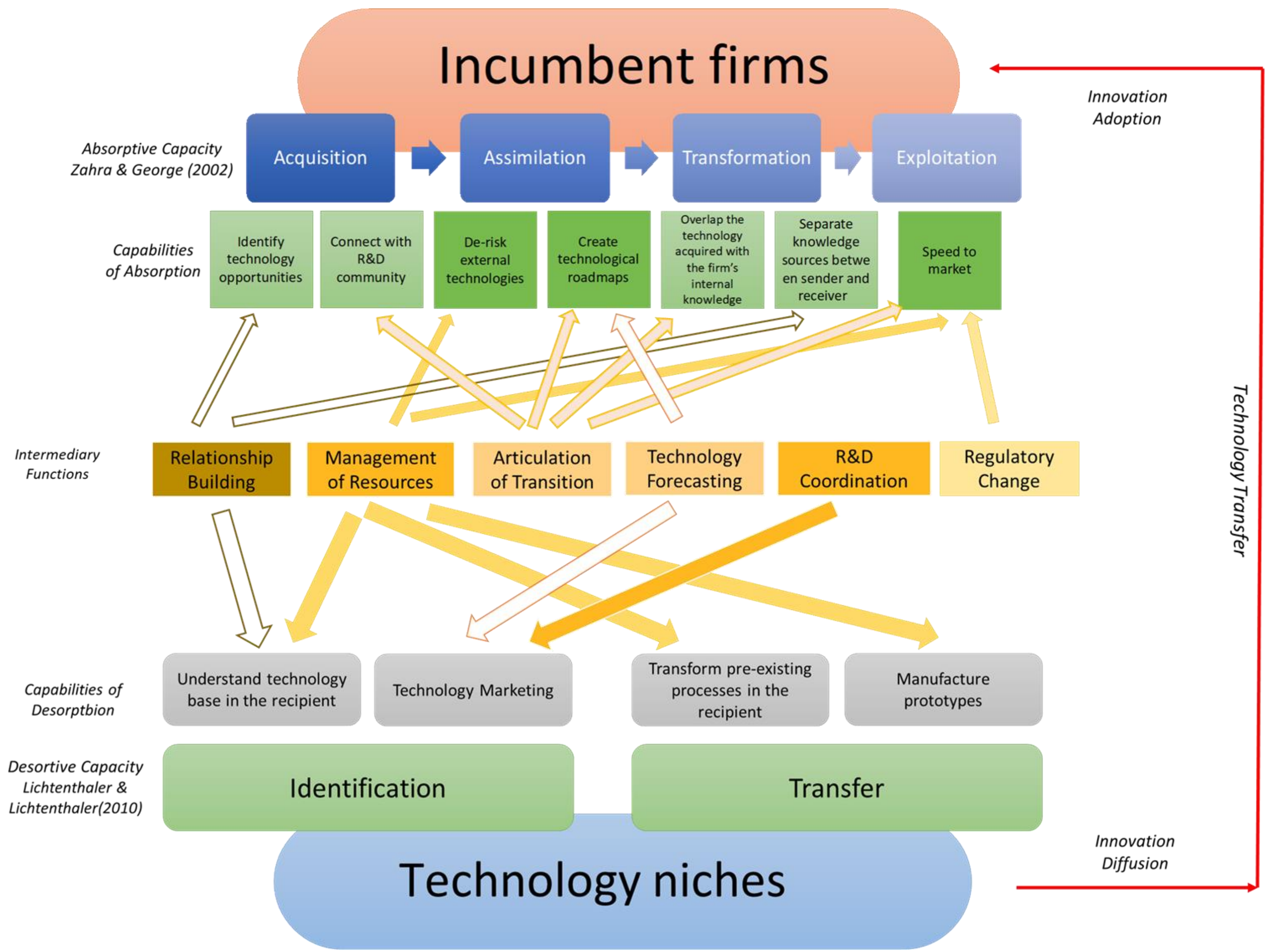

Figure 7.11 Summary of results of intermediary functions supporting the development of capabilities in absorptive and desorptive capacity

In summary, the conceptual framework was developed from the general transition literature and it could be considered a model for a wider audience. However, it was initially constructed to explore the empirical context of the UK energy supply transition. It can be also applicable to similar industries where powerful incumbents manage a complex system that provides an essential social function (telecommunications, water treatment, public transport, among others). These regimes are under permanent pressure to modify unsustainable practices through the integration of new technologies. Such a process can be facilitated with the assistance of transition intermediaries. Consequently, the conceptual framework can have a general application to other industrial sectors with these characteristics.

This is possible due to the conceptual framework was built using diverse theories that offered a deep explanation of the diffusion and adoption of technology innovation by niche and incumbent actors with the support of intermediaries. Accordingly, this thesis argues that the tumultuous process of a socio-technical transition cannot be analysed using a unique theoretical approach. Instead, the analytical procedure must consider different conceptualisations that reflect the complexity of promoting profound transformations, as this framework did.

7.5 Management implications and public policy recommendations

Thus far, this Chapter has presented the theoretical contributions the research has made to the broad transition literature and the assessment of the conceptual framework. Now this section will offer suggestions for managers and policymakers.

Given the strong focus on collaboration in this research, the findings share a great deal of overlap between managerial practices and policymaking. As this thesis has discovered, the intermediary functions have a significant impact on the innovation management practices of both incumbent firms and socio-technical niches. To create policies that influence both actors, the intermediaries often observe their behaviour to design programmes that can be applied to managerial practices at niche and incumbent levels. Consequently, the proposals outlined here are a mix of management suggestions, coupled with policy recommendations. These underline the extent to which policy implications can intertwine with the managerial capabilities to improve the diffusion and adoption of technology innovation in the UK energy supply sector.

The following recommendations are separated into three areas. Sub-section 7.5.1 will discuss suggestions for enhancing absorptive capacity in incumbent firms. Sub-section 7.5.2 will propose recommendations for fostering desorptive capacity in socio-technical niches. Finally, sub-section 7.5.3 will address the deployment of intermediary meta-function.

7.5.1 Incumbent firms and absorptive capacity

This sub-section highlights four priorities for incumbents' managers that they can consider for improving the absorption of new technologies in incumbent firms. Likewise, four recommendations to policy are presented to support these managerial decisions, providing guidelines to enhance the collaboration among actors in the UK technology innovation system.

First, this research has found that technology innovation aligned with the incumbent's operations have better opportunities to be absorbed by utility firm (sub-section 5.3.1). This approach has a significant repercussion because it explains how incumbent firms internalised new technologies in their organisational routines. For this reason, recommendations can be made to incumbents' managers for systematising and codifying such routines. This means that the firm should understand organisational routines and then record them in written documents. This will make them accessible through corporate electronic database systems, which can be transmitted to external partners. Thus, such codified knowledge can be obtained from actors outside of the firm, like socio-technical niches, who can use it to design purposeful innovation.

This action can be supported by an intermediation policy to capture critical routines that can be relevant for adopting technology innovation beyond incremental improvements. Important barriers must be overcome by the policy in this case, in which incumbent firms might be reluctant to publicly share routines and practices that probably contain confidential information about business operations. Consequently, incentives must be used to get this information, such as preferentially access to the technology innovation produced by niches, ahead of competitors.

Then, the codification of routines in incumbent firms can be presented to niches for elaborating technology designs that can facilitate innovation adoption in incumbents' practices. In this case, the innovation would be adapted to the existing routines of the organisation and not vice versa. Through this policy suggestion, incumbent firms would not need to modify routines to adopt new technologies, as most of the innovation literature has recognised is a problem for technology absorption (Hoeve and Nieuwenhuis, 2006).

Second, this thesis has concluded that UK energy incumbent firms' capabilities to integrate technology innovation have become rigid, affecting the possibility of meeting the 2050 net zero goal (sub-section 5.3.2). The investigation also found that transition intermediaries are key actors in modifying these "business as usual" patterns and support the evolution of capabilities. Consequently, the recommendation for incumbents' managers is to monitor the development of capabilities as a result of the intermediation's support. The overall insights obtained through the conceptual framework (Section 5.5) can provide important guidance in this aspect by pointing out the specific capabilities that need to be observed and the intermediary functions that support their evolution. This can also help policymakers to measure the modification of technology-related capabilities in incumbent firms after they have received intermediation resources. In particular, intermediaries should confirm if these resources have led to commercial exploitation of absorbed new technologies in incumbent firms. An important output of this relationship is the launch of a new product that directly contributed to reducing carbon emissions in the energy supply sector or similar industries in which sustainability is a major goal.

Third, this research has uncovered that UK energy incumbent firms' capacity to absorb new technologies is affected by external factors. The most important is maintaining the security of the energy supply system (sub-section 5.1.1). Therefore, this external factor generates rules that affect the absorption of net zero technology in incumbent firms. To tackle this situation, the suggestion to incumbents' managers is to localise parts (or nodes) in the energy supply system that are not only related to energy security and attempt to integrate purposely technological innovation that can improve the sustainable aspect of the energy supply system. Transition intermediaries have commenced such an approach according to the results obtained by this thesis. Case Study G was an example where intermediaries have promoted the integration of digital technologies to manage the intermittency of renewable energy supply. Now, transition intermediaries need to create a specific public policy to encourage the long-term adoption of these types of innovation in utility companies.

In this case, the conceptual framework (Chapter 3) can offer a strong direction to promote such technology absorption in incumbent firms by deploying programmes based on intermediary functions. For example, the intermediary function of Technology Forecasting can anticipate the areas of the energy supply system where new technologies can be introduced. In turn, this can enhance the capability of identifying technology opportunities in incumbent firms. Then, the intermediary function of R&D Coordination can encourage the development of new technologies by promoting in incumbent firms the capabilities of connecting with the R&D community and de-risking external technologies. Finally, the intermediary function of Regulatory Change can establish new norms pushing adoption in incumbent firms by strengthening the capability of speed to market. As can be seen, the conceptual framework can guide policy recommendations by emphasising which capabilities these interventions might target and why.

Fourth, by suggesting that transition intermediaries provide critical resources replacing internal R&D and innovation experiments in absorptive capacity (sub-section 7.3.1.1), this research offers important insights to business practitioners and policymakers. The findings have shown that these intermediary resources enrich the incumbent's knowledge base in areas where they are not familiar (sub-section 5.1.1). To take advantage of these resources, the firm must develop an organisational memory[14] where the outputs created by the intermediation's R&D can be stored. Thus, as the intermediaries are producing results through R&D activities, the incumbent firm can learn how to integrate these outputs into their business operations. This will allow utilities to accumulate information that is internalised as organisational knowledge, retained and become available for commercial exploitation.

To meet this goal, the incumbent firm can have repositories of such knowledge in a corporate library, where the information is organised and classified. This will facilitate communicating the acquired information within the firm in frequent bulletins and seminars, in which the

[14] Organisational memory is defined as the repository of knowledge that results from learning (Chang and Cho, 2006).

technology application is explained to employees. To reinforce the accessibility of knowledge, the firm can use an intranet to make it permanently available to all its members. As the employees employ new knowledge, successful case studies would emerge contributing to increasing the organisational memory. This positive use of knowledge must be captured by the corporate librarians to be promoted throughout the firm by the internal communication department. This will foster innovation capabilities in incumbent firms. Consequently, managers should develop a coherent strategy to not only access but retain the R&D resources provided by transition intermediaries to configure the necessary knowledge base for absorptive capacity.

In this regard, policymakers should consider the different contexts where absorptive capacity takes place to deliver R&D resources and improve innovation experiments. Transition intermediaries leverage important instances of R&D consortia (Case Study B), offering the chance to share R&D resources with industrial actors. Such initiatives denote boundaries in which actors interact under experimental conditions, conforming a temporal type of absorptive capacity that accepts new ideas. However, these characteristics can be difficult to translate into the routines of incumbent firms.

This challenge can be addressed by developing programmes with further tax schemes for launching new products. This means that utility firms can claim the investment needed to move the low-carbon technology from R&D demonstration to the market. These expenses would cover aspects such as manufacturing, building new or altering existing energy supply infrastructure, and even marketing. Therefore, by reducing the initial cost of launching a new technology into the energy supply market, the incumbent firms would be more inclined to integrate sustainable innovation into their business practices.

These suggestions, summarised in Table 7.3, consider a balanced approach where the calls are not precisely to erode practices of the regime as other policy recommendations have been proposed using the TIS and MLP frameworks (Meelen and Farla, 2013). According to Ford and Newell (2021), these type of recommendations are difficult to apply due to the natural resistance of incumbency's stakeholders to defend against transformations. Consequently, a collaborative approach is more feasible to implement, in which policy does not erode incumbent practices but attempts to understand these –with the support of utility managers– and use them as leverage for the adoption of net zero technologies.

Table 7.3 Summary of managerial implications and policy recommendations for enhancing absorptive capacity in incumbent firms

Dimension	Area of Concerns (Barriers and Challenges)	Evidence from Research's Results	Managerial Suggestions	Policy Recommendations
Absorptive capacity in incumbent firms	Adoption of new technology is driven by incumbents' operational routines. This inhibits absorbing radical innovation.	Incremental innovation aligned with incumbent's operations of a centralised energy system has better opportunities to be absorbed by utility firms (sub-section 5.3.1).	Systematising and codifying operational routines.	Encouraging to capture these routines that can be used by niches for designing new technologies facilitating its adoption in incumbents' routines.
	Incumbents' capabilities to integrate new technology have become rigid, affecting the possibility of meeting the 2050 net-zero goal.	Lack of flexibility to modify existing incumbents' processes blocking the absorption of technology innovation (sub-section 5.3.2).	Monitoring the development of capabilities as a result of intermediation's support.	Observing modifications of technology-related capabilities after incumbents have received intermediation resources.
	Incumbents' absorption of new technologiesis affected by external factors. The most important is the energy system security.	Incumbents integrate incremental technology that improves efficiencies on the security of the energy system; but not sustainable aspects (sub-section 5.1.1).	Finding nodes in the energy system that are related to sustainable aspect in the energy system for technology absorption aims.	Encouraging the long-term adoption of technology innovation in energy nodes. The conceptual framework can offer direction for policy fostering specific capabilities in incumbent firms for this purpose.
	Incumbents can have difficulties to develop an organisational memory to store intermediaries' R&D resources.	Intermediaries' R&D resources usually are focused on areas where incumbents are not familiar (sub-section 5.1.1).	Develop a coherent strategy to not only access but retain the R&D results provided by innovation intermediaries to configure the necessary knowledge base for absorptive capacity.	Build a programme for inserting the results obtained in innovation experiments to incumbents business operations with further tax schemes for launching new products.

7.5.2 Socio-technical niches and desorptive capacity

This sub-section makes suggestions to niche managers and policy recommendations in three main areas of desorptive capacity.

First, this research has emphasised the difficulties that niches face when they attempt to insert technological innovation into incumbents' operations. The web of regulations, routines and infrastructure is difficult to modify, constituting a high barrier to innovation diffusion (sub-sections 6.1.1 and 6.1.2). Transition intermediaries have made a strong effort to address these issues by creating networks (sub-section 6.1.2) and facilitating technology demonstrations (sub-section 6.2.2).

In this case, the policy proposal suggests the combination of both elements in two instances. First, niches implement the suggestions made by industrial experts from networks. Second, niches demonstrate the improved technology design in real-world testing. To facilitate access to these demonstration trials, socio-technical niches can obtain an innovation voucher that gives them preferential access to living labs. This voucher can be obtained after the niche has followed the recommendations proposed by industrial experts in a previous stage. Transition intermediaries can monitor the technology development derived from such suggestions and confirm if these have been met by niches to finally provide the innovation voucher. This will give access to living labs or similar real-world demonstrations to niches, where they will connect with incumbent firms for testing the technology functionality with real users. Accordingly, niche managers can focus the technology development to obtain innovation vouchers, guiding the development of innovation towards a coherent system of sustainable energy proposed by intermediaries. Bridging both initiatives might reduce time and effort in niches for demonstrating maturity in technology development and potentially accelerating the diffusion of low-carbon innovation.

Second, the findings have highlighted the importance of learning for socio-technical niches. This is mostly produced through a network of actors built by transition intermediaries (sub-section 6.1.2). By using this resource, actors can collaborate to reduce the inherent risk of innovation by consistently iterating the new technology. However, results have also shown that learnings at this point are obstructed by the strong interconnection of the energy supply system, in which the modification of one piece can have negative effects on the rest of the system (sub-section 6.1.2). This indicates that niche managers must constantly search for the most flexible opportunities to collaborate with incumbent firms without affecting the security of the energy supply.

Consequently, policy recommendations should focus on strengthening such a relationship. This can include an economic scheme of low-carbon incentives for early industrial users to adopt niche technologies. It will consist of financial instruments such as tax deductions to enable the diffusion of new technologies in sectors where emission reduction is critical, such as transport and heating. This can shape a technology market for diffusing low-carbon innovation in critical areas eager for net zero solutions.

Third, the results have addressed the role that intermediaries have in promoting business skills in socio-technical niches (sub-section 6.2.1). This enables niches to understand the specific operations of the utility companies and later deliver a new technology that fits into incumbents' practices. It is a critical aspect that niche managers must consider in technology development and assess if further information is needed. However, the niches' access to this information happens through middle informants that are facilitated by intermediaries (Case Study P). This might provide valuable but still incomplete information that policymakers can improve by offering in-residence stays for niche agents in utilities' offices. This will offer first-hand information to niches facilitating the understanding of critical processes in incumbent firms. This can be extremely helpful to design purposeful innovation that appropriately fits with the practices of utility companies.

These recommendations, summarised in Table 7.4, offer a boosting approach to socio-technical niches for compenetrating with the incumbents' routines and processes. This will facilitate understanding the adopter's perspective in deep and strengthening niches' desorptive capacity. Such an approach is aligned with the recommendations of finding multidisciplinary pathways to bring forward innovation, involving different actors that collaboratively can bring sustainable technologies (Mlecnik et al., 2020).

Table 7.4 Summary of managerial implications and policy recommendations for enhancing desorptive capacity in socio-technical niches

Dimension	Area of Concerns (Barriers and Challenges)	Evidence from Research's Results	Managerial Suggestions	Policy Recommendations
Desorptive capacity in technology niches	The web of regulations, routines and infrastructure are difficult to modify for integrating new technologies, constituting a strong barrier for innovation diffusion.	Technology niches are not fully aware of these factors, making difficult the diffusion of low-carbon innovation (sub-sections 6.1.1 and 6.1.2).	Seeking advice from industrial experts who can explain how to navigate these barriers. This provides inputs for progressing in the TRL scale and accessing intermediaries' testing facilities, such as living labs.	Provide innovation voucher to niches that have followed the suggestions made from industrial experts. These vouchers can be used to access testing facilities. This recommendation will bridge diverse intermediaries initiatives, reducing efforts in niches for demonstrating maturity on technology development.
	Importance of learning for technology niches by linking with a network of built by innovation intermediaries	Learnings are obstructed by the strong interconnection of the energy system, in which the modification of one piece can have negative effects in the rest of the system (sub-section 6.1.2).	Search for further opportunities to collaborate with incumbents through the support of intermediaries. This offers vital chances to learn and improve their technology development.	Strengthening this relationship by implementing an economic framework of incentives via tax deduction. This will diffuse new technologies in sectors where learning about emissions reductions is critical, such as transport and heating.
	Difficulties to understand the specific operations of the utility companies and later deliver a new technology that fits into these practices.	Intermediaries offer valuable information in this regard to niches. But this happens through middle informants that might provide incomplete information (case study P).	Constantly assess this information into the new technology development. Consider if new information is needed.	Providing in-residence stay of niches actors in incumbents' office. This will offer first-hand information to niches facilitating the understanding of critical processes of the recipient organisation of the new technology.

7.5.3 Implications to transition intermediaries

Having covered the standpoint of incumbents and niches, this sub-section now focuses on managerial suggestions and policy recommendations to enhance the position of transition intermediaries. The proposals aim to enhance the meta-function of transition intermediaries, described in sub-section 7.3.3.

In the first case of absorptive capacity in incumbent firms, this meta-function can have important implications for practice. As was discussed in sub-section 7.3.3.1, the intermediary meta-function deploys regular activities that help to mobilise the technology innovation across the range of organisational departments in incumbent firms. Significantly, the meta-function coordinates capabilities in incumbent firms by helping them to build links between different organisational skills that contribute to the integration of technology innovation. This offers the opportunity to break the path-dependency of technology absorption that the operational experience has generated in incumbent firms.

As the meta-function provides the mechanisms to initiate the commercialisation of acquired new technologies, it can constitute a powerful driver for incumbent firms to continuously adopt low-carbon technologies. Consequently, the increasing commercialisation of low-carbon technologies should improve the competitive position of the incumbent firms by moving them closer to meeting the 2050 net zero goal. This could attract a new generation of shareholders, more inclined to invest in clean technologies in the energy supply industry.

The development of such events –pushed by intermediary meta-function– can be instrumental in moulding the future strategy of utility firms. However, participants of this research have expressed concerns that utility firms are not sufficiently proactive in making the transition to the business of tomorrow (sub-section 5.1.1). For this reason, incumbents' managers must shift towards a significant change in culture by implementing a reward system that supports the absorption of new technologies into the company. Moreover, they need to give innovation time to grow, promoting the accumulation of experience over a considerable period.

Policymakers, in turn, can develop stronger ties among transition intermediary functions for enhancing the meta-function. As the conceptualisation of innovation has taught us (Section 2.1), this requires an extended time to develop. Therefore, a credible path towards delivering a consistent deployment of intermediation's meta-function that supports technology innovation must be developed in the long term by the public policy.

In the second case of desorptive capacity in socio-technical niches, the meta-function supports new technologies to arrive at the final stages of commercialisation. This has an important implication in innovation management because indicates that socio niches can leverage the development of desorptive capacity through the support of intermediaries. Consequently, the intermediary meta-function accelerates the learning in socio-technical niches to externally exploit new technologies. Niches managers must acknowledge this opportunity and exploit intermediation resources at full strength. Particularly, those providing business skills, an organisational capability where niches are weaker. Niches can allocate efforts to detect intermediation resources aiming to develop business capabilities, such as commercialisation workshops, IPRs strategy seminars and regulation updates, to name a few. This will increase the connection in niches with the business validation feature of the meta-function.

These policy recommendations aim to fortify the meta-function in the realised desorptive capacity, where only one function is operating in this dimension (see Figure 7.7 for further details). This requires the integration of additional intermediary functions that can support the outward transfer of technology innovation. According to the results (sub-section 6.1.1), important managerial recommendations can be made for niches to improve their initial knowledge about the market where incumbent firms conduct business. Therefore, the policy suggestion points to adding mechanisms related to the function of Relationship Building. The recommendations consist of supporting business skills that allow niches to propose superior and feasible economic gains to incumbent firms. This proposal will foster even further the matchmaking between producers and adopters of new technologies in the UK energy supply sector. Moreover, it will facilitate niches to obtain additional learning in connecting with incumbent actors and enhance their capabilities for effectively diffusing innovation for net zero goals.

Table 7.5 summarises both recommendations by suggesting specific actions for approaching positions between incumbent firms and socio-technical niches, generating a feasible environment of collaboration.

Table 7.5 Summary of managerial implications and policy recommendations for enhancing the meta-function of transition intermediaries

Dimension	Area of Concerns (Barriers and Challenges)	Evidence from Research's Results	Managerial Suggestions	Policy Recommendations
Intermediaries' Meta-function	Intermediaries' meta-function deploys regular activities that help to mobilise the technology innovation across the range of organisational division in incumbent firms.	Concerns that utility firms are not sufficiently proactive in making the transition to business of tomorrow (sub-section 5.1.1).	Drive a change in culture by implementing a reward system that supports the introduction and application of new technologies into the incumbent firm.	Develop stronger ties between innovation intermediaries' functions for enhancing the meta-function in the long-term. This will integrate various mechanisms supporting the overall development of low-carbon technologies in the long-term.
	Intermediaries' meta-function might accelerate the learning in technology niches to externally exploit new technologies.	Meta-function only has one intermediary's function operating in the transfer of technological innovation by niches (sub-section 6.2).	Niches managers must improve their initial knowledge about the market where incumbent firms conduct business.	Integrate additional intermediaries' functions that can support the transfer of technology innovation from niches to incumbents. Particularly, around relationship building.

7.6 Chapter summary

This chapter has discussed the results from the previous sections of analysis in the context of the wider literature. Accordingly, it has outlined the main contributions this research has made to three bodies of knowledge: (i) absorptive capacity, (ii) desorptive capacity and (iii) the role of transition intermediaries in connecting both during socio-technical transitions. Additionally, it assessed the conceptual framework. Finally, this chapter has presented managerial implications and policy recommendations for strengthening the connection between incumbent firms and socio-technical niches by transition intermediaries. The following section will now present the main conclusions of this thesis.

8 Conclusion

This final chapter will draw upon the insights obtained in the previous sections by outlining the research questions, in Section 8.1. This will be followed by the assessment of key contributions, in Section 8.2. The implications for practice and policy will be summarised in Section 8.3. Finally, the conclusions will help to inform future research avenues, in Section 8.4.

8.1 Answering the research questions

The structure of this thesis proposed two research questions in the Introduction Chapter (pp. 3-4), which were answered in the Analysis Chapters 5 and 6. These were addressed using the conceptual framework (Chapter 3), with the theoretical concepts based on three strands of literature (TIS, MLP and RBV) as critical pieces guiding the inquiries. The following subheadings summarise the answers to both research questions.

A. How do transition intermediaries support the development of absorptive capacities in utility incumbent firms of the UK energy supply sector?

The research design investigated this question by using a conceptual framework (Chapter 3) that inserted a list of capabilities (Table 2.6) into the absorptive capacity's dimensions proposed by Zahra and George (2002): acquisition, assimilation, transformation and exploitation. The framework explored how these capabilities are developed in the UK utility incumbent firms by the influence of six transition intermediary functions identified from the literature (Table 2.5). To conduct this inquiry process, the analysis was divided into two phases.

First, the analysis was focused on exploring the internal development of capabilities by incumbent firms previous to the intervention of transition intermediaries for engaging with sustainable technology resources. This decision was made following the suggestions found in the literature explaining that capabilities exist before the acquisition of new resources (Eisenhardt and Martin, 2000). In this case, the findings indicated that incumbent firms have developed limited capabilities for integrating new knowledge. The evidence indicated that innovation management capabilities have shown a strong tendency to be rigid. They exhibited limited signs of learning to absorb technologies that differ from the efficiency paradigm. It was found that the capabilities to adopt technology innovation in incumbent firms are strongly dictated by the centralised energy supply system and the profile of shareholders who prefer stable business processes that generate steady income. This is in opposition to deploying riskier projects based on technology innovation that can meet sustainability goals, but at the same time might disrupt operational efficiency. Therefore, these results are consistent with the portrayal of incumbent firms presented by most of the MLP literature (Geels, 2014), as guardians of dominant socio-technical regimes.

Second, the analysis proceeded to explore how capabilities are developed by the influence of transition intermediary functions (sub-section 2.2.2.2), facilitating the absorption of technology innovation by energy suppliers that can contribute to achieving the UK 2050 net zero goal. The results showed that intermediation functions are critical to developing each of the capabilities contained in the dimensions of absorptive capacity, according to the conceptual framework. The intermediation functions seek to acquire, assimilate, transform and exploit low-carbon technologies that are beyond the efficiency improvement of current operations set by incumbent firms in the UK energy supply sector. Through these efforts, transition intermediaries provide key resources that replace the lack of incumbents' investment in R&D and innovation experiments, such as laboratories, demonstration centres, scientific and technology staff, among others. This configures a knowledge base whereby incumbent firms can integrate innovation, gradually replacing the carbon technology platform. Consequently, transition intermediaries are critical to enhancing capabilities in each dimension of absorptive capacity.

As a whole, these findings contrast with the prior assumption of the literature that considered internal R&D resources (Cohen and Levinthal, 1990) and innovation experiments (Zahra and George, 2002) as necessary investments at the firm level to develop absorptive capacity (Dyer and Singh, 1998; Lane and Lubatkin, 1998: Todorova and Durisin, 2007).

The implications are significant for the energy transition because reveal that incumbent firms can absorb radical technology with the assistance of transition intermediaries. Rather than substantially investing in creating a knowledge base from internal R&D. An activity in which energy suppliers have scarce prior experience.

B. How do transition intermediaries assist the cultivation of desorptive capacity in socio-technical niches of the UK energy supply sector?

The process of analysis for this second research question took a similar approach to the first one. The conceptual framework (Chapter 3) introduced a list of capabilities (Table 2.7) into the desorptive capacity's dimensions defined by Lichtenthaler and Lichtenthaler (2010): identification and transfer. The framework investigated how these capabilities are enhanced by the transition intermediary functions (Table 2.5). The inquiry process was divided into two phases of analysis as well.

First, the investigation focused on exploring the development of capabilities by socio-technical niches previous to the intervention of transition intermediaries. Then, it proceeded to explore how capabilities for diffusing new technologies have been developed with the assistance of transition intermediary functions.

The first phase of the analysis found that the capabilities to diffuse technology innovation in niches are characterised by the lack of commercial awareness when the technological projects begin. Most of these are initiated to solve a technical problem. As a result, they have a weak business strategy that lacks a clear identification of the customer's needs, poor assessment of the economic components of the project and scarce knowledge of the regulations to implement the new technology into the energy market. In such a regard, the endogenous capabilities of niches are insufficient to deal with the complex process of developing a technology innovation presented in the Literature Review (Section 2.1). These results are aligned with the definition of socio-technical niches provided by Schot and Geels (2008), indicating that innovation producers, like R&D projects, start-up firms, and academic spinoffs, are highly unstructured and only through intensive experimentation they can learn the best way to scale new technologies.

The second phase of the analysis detected that transition intermediaries are fundamental to support such experimentation by providing critical learnings that enable niches to scale up new technologies. This offers a better opportunity for niches to connect with incumbent firms, enhancing the possibility of transferring low-carbon technologies to utility companies. The results revealed that intermediation's functions are essential to developing each of the capabilities comprised in desorptive capacity. These functions procure niches to identify opportunities for technology transfer and later support them to insert the innovation with larger industrial players. Through these efforts, transition intermediaries offer critical assistance to socio-technical niches by developing key pieces of a business strategy for commercialising a low-carbon technology. Such core elements consist of identifying the target market, creating business cases to define the economic feasibility of the technological project, and leveraging regulation to support the introduction of the innovation into the energy supply system. Therefore, this research has discovered that transition intermediary functions are vital to developing capabilities in both dimensions of desorptive capacity in socio-technical niches.

These findings demonstrate that desorptive capacity can be built through interactions with other actors. Particularly, transition intermediaries facilitate these links with incumbent firms as the main recipient organisations of new technologies developed by niches. This is contrary to the assumption made by the desorptive capacity literature that suggested that technology diffusion happens through the expensive development of a large patent portfolio (Lichtenthaler and Lichtenthaler, 2010). Only by this option, the organisation can repeat multiple licensing agreements until learns how to diffuse innovation (Bianchi and Lejarraga, 2016).

The implications for socio-technical niches are noteworthy because they can avoid the costly process of constructing a patent portfolio. This can be instead achieved through the support of transition intermediaries which provide affordable and accessible opportunities to learn the best way to diffuse low-carbon technologies in the UK energy supply sector.

8.2 Assessment of key contributions

Thus far, this chapter has presented a summarised version of the answers to the research questions. These briefly included the main contributions this thesis has made to theory. Now the contributions will be assessed in this section based on the three main categories of novelty, significance and rigour in energy social science (Sovacool et al., 2018).

In terms of novelty, this thesis synthesised existing theories to produce an original conceptual framework that contributed to obtaining novel insights into the relationship of incumbent, niche and intermediary actors of the UK energy supply sector. The conceptual framework combines three main theories in MLP, TIS and RBV to explore the drivers and mechanisms for these actors to diffuse and adopt technology innovation during a socio-technical transition. In this case, the motivation to combine such theories was the perceived limitations that separately each of them had for analysing the topic of research. Therefore, the conceptual framework synthesised existing theories from evolutionary economics (MLP, variation and selection, path dependence and lock-in), science and technology studies (TIS, social constructionism, network theory) and neo-classical management approach (RBV, factors of production, competitive advantage) to analyse the generation of capabilities through a collaborative heuristic of technology innovation management.

The conceptual framework was able to establish connections between three types of actors and their efforts to transform the energy supply system towards sustainability. In presenting the results of this important topic in the transition literature, this thesis has brought clarity to the topic of research by demonstrating how such a triad of actors collaborate through the diversity of activities they pursue to bring technological innovation to the energy supply industry. The degree of novelty of the results can be separated into three groups, placing these actors as the central point of each core contribution.

First, the findings showed that incumbent firms in the UK energy supply sector behave according to the description provided by some parts of the MLP literature. These are established companies that maintain, defend and incrementally improve the regime where they belong (Geels et al., 2017; Pinkse and Groot, 2015, Smink et al., 2015). The results demonstrated the importance that the centralised infrastructure of energy supply has on incumbent firms. This constitutes a set of rules that filter the integration of new technologies based on energy security considerations.

Second, this thesis selected socio-technical niches as a sample for examining desorptive capacity. This contrasts the approach taken by this body of literature, covering established technology firms in dynamic industrial sectors (Lichtenthaler and Lichtenthaler, 2009 and 2010). By considering smaller organisations, this thesis discovered that the diffusion of innovation is a multifaceted process that involves diverse activities for disseminating new technologies in a complex sector to transform, such as the energy supply.

Third, transition intermediaries address those issues by performing functions in combination. Thus, one intermediary function performs on top of the other in a collaborative form. This helps to tackle the complex problems of developing technology innovation, exposed in the Literature Review Chapter (Section 2.2). This thesis argues that the pluralistic support of different intermediary functions configures a meta-function that helps to develop capabilities in incumbents and niches. This idea resonates well with the concept of "motors of innovation", described as the cooperation of multiple TIS functions (Suurs, 2009).

In terms of significance, this thesis can offer an important contribution to the transition literature by explaining how actors at different levels collaborate to produce technological innovation for sustainable purposes. Traditionally, this body of knowledge has represented technology change as a battle between emerging innovation that challenges incumbent design (Geels, 2002). This follows the classical Schumpeterian narrative of creative destruction where technology substitution happens through competition. However, this approach offers important barriers in the energy supply industry, where this process confronts institutional lock-in associated with energy security. Accordingly, this thesis considered a different perspective in which technological change is driven by collaboration between two actors with little history working together in the energy supply sector (i.e., incumbent firms and socio-technical niches). Transition intermediaries are a fundamental third actor that brings together the technology producer (niche) and adopter (incumbent) by generating capabilities, during the turbulent times of a socio-technical transition. The insights generated by this research are significant in modifying the understanding of how technological innovation can be produced to address recurrent sustainable problems.

For practitioners, the significance lies in the great impact that transition intermediaries have on innovation management at both levels of adoption (incumbent) and diffusion (niches) of new technologies. Therefore, both types of actors can develop further actions to strengthen even more this fundamental relationship. In this case, the complementarity resources of niches can help incumbents to achieve sustainability goals. This can be possible by accessing intermediation support, which in turn seeks to develop capabilities for managing technological resources in both levels of actors. Detailed implications for practice and policy will be further summarised in next Section 8.3.

In terms of rigour, this thesis took great care in establishing research objectives by selecting an appropriate method of inquiry and interpreting results. Considering the lack of theoretical perspective on the main topic of research, the application of abductive reasoning (Coffey and Atkinson, 1996; Tavory and Timmermans, 2014; Thornberg, 2012) through the reflective cycles operation (Blaikie and Priest, 2017) provided a balanced approach. This allowed the researcher to explore existing literature as well as analyse the collected data achieving sufficient sensitivity to interpret information. The abductive reasoning proved to be an adequate option to enter the field with existing theories that were fundamental to guide the investigation. This enabled him to examine the main topic of research and relate individual behaviours from different organisational levels, producing new insights in comparison with the transition literature. This was possible through a mixed balance of abductive logic with a strong component of verification between primary and secondary sources. The researcher conducted 40 semi-structured interviews with relevant informants of the technology innovation system in the UK energy supply sector. These were examined through thematic analysis and later compared with secondary sources. In this regard, the case studies served as an effective complementary method for corroborating the results from the primary source of information. Due to the analysis of qualitative data being subjective and posing a problem against validity, the case studies provided sufficient verification to contrast information. Moreover, it shed light that contributed to developing theory. This was a critical aspect that supported the qualitative method to be rigorous when it was applied to this investigation. Importantly, it was not only the empirical elements found by this research but also the literature review that contributed to developing new explanations and meeting the requirements associated with a doctoral investigation.

8.3 Implications for practice and policy

The collaborative approach of this thesis acknowledges that the implications for practitioners share an overlap between innovation management and policymaking. The recommendations offered in Section 7.5 sought to improve the links between the producer (i.e., socio-technical niche) and adopter (i.e., incumbent firms) of technology innovation by the action of transition intermediaries in the UK energy supply industry. These aim to balance the emphasis put on energy security that according to the results of this thesis have inhibited the introduction of radical innovation for addressing sustainable challenges.

As a central point, the findings underlined the development of capabilities in incumbent firms and socio-technical niches as a key result of transition intermediaries deploying functions. Accordingly, the following paragraphs will summarise the recommendations for business managers at both incumbent and niche levels to increase the presence of innovation managerial capabilities. These suggestions are accompanied by specific public policies to support managerial decisions.

At the incumbent firm level, managers must implement a system for observing the enhancement of capabilities generated by the support provided by transition intermediaries. The results of this thesis explained that intermediation resources replace internal R&D and innovation experiments. These resources enrich the incumbent firm's knowledge base in areas where they are less familiar, such as those associated with the introduction of disruptive technologies to meet sustainable goals. To take advantage of intermediation resources, the incumbent firm must create repositories for accumulating such knowledge in a corporate library. There, information can be organised and classified. In this way, the experience of conducting innovation can be communicated within the firm through digital bulletins and seminars. This will create the opportunity to reuse information in similar chances of technology adoption, fostering even further the development of capabilities to effectively launch new products aiming at the net zero goal.

Policymakers can strengthen these information systems for developing new products by proposing programmes based on tax exemptions. This would allow utility companies to claim the investment needed for moving innovation outputs −obtained through intermediary resources− to the market. The tax exemption would cover these expenses, such as manufacturing, building new energy supply infrastructure and even marketing.

At the socio-technical niche level, managers receive extensive support from transition intermediaries to understand the industrial, legal and economic context of the energy supply sector, in which they attempt to diffuse new technologies. Consequently, niche managers must permanently search for opportunities to interact with incumbent firms through the networks facilitated by intermediaries. This offers valuable inputs to continuously learn the direction that technology development should take, facilitating its insertion in the energy supply system.

Policymakers can support this connection by providing innovation vouchers to socio-technical niches. This will give them access to demonstration facilities where niches will link with incumbent firms for testing the technology innovation. Therefore, niche managers will focus their efforts on obtaining such vouchers, directing the innovation development towards an articulate technology market designed by intermediaries to transform the energy supply system into a net zero sector.

Finally, the Discussion Chapter argues that intermediaries deploy functions in combination with configuring a meta-function (sub-section 7.3.3). This helps to mobilise the internal capabilities of both niche and incumbent actors, enabling them to move forward to the latest steps of technology commercialisation. In this case, the policy recommendation is developing the meta-function in the long term by integrating further intermediaries' mechanisms. In particular, expanding the meta-function in the realised desorptive capacity, where only one intermediary function works in this dimension (see Figure 7.10 for more details). This policy suggestion aims to add mechanisms that will facilitate niches to obtain additional learning for connecting with incumbent firms. Specifically, promoting business capabilities in niches and developing superior economic results of technology innovation, increasing the receptiveness of incumbent firms. This will provide better coordination of actors and push low-carbon technologies to be rapidly integrated into the energy supply industry.

8.4 Future research considerations

This final sub-section explores possible lines for further research that this doctoral researcher aims to uptake for academic publications beyond this PhD study. Firstly, this research has investigated the technology resources that niches can provide to incumbents, using the conceptual framework as a fundamental tool to proceed in the analysis. However, this did not cover the other way around about what are the elements that incumbent firms provide to socio-technical niches, once they have adopted the technological innovation. This would help to build a complete feedback between both ends of the technology transfer process. Incumbent firms possibly provide legitimacy to the socio-technical niches, which constitutes a form of social capital (Lin, 2002). This is based on the notion that incumbent firms offer critical resources that niches access through networks, allowing them to identify opportunities, mobilise technological knowledge and foremost build legitimacy for their innovation projects, supporting the new technology to be adopted in the market (Stam et al., 2014). This was an aspect that the conceptual framework did not cover in this thesis. By doing so, it will contribute to improving our understanding of how the creation of social capital influences the development of desorptive capacity in socio-technical niches and potentially accelerates the creation and diffusion of low-carbon innovation.

Secondly, there is the opportunity to conduct a series of in-depth case studies to investigate the overall results previously obtained in this research. This thesis addressed technological innovation in the UK energy supply sector as a whole, without exploring the decarbonisation challenges in specific sectors of applications, such as transport, heating and smart grid. The research idea is to select six case studies (two for each of these challenges), in which intermediary functions have influenced the development of innovation capabilities, accelerating the technology transfer from a socio-technical niche to an incumbent firm. In this instance, the adopter of the technology innovation would be a specific business unit of the utility company, analysing how different divisions integrate innovation according to their position in the energy supply chain. For example, heating in transmission, transport in distribution, and smart grid in retail. The results could inform energy managers and policymakers about the behaviour of specific divisions of incumbent firms towards adopting technological innovation.

Thirdly, further research may focus on the composition of niches and their presence in the technology supply chain of the energy sector. The technology supply chain is formed of different technological pieces that in combination offer a final product or service to energy firms (Andersen and Gulbrandsen, 2020). This was an aspect mentioned by the interviewees but not analysed by this thesis. Often the complexity of the technology supply chain prevents easily observe what is the level of influence that new technologies –supported by intermediaries– would have in the final product or service. To investigate this topic, the proposal might consider a codified form of intellectual property. Precisely, patent databases contain historical catalogues of technological innovation. These are important indicators of the research activity and collaboration between companies in the technological specialisation of an industrial sector (Griliches, 1990). Consequently, this research avenue aims to analyse the penetration of technology innovation into the energy supply sector using patents as the main source of data.

Fourthly, the origins of transition intermediaries were not fully investigated by this research. Most of the organisations analysed here have a public origin but others have been developed by industrial efforts to address the private sector's goals. In this regard, renewed concerns have been declared about meeting the 2050 net zero goal (CCC, 2022b). This current development of events was partially touched by Section 1.1, such as Brexit, Covid-19, and Ukraine's invasion, which are affecting the UK energy supply system with unpredictable consequences. How can intermediaries respond to these international affairs? What type of resources and capabilities do they require to deploy a specific agenda? And who will fund them? This can cover important gaps around the scarce discussion about intermediation power that this research did not completely cover.

Fifthly and finally, there is a pending question about how the transition intermediary functions promote technology management capabilities in similar centralised energy supply systems located in different countries. Particularly, in nations of the so-called Global South where the dominant position of incumbent firms and socio-technical niches has developed differently compared to the UK energy supply sector. This could provide relevant insights to understand how transition intermediaries interact with systemic actors in less developed TIS. Moreover, it could add about the formative capabilities of transition intermediaries in such cases. How are these established? How do they operate? What capital does society or government need in place to make sure they work? To answer these questions, the conceptual framework can be applied to provide explorative insights into the intermediary functions to promote capabilities in other socio-technical systems of the Global South (e.g., water treatment, transport, telecommunications). This will help to describe the main barriers to technology innovation in different sectors, developing new insights into transitions in diverse geographical areas with presumably weaker technology innovation systems.

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10 Appendices

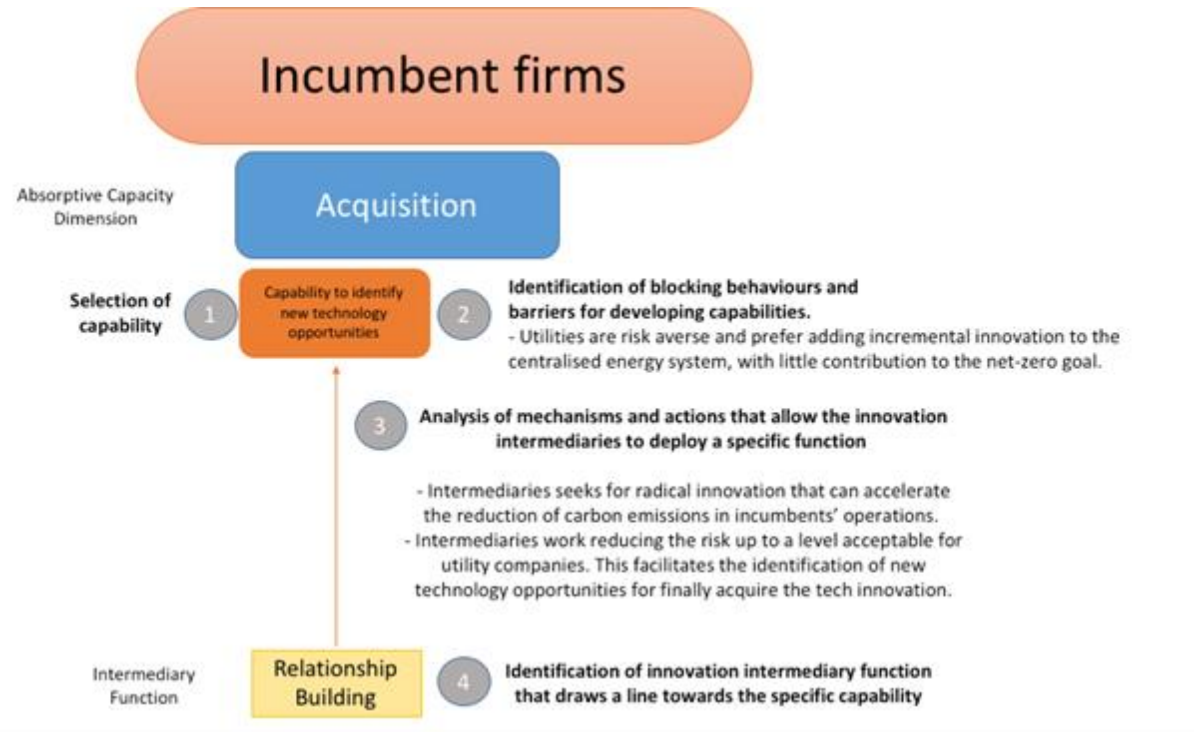
10.1 Appendix A: List of interviews

PILOT STUDY			
INTERVIEW CODE	SAMPLE CATEGORY	JOB TITLE	DATE INTERVIEW
INC A	Incumbent	Former Environmental Engineer	28/8/19
INT B	Intermediary	Former Civil Servant	5/11/19
INT C	Intermediary	Advisor	14/11/19
INT D	Intermediary	CCC Member	20/11/19
NIC A	Niche	Head of Corporate Affairs	30/1/2020
MAIN STUDY			
INTERVIEW CODE	SAMPLE CATEGORY	JOB TITLE	DATE INTERVIEW
INC 1	Incumbent	Investment Director	19/2/2020
INC 2	Incumbent	Head of M&A	12/2/2020
INC 3	Incumbent	Head of New Technology	20/2/2020
INC 4	Incumbent	Head of Innovation	4/2/2020
INC 5	Incumbent	Innovation Manager	2/4/2020
INC 6	Incumbent	Head of Regulation	28/10/2020
INC 7	Incumbent	Director	12/11/20
INC 8	Incumbent	Former Research Director	12/11/20
INC 9	Incumbent	Head of Policy	27/11/20
INC 10	Incumbent	Network Engineer	26/2/2020
INC 11	Incumbent	Former Change Lead	18/11/20
INC 12	Incumbent	Network Engineer	26/2/2020
INT 1	Intermediary	CTO	2/3/2020
INT 2	Intermediary	Technology Director	20/9/2020
INT 3	Intermediary	Senior Manager	30/9/2020
INT 4	Intermediary	Operational Director	11/9/2020
INT 5	Intermediary	Senior Manager	11/2/2020
INT 6	Intermediary	Project Manager	21/9/2020
INT 7	Intermediary	Integration Manager	21/2/2020
INT 8	Intermediary	Consultant	13/9/2020
INT 9	Intermediary	SME Manager	22/4/2020
INT 10	Intermediary	R&D Director	28/4/2020
INT 11	Intermediary	Senior Manager	22/4/2020
INT 12	Intermediary	Innovator Support	17/3/20
INT 13	Intermediary	IP Director	25/06/21
NIC 1	Niche	Researcher	13/3/2020
NIC 2	Niche	Head of Commercialisation	21/4/2020
NIC 3	Niche	Senior Manager	30/11/2020
NIC 4	Niche	Senior Consultant	18/2/2020
NIC 5	Niche	CTO	27/10/2020
NIC 6	Niche	Founder	17/11/20
NIC 7	Niche	CFO	11/11/20
NIC 8	Niche	Founder	18/11/2020
NIC 9	Niche	CEO	27/11/20
NIC 10	Niche	Business Manager	17/3/20

10.2 Appendix B: Extract from a coded interview

Extract of Interview	Coding Categories
HG: What do you think is the main characteristic of your intermediary organisation in the UK energy supply sector? Our organisation was created to try to encourage innovation in a way that wasn't driven by funding. To do that, we establish a relationship between government, industry and academia. We provide facilities and expertise to support the journey from innovation to commercialisation. We run programmes and activities to get people together and achieve collaborative outcomes.	**Intermediary functions** • Relationship Building creating networks between actors. • Management of Resources by offering facilities to demonstrate new technologies.
HG: How do you think the competitive environment in the energy supply industry influences large utility companies to absorb new technologies? In the time being in the energy sector, I have seen changes. One of the really helpful things has been the declaration of net zero. This has focused the attention of the sector. I think with that you really focus people's attention. But there seems to be some reluctance from certain players. The work that we do as intermediaries is to shift these organisations to think about more to connect with innovation. There is a desire to contribute to net zero, a sense of corporate responsibility. They now know they need to support innovation activities. But they seem to be much more engaging broadly with a broad policy framework that pushes towards this direction.	**Intermediary functions** • Regulatory Change by promoting a clear goal to guide the energy supply sector. • Relationship Building to link innovation with actors.
HG: Do you have any thoughts about how these companies have conducted innovation previously to the net zero policy? EB: If I take the distribution network operators and gas networks, they used to rely on Ofgem's scheme. That was called the Low-carbon Network Innovation Fund. They tended to be targeting the Ofgem funds. But the innovation outcomes from there tended to become business as usual.	**Absorptive capacity** • Acquisition by using public funding to integrate new technologies. These followed a path-dependency though.

10.3 Appendix C: Worked example of mobilising the analytical framework



10.4 Appendix D: List of case studies

Case Study Code	Name
A	Knowledge Transfer Network (KTN)
B	Innovate UK
C	Power Networks Demonstration Centre (PNDC)
D	Catapult Centre in Offshore Renewable Energy (ORE)
E	The Carbon Trust
F	Power Networks Demonstration Centre (PNDC)
G	Catapult Centre of Energy Systems (ES)
H	UK Intellectual Property Office (UKIPO)
I	Energy Technologies Institute (ETI)
J	Catapult Centre of Energy Systems (ES)
K	The Digital Manufacturing Innovation Hub (DMIW)
L	Sustainable Ventures
M	The Energy Innovation Centre (EIC)
N	The European Marine Energy Centre (EMEC)
O	Scottish Enterprise
P	The High Value Manufacturing Catapult (HVMC)
Q	The Michelin Scotland Innovation Parc (MISP)
R	Catapult Centre of Energy Systems (ES)