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Venturing into Heavy Industry

Exploring the role of venture capital financing in industrial cleantech innovation in the Nordic region

Jonathan Dennis

Supervisor

Philip Peck

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Tel: +46 – 46 222 02 00, Fax: +46 – 46 222 02 10, e-mail: iiiee@iiiee.lu.se.

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Abstract

Venture capital (VC) plays a vital role in supporting the development of emerging startup innovation, including cleaner technologies better known as *cleantech*. The application of VC is however distributed unevenly across sectors of the economy, often overlooking difficult to innovate areas such as the *industrial sectors*. This study explores the role of VC financing in supporting the development of industrial cleantech innovation in the Nordic region. This was pursued by identifying the key factors influencing investors when selecting prospective investments and by evaluating whether the VC model has the *potential* to be adjusted to enable it to fit the needs of industrial cleantech development. This was achieved by following an *explanatory sequential mixed methods* approach, involving the collection of firm-level industrial cleantech data between 2007-2018 covering the Nordic region and semi-structured triangulation interviews from active investors in the cleantech sector. The findings highlighted a number of themes that reflect the challenges and considerations encountered by VC investors; these included business fundamentals, high capital expenditure (capex), market conditions, technology, the mandate of the VC firm and the degree of government involvement. The study also found evidence that VCs in the region have adjusted aspects of their operating model to accommodate the demands of industrial cleantech, including greater patience with capital, adjustments to syndication composition, structural mandate changes and evidence of an IPO exit avenue. The study concludes with a reflection on the constraints of the VC model in supporting the delivery of high-level sustainability goals. Future research is required related to the underlying investors of VC funds, the broader deal flow landscape, further analysis of successful examples and a focus on the individual characteristics of entrepreneurs and financing professionals that operate in this area.

Key words: Venture capital, cleantech, innovation, finance, investment, sustainability, Nordic region

Executive Summary

At a global level, more investment is needed in technologies that support the transition to a more sustainable economy. A critical element in this transition is the development and widespread deployment of cleaner technologies, known as *cleantech*. Cleantech encompasses a broad range of industries covering areas such as energy efficiency, manufacturing, recycling and waste, biofuels, chemicals and, advanced materials. There are many factors that impact the growth and development of cleantech innovation, not least the *access to finance*.

Venture capital (VC) is often considered one of the main sources of finance for emerging innovation and plays a critical in earlier stages of the development process. VCs are a financial intermediary that invests directly in high growth prospect private companies, in exchange for an equity stake. Whilst the VC model has the proven potential to support young companies to develop, it does so *inconsistently* across the economy. This is particularly true for the so-called *heavy* investments such as those from *industrial sectors.*

According to existing literature, investment in cleantech differs from typical VC investments, tending to have higher risk profiles, greater capital intensity, less favourable exit opportunities, and extended development timescales. These challenges have called for some to argue that the traditional approach to VC needs a radical reworking to more effectively support innovation in the cleantech sector.

The aim of this research, therefore, was to explore the role of VC financing in supporting the development of industrial cleantech innovation in the Nordic region. This research was pursued to better understand the challenges associated with investment in this area that may be constraining the further roll-out of innovation. This study was also aimed at providing supporting research to industry practitioners who approached the IIIEE to support related work in the area of industrial cleantech within the Nordic region.

This thesis presented two research questions (RQs) that sought to realise this aim. The first RQ looked to identify the key factors influencing VC investors when investing in industrial cleantech, to understand the barriers and considerations made when investing in these areas. The second RQ considered whether there is *potential* for adjustments to be made to the VC model, to determine whether changes can be made to enable more effective support of industrials cleantech development. The research questions were presented as follows:

Research question 1(RQ1)

- *What are the key factors influencing VC investors when investing in industrial cleantech in the Nordic region?*

Research question 2 (RQ2)

- *Is there potential for the VC model to be adjusted to enable more effective support of industrial cleantech development?*

The research approach that this study most closely follows was an *explanatory sequential method*, whereby initial quantitative research was obtained and then supported and furthered by subsequent qualitative research. The quantitative data was comprised of *company-level data* from the region covering key aspects of each company's funding history which could be linked to aspects of the VC model. The data was drawn from sources in the Nordic region between the period of 2007-2018. The subsequent qualitative data was obtained through semi-structured interviews from VC and corporate investors with experience in cleantech and Nordic markets.

The findings for RQ1 returned six themes that highlighted the main challenges and considerations encountered by VC investors when evaluating prospective investments in industrial cleantech. The themes identified were as follows: business fundamentals; high capital expenditure (capex); market conditions; technology; the mandate of the VC firm, and government involvement. Most of the factors identified aligned with those highlighted in existing cleantech literature, with close references to capital intensity, technological complexity and extended development timescales. Within each of the factors identified, this study's findings added greater depth and detail such as the timing and magnitude of capital intense events, market conditions, technical expertise of VC professionals and government involvement. The results also connected to literature that discussed processes of investment or deal selection.

The findings for RQ2 provided preliminary evidence that VCs in the region have already adjusted aspects of their operating model to accommodate the demands of industrial cleantech in comparison to more VC traditional approaches. These adjustments covered four main areas. First, the extended development timescales of industrial cleantech have led to *greater patience* by investors in this area, with expectations of return on capital being stretched above 5 years and at times beyond a 10-year horizon. Second, the role of syndication was a prominent feature of the results and offered an area for potential VC influence and adjustment, notably with the presence of corporate investors who provide *technical validation* and *support in commercialisation*. Third, triangulation interviews highlighted examples of structural adjustments to VC firm mandates; these including *independency* and *evergreen* structures. Lastly, whilst not a direct adjustment to the model the presence of an IPO exit avenue through Nasdaq First North was identified in the quantitative data.

Further conclusions to the study discussed continued constraints to the VC model and specifically whether the VC-backed startup landscape is the best-placed venue to deliver the far-reaching changes that are needed in industrial sectors. It was highlighted that the VC model still dictates that certain investments will be out of the scope if they exhibit risk and return profiles that are non-competitive in the market. In this way, the *bandwidth* for VC investment is capped to a certain range and may overlook potentially impactful technologies. In response, there is a call for government action to provide further support for private VC actors when investing in these challenging industrial sectors, including direct subsidies, continued support through government-backed VCs (GVCs) and regulation by standardising what is classified as sustainable for investment purposes.

The conclusions to the study also tied back to the external practitioners by way of recommendations that highlighted some core focus areas. The recommendation was directed at four main areas, including close consideration to the syndication process, the importance of corporate involvement for industrial cleantech investment, the potential for compatible *bolt-on* technologies and a reflection on the frequency of deal flow in these sub-sectors within the region.

Finally, given this research was conducted in an exploratory manner, ample opportunities for further research were recorded, three of these were considered of immediate importance. First, further research could be directed at an assessment of the underlying investors (LPs) that are active in cleantech to understand expectations of return in this area and their relative influence on VC investment operations. This assessment would also provide more of an indication as to the capital resources that are aligned to cleantech, referencing back to the investment gap highlighted in the problem definition of this study. Secondly, further research could look at the full spectrum of industrial cleantech firms, including those that had *not* been successful in attracting some form of VC investment. Understanding this piece of the puzzle could better highlight the barriers for investment in this area and provide a comparison to the more 'successful' companies that have already gained investment support. Finally, an additional analysis could be undertaken to understand the *relative success* of the industrial cleantech companies within a given sample. This would provide greater clarity as to the financing conditions that supported these companies in reaching some measure of success. Finally, further research was proposed to explore the individual characteristics of entrepreneurs and financing professionals that operate in this area. This further research would shed light on the pathways and mechanisms for technological development in this challenging area.

Contents

Abbreviations

VC – Venture capital

GVC – Government backed venture capital

GP – General partners

LP – Limited Partners

R&D – Research and development

IPO – Initial public offering

1 Introduction

Today, humanity faces three unprecedented and mutually reinforcing challenges: climate change, the loss of biodiversity and the overuse of critical natural resources. Limiting global warming to 1.5 °C will require "rapid, far-reaching and unprecedented changes" across all aspects of society, including *industrial sectors* (IPCC, 2018). Industrial sectors encompass a range of heavy industries including the production of key materials and chemicals and manufacturing processes. According to International Energy Agency (IEA), the industrial sector accounts for around 37% of global total final energy use and represents 24% global greenhouse gas emissions (IEA, n.d).

There is growing urgency among businesses, the scientific community, and wider society that a transition to a low-carbon, resource-efficient economy is imperative for ongoing sustainability (Marcucci and Turton, 2015; Polzin, 2017; Bataille et al., 2018). A critical element in the transition to a more sustainable society is the development and widespread deployment of cleaner technologies (Iyer et al., 2015; Schandl et al., 2016), commonly known as *cleantech*. Cleantech emerged as an identifiable investment sector in the year 2000. As with most economic sectors it was affected by the 2008–2009 financial crisis but demonstrated a promising recovery that outstripped other sectors, notably the oil and gas industry (Georgeson et al., 2014).

As the term is used today, cleantech encompasses a broad range of industries covering areas such as energy efficiency, manufacturing, recycling and waste, biofuels, chemicals and advanced materials (Cummings et al. 2016). As will be discussed later in this thesis, there are multiple definitions of cleantech. However, as a starting reference, Gosens et al. (2015) defines cleantech as "Technologies that have a reduced environmental impact, i.e., have reduced environmental emissions or natural resource use, when compared with conventional technologies in providing similar products or services." (p. 379).

There are many factors that impact the growth and development of cleantech innovation. The policy context for low carbon innovation has been shown to be influential in the rate and direction of technological development (Newell et al., 2006; Polzin, 2017). It is well recognised that the development of a strong institutional environment encourages entrepreneurship and innovation including laws, capital market developments and cultural norms (Lerner and Tåg, 2013). There are also macro factors such as the price of oil and micro factors which include a company's strategic choices that have been shown to be influential (Bjornali and Ellingsen, 2014). However, often cited as one of the biggest barriers for innovation as identified by scholars is the *access to finance* (Lerner, 2002).

Venture capital (VC) is often considered one of the main sources of finance for emerging innovation (Kortum and Lerner, 2000; Oakey et al. 2003). VCs are a financial intermediary that invest directly in high growth prospect private companies, taking an active role in their development, with the goal of maximising financial return (Metrick and Yasuda, 2010). There is substantive research explaining the influence that VCs have on economic growth (Samila and Sorenson, 2010), company success rates (Gompers and Lerner, 2001) and the role they play in stimulating technology development and innovation (Bürer and Wüstenhagen, 2009; Colombo and Grilli 2010; Samila and Sorenson, 2010).

One crucial aspect of this role is supporting startup firms through the most precarious stage of their development known as the *valley of death*, which relates to the shortage of funding during early technology development stages through to the viability of the new technology for commercialisation (Cumming et al., 2016). Unlike most other investors, VCs are able to provide capital to young companies at this stage of development, primarily due to their ability to take on risks, even when write offs of investments are so common (Marcus et al., 2013). Without VC involvement during this period the development process would take far longer, and technologies would not be able to grow widely enough to deliver their full benefits to the industry and society (Marcus et al., 2013).

Whilst the VC model has the proven potential to support young companies to develop as described, it does so *inconsistently* across the economy. Marcus et al. (2013) suggest that VCs tend to avoid funding high risk and capital-intensive manufacturing and production companies in favour of companies that focus more information technology-based solutions in relation to the energy sector. Indeed, in relation to clean energy development, Ghosh and Nanda (2010) state that sustaining VC investments in the sector will require a "radical reworking of the VC fund structure and terms" (p. 17). Given the prominent role that VC plays in many aspects of firm development this is a problem, likely hindering the development of industrial innovation and represents a significant barrier in the transition to a more sustainable economy.

Working with industry practitioners and cleantech professionals, this thesis aims to explore the role of VC financing in supporting the development of industrial cleantech innovation, to better understand the challenges and constraints associated with investment in this area. The study focuses on the Nordic region, which has demonstrated leadership in both innovation and cleantech development and represents the fourth largest market for VC in Europe (Invest Europe, 2018).

1.1 Background to research project

1.1.1 Interaction with industry practitioners

This research project was initially prompted by two external industry practitioners who approached the IIIEE in search of research support in the area of industrial cleantech within the Nordic region. Both industry practitioners have experience in VC and the technology space which provided valuable practical grounding to the research from the outset. The industry practitioners also reached out to *Cleantech Scandinavia*, a renowned provider and promoter of Nordic Cleantech who collaborate with a range of actors in the region including investors, venture funds, industrial ventures and multinational companies (Cleantech Scandinavia, n.d). Cleantech Scandinavia agreed to support the research, through the provision of company level data of cleantech firms and later in making introductions to investment actors in the region.

This series of events helped shape the choice of research approach presented in this study, namely the selection of the *explanatory sequential method*. This method begins with initial quantitative research and follows up these findings with supporting qualitative research. The requirement for some form of quantitative outcome was a key ask from the industry practitioners and so informed the basis of the research approach which was later built upon (as described in Section 3).

Furthermore, early interactions with the above external actors were exploratory in determining certain high-level scoping decisions for the study. As such, the work sought to further explore areas of knowledge that presented particular interest to these industry practitioners. Focusing on the financial drivers was a starting point, specifically on financiers (principally VCs) role in the innovation development process. Other key scoping areas included the Nordic region and a focus on sub-sectors of cleantech, namely: manufacturing, chemicals, materials. An overview of the key scoping stages is shown below (*Figure 1*).

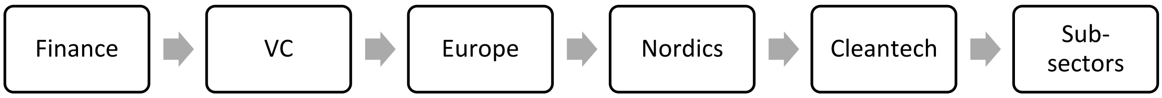

Figure 1: High level scoping of the project as per discussions with industry practitioners.

Accordingly, the author set out to construct a project to support the industry practitioners with future-oriented work in this space, whilst situating and furthering the research in relevant academic fields. In essence, this involved a focus on how VC has supported industrial cleantech in the region, drawing on key elements of the VC model in alignment with available project data. It also involved developing a deeper understanding of investment in this challenging area, to identify key barriers, constraints and highlight any potential opportunities. The insights provided were aimed at providing the foundations for further practical work and to shed light into relatively under researched cleantech sectors.

It was recognised that this research journey would be exploratory in nature, testing an approach that had the potential to yield useful information about the VC cleantech investment landscape. From the outset, there was also recognition that the research would be sensitive to data availability and that the scope would likely need adapting. This was anticipated because the exact details of the data were not available until a few weeks into the project and also the preceding knowledge that comprehensive startup firm data is limited by nature. To account for this uncertainty, two preliminary research plans were outlined when drafting initial proposals; one relied on quantitative data only, while the other detailed additional data collection steps including the use of triangulation interviews if needed. As such, the research involved an iterative process with the understanding that methodological changes may be encountered.

1.2 Problem Background

At a global level, more investment is needed in technologies that support the transition to a more sustainable economy. According to the Intergovernmental Panel on Climate Change (IPCC) latest special report, annual investments in low-carbon energy technologies and energy efficiency need to increase by a factor of 6 by 2050 compared to 2015 levels to meet certain scenarios (C.2.6) (IPCC, 2018). Within the EU, it is estimated that the 2030 climate and energy goals alone need an additional EUR 180 billion annually (European Commission, 2018), with the overall investment gap in transport, energy and resource management infrastructure reaching EUR 270 billion (European Commission, 2016). A lack of understanding of the barriers that financial intermediaries (including VCs) face in closing these investment gaps may be restricting investment flows in relevant areas such as cleantech and constraining the further roll out of innovation. Given the dominant role that the finance sector has for the economy, society and sustainable development (Scholtens, 2009; Weber, 2014), this is a priority issue that merits further investigation.

A review of existing literature in finance and innovation fields highlights a number of specific challenges associated with investment in cleantech sector. Cleantech VC investment differs from typical VC investments, tending to have higher risk profiles (Ghosh and Nanda, 2010;

Cumming et al. 2016), greater capital intensity (Gaddy et al. 2017), less favourable exit opportunities (Ghosh and Nanda, 2010), policy uncertainty (Foxon and Pearson, 2008) and extended development timescales (Ghosh and Nanda, 2010). This has been shown to be particularly true for the so called *heavy* or 'deep technology' investments (e.g. chemicals, materials or manufacturing) in comparison to *lighter* industries such as software services that do not involve tangible product (Gaddy et al., 2017). Indeed, some scholars argue that the traditional approach to VC investing must face changes in order to more effectively support innovation in the cleantech sector (Marcus et al., 2013).

Moreover, there are a number of research gaps that can be identified through a review of literature relating to VC. First, much of the foundational work in relation to VC activity is based on US data (e.g. Sahlman, 1990; Gompers, 1995; Sapienza et al., 1996). This is a problem as there are well documented differences in how the VC model has been applied depending on the regional context, especially between the US and EU. For example, studies have demonstrated differences in the VC-firm strategic relationship (Hege et al., 2009), investment selection patterns (Bertoni et al. 2015) and institutional contexts such as financial market maturity (Lerner and Tåg, 2013; Corsi and Prencipe, 2019). Similarly, there is also a case to expand research in an EU context. Indeed, Bertoni et al. (2015) noted that the literature related to VC in Europe lacks systematic coverage and more often relates to value creation aspects of VC involvement (Bottazzi et al., 2008; Cumming and Johan, 2007).

Second, whilst the foundational studies in the US have substantially developed the academic field, they have done so to a large extent prior to the emergence of cleantech market in the early 2000s. As a result, there are relatively few studies that overlap the VC model in conjunction with cleantech, even less focusing on specific sub-sectors. A notable exception to this is Gaddy (et al. 2017), who investigates several sub-sectors bridging the years of the financial crisis using US data. Other exceptions to this are more often based on research that is dedicated to clean energy (Moore and Wüstenhagen, 2004; Ghosh and Nanda, 2010; Marcus et al. 2013) or discuss the cleantech industry in more general terms (Migendt et al., 2017; Polzin 2017). The lack of up to date and comprehensive coverage in the cleantech sector is arguably a problem given the rapid changes that the sector has experienced in such a short space of time. As such, there is a greater need for more regular studies to keep up to date of changes and look further into sector-specific characteristics that may misalign with traditional understanding. Furthermore, there is a dearth of literature in the Nordic region specifically relating to the financing of cleantech. Given that cleantech in the region is considered world leading, this is perhaps a surprise. Notable exceptions discussing private finance in Finland, Sweden and Germany include Bergset (2014) and Sonnenschein and Saraf (2013) who evaluate public cleantech financing in Denmark, Finland and Norway.

1.3 Aim & Research Questions

The aim of this research is to explore the role of VC financing in supporting the development of industrial cleantech innovation in the Nordic region. This research was pursued to better understand the challenges and constraints associated with investment in this area and provide supporting research to industry practitioners active in this space. Against the background described in the previous sections, and pursuant to the knowledge gaps outlined, this thesis presents two research questions (RQs) that seek to realise this aim. The first RQ looks to identify the key factors influencing VC investors when investing in industrial cleantech, to understand the barriers and considerations made when investing in these areas. The second RQ considers whether there is *potential* for adjustments to be made to the VC model, to determine whether changes can be made to enable more effective support of industrials cleantech development.

The research questions are as follows:

Research question 1(RQ1)

- *What are the key factors influencing VC investors when investing in industrial cleantech in the Nordic region?*

Research question 2 (RQ2)

- *Is there potential for the VC model to be adjusted to enable more effective support of industrial cleantech development?*

1.4 Limitations and scope

This study has been scoped to focus on VC financing of industrial cleantech within the Nordic region. The industrial sub-sectors will include companies that are broadly defined as manufacturing, materials (both advanced and basic) and chemicals. The Nordic region for the purposes of this study will include Sweden, Norway, Denmark and Finland.

This project relied on secondary data sources to obtain a sample of industrial cleantech companies across the region. This was a necessary circumstantial limitation as collecting primary data from scratch was not within the time allowances of this study. Moreover, the application of *company level data* to better understand the relation between VC and cleantech development was not without its limitations. Whilst this enabled an overview as to where investment had been placed and the nature of its placement, the data was unable to provide a clear understanding as to the motivation behind the actions. This aspect was mitigated, to an extent, by the triangulation interviews.

The choices made on the scoping decisions, as guided by the industry practitioners, targeted sub-sectors of cleantech. This was a justified element of the problem definitions as described previous, however, it limited the generalisability of results across other sectors of cleantech, particularly those areas that are not considered heavy in the same way industrials are. Indeed, the same limitation applies to the scoping by region which has its own institutional context, especially with regards to government backed VC involvement. A second significant choice relevant to this delimitation section relates to definitions. As described in Section 3.4.1, a number of working definitions were outlined for this study to assist with sample selection. The definitions were deliberately broad and necessary to ensure the results were aligned with research aims, however, they still represent a point of intervention that influenced the sample collected.

The other significant choices were related to the areas of the VC model that were focused on to support the outcomes of RQ2. As discussed in the methodology section (Section 3), the data available influenced the areas that were possible to evaluate e.g. the VC attributes focused on in this study. As a result, it was not possible to cover all areas of the VC model that were outside of the scope of the data. A particular aspect of the VC model or process that was not reflected in the data was the decision-making process of the VCs in determining an investment. This was recognised as key area that influenced the projects aims and so was integrated into the research by way of the triangulation interviews.

The research approach of this project was exploratory in nature. As an exploratory study the results of the quantitative and qualitative analysis were not large enough to be treated with any statistical rigour. As such, the samples selected should be treated as *indicative*, reflective of the sub-sectors of cleantech and provide the basis for further practical exploration and research.

1.5 Ethical considerations

As described in the background to this thesis, the project was prompted by industry practitioners. This was not a paid relationship and so the involvement by the author was for the purposes of completing a thesis project. Whilst the external involvement did influence the scoping decisions, the research steps were executed independently. The quantitative data and subsequent analysis will be shared with the industry professionals as an outcome to the project.

Some of the sources of data presented in this study were from private sources and at times were derived from paid for platforms provided for by the industry practitioners. As such the company names have been removed from this thesis.

All interviews were conducted with confidentiality, consent and courtesy. The latter was adhered to through ensuring interviews did not exceed the agreed time limit of 30-35 minutes, which was important given the seniority of the interviewees with likely busy schedules. Conducting interviews anonymously also helped elicit open responses to questions, although the question areas by their nature were unlikely to have stimulated any contentious responses. The interview recordings and written notes have been stored by the author and will be deleted following the conclusion of this project.

Finally, it should be noted that the research proposal was reviewed with regard to the criteria for research requiring to go through the ethics review board at Lund University and has not been found to require a statement from the ethics committee

1.6 Disposition

The previous *Chapter 1* provided a background and context to the study area and outlined the aim and research questions, thus providing a foundation for this research project.

Chapter 2 outlines the literature review which covers four areas: Nordic context, innovation, cleantech and the VC investment model. This will follow with an outline of the preliminary conceptual framework and its associated theories that support the interpretation of the latter stages of the project.

Chapter 3 describes the methodology used for this study, giving details of the steps taken to collect and analyse quantitative and qualitative results.

Chapter 4 presents the results of the qualitative triangulation interviews and the quantitative data.

Chapter 5 provides a discussion and analysis of the results, expands on the conceptual framework and provides a reflection on the implications of the method selected for the study.

Finally, *Chapter 6* will complete the study with some concluding remarks, recommendations to industry practitioners and proposals for further research.

2 Literature review

This chapter begins with a background on the Nordic context, including an overview of innovation, cleantech and VC trends in the region. Selected areas of innovation literature will follow, which are relevant to the study and introduce the concept of innovation and its interaction with finance.

2.1 Nordic context

This section provides a high-level overview of the key areas linked to this study in relation to the Nordic context. Highlights are provided at a regional level for innovation, cleantech and for VC.

Innovation in the Nordics

The Nordic region has a long tradition of supporting innovation, often setting trends through innovation-based development, with all four countries consistently featuring highly on innovation rankings, including the regional innovation scoreboard developed by the European Commission. The scoreboard summarises performance using indicators that cover four main areas including framework conditions, investments, innovation activities and impacts (European Commission, 2019). Nordic countries score well in each of these indicators, however there are particularly high scores in framework conditions (e.g. % population with completed tertiary education), innovation activities (firm level efforts) and investment (through R&D expenditures). According to results of the 2018 report, three of the top 5 regions in Europe can be found in the Nordics (European commission, 2019). This conducive innovation environment has supported a relatively large number of high-profile growth companies over the last couple of decades. As of 2018, 15 companies exceeding €1 billion (e.g. unicorns) have emerged with a combined market value corresponding to 6% of Nordic GDP. (Næss-Schmidt et al., 2019).

Cleantech in the Nordics

Alongside innovation, the Nordic region demonstrates strength in supporting cleantech development. In 2017, the Global Cleantech Innovation Index (GCII) report scored the Nordic region as the strongest region for *cleantech* startup creation and leadership for the first time. The top three positions (out of the 40 countries) are held by Denmark, Finland and Sweden which all demonstrated signs of additional growth and an increasing number of cleantech funds (Sworder et al., 2017). The overall score for each country is based on an average between inputs of innovation (e.g. development of technology supply) and output of innovation (e.g. ability to commercialise innovation). The lowest scoring Nordic country was Norway (9th), although it is also the country with the highest R&D budget for cleantech based on data from 2013-15. Overall the Nordic nations performed most strongly in government backed cleantech innovation drivers, such as public R&D expenditure and supportive cleantech policy, as well as significant strength in private investor activity in cleantech relative to GDP (Sworder et al., 2017).

Venture Capital in the Nordics

There has been a presence of VC in the Nordic region since the 1980s, following the liberalisation of the financial markets across the region (Hyytinen and Pajarinen 2001). In the years that followed, government has played a significant role in stimulating the VC markets in the region, for example with the establishment of state backed VC funds in Sweden and well-funded support programs in Norway (Hyytinen and Pajarinen 2001). Between 2007 and 2017 the Nordic region (including Norway) ranked fourth in Europe in terms of total VC investment after the UK, Germany and France (Invest Europe, 2018). The investment across this period, split by country, is shown in *Figure 2* below. The region also ranks favourably in terms of VC investments in comparison to GDP at 0.04% compared to 0.02% in the OECD (Næss-Schmidt et al., 2019).

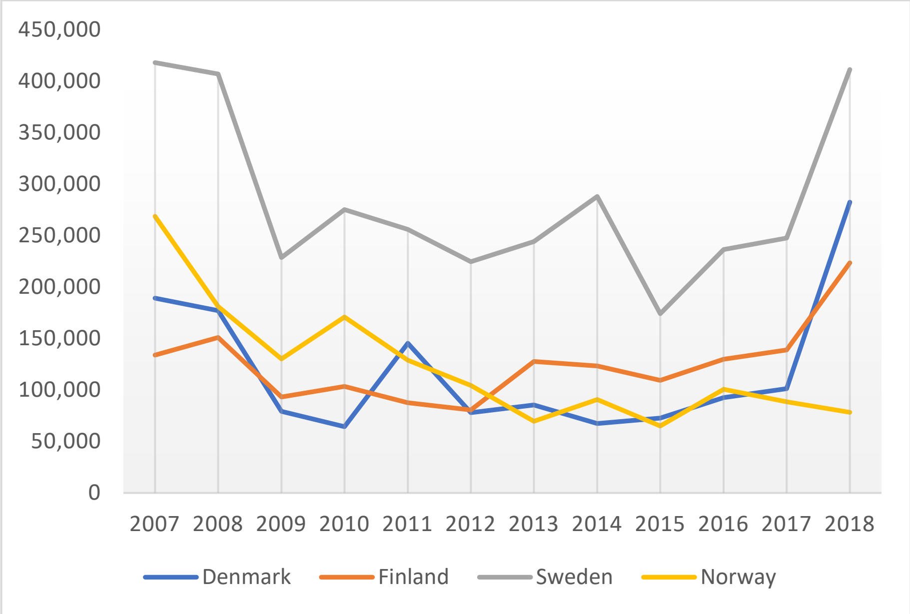

Figure 2: Total VC investment (in thousands of euro) between 2007 and 2018. Based on raw figures from Invest Europe database (Invest Europe, 2018).

2.2 Innovation

This section on innovation has been highlighted at this early stage in the study to assist with the interpretation of the research in the subsequent stages. The concept of innovation will be defined and discussed in relation to aspects of financing, as well as outlining two principle avenues of emerging innovation.

2.2.1 Defining innovation

When discussing innovation, it is important to first clarify terminology. Often invention and innovation are used interchangeably. For researchers, academics and policy makers it is important to clarify the differences between the terms given the precise meaning and applications of the terms can be quite different. Invention is "…about discovery and the creation of something novel that did not previously exist.", whereas innovation "…carries invention further with the commercial realization of the value of the invention or the receipt of an economic return." (Feldman, 2004). Commercialisation in this context is the process of turning invention into innovation which involves the need for financial resources and the concept of *value* (Feldman, 2004).

According to the definition presented by OECD (2005) below, innovation comes in many forms. There are distinctions of product and process, as well as introducing innovation through management and organisation structures.

"*An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations.*" OECD (2005)

In relation to this study a more specific definition has been provided (below) relating to *technological process innovation,* given its relevancy to cleantech deployment that often relies on the improvement of existing processes with reduced environmental impact.

"Technological process innovation is the adoption of technologically new or significantly improved production methods, including methods of product delivery. These methods may involve changes in equipment, or production organisation, or a combination of these changes, and may be derived from the use of new knowledge." OECD and Eurostat (1997)

2.2.2 Financing innovation

One of the principle avenues for financing innovation and key to driving economic growth and technological innovation is a well-functioning financial market (Brown et al., 2009). In basic terms, financial markets redirect capital from where is being saved to where it is needed achieve through a range of financial intermediaries (e.g. banks, venture capitalists, private equity firms). Therefore, innovation depends on the *adequate supply* of capital to emerging sources of innovation (e.g. entrepreneurs). The economics of this arrangement relies on the entrepreneurs being *productive* with this capital so that financiers receive a return on their investment (Nicholas, 2011). Furthermore, it is important to note that the *demand* of capital from the sources of innovation is highly variant. Each firm, even of the same size will have different cost structures, operate in different markets and are subject to different forms of competition, all of which impact their financing needs (Mazzucato, 2013).

To understand the relationship between finance, innovation and growth it is important to also understand some defining features of innovation. One feature relates to how the innovation process is inherently *uncertain.* This means that the outcomes are unknown or unclear, which makes it difficult for financiers to fully evaluate innovative projects (Kerr and Nanda, 2015). In this way uncertainty is distinctly different to risk, in that the probabilities of the outcomes are often not clear of entirely unknown (Kerr and Nanda, 2015). Mazzucato (2013) also recognise this point, stating that technological change introduced by innovation "…produces uncertainty for all the economic actors involved, those investing in it and those experiencing its effects."(p. 851). Another feature relates to the return profile of investment in innovation which are often heavily skewed. This makes standardising the evaluation process very difficult, particularly in young start-up firms, and requires a specialist investor capability often in the form of a VC firm (Kerr and Nanda, 2015). This also leads to a range of evaluation methods by the investor, whose actions are impacted by a myriad of incentives and circumstantial factors (e.g. costs, networks, governance structures) (Kerr et al., 2014).

2.2.3 Incumbent vs. new entrants

There are two avenues of innovation that have developed in literature related to entrepreneurship and innovation: one line focuses on the corporate or incumbent entrepreneurship process, the other focuses on the role of new entrants through individual entrepreneurs (Hagedoorn, 1996; Hockerts and Wüstenhagen, 2010). One stream of literature based on a perspective of economy of scale, argues that large firms are more innovative due broader resource bases that allow them to invest more heavily in research and development (R&D) (Hockerts and Wüstenhagen, 2010). In contrast, Aron and Lazaer (1990) argued that younger, smaller firms are more prone to riskier product strategies when compared to more established firms, and whilst the failure rates are higher, they are more successful at bringing more disruptive innovation to the market (Lerner and Tåg, 2013). Hockerts and Wüstenhagen (2010) present a more dynamic approach to the interactions between these actors, suggesting each avenue influences the other. For instance, it is argued that an industries early sustainability transition is more likely driven by new entrants and that incumbents often react to changes by undergoing sustainable entrepreneurship activities of their own (Hockerts and Wüstenhagen, 2010). This dynamic also introduces the concept of *innovation transitions*. Early work presented a view of *creative destruction* where every time a new disruptive innovation is created, another is destroyed (Schumpeter, 1942). Over the decades this view that one technology is substituted by another has matured, with some literature demonstrating that certain industries undergo more of a *stepwise reconfiguration* where the incumbents survive by integrating with the new technologies (Berkers and Geels, 2011).

2.2.4 Stages of Innovation

This study focuses on young startup firms and their contribution to emerging technologies within industrial cleantech. The lifecycle of a startup firm is characterised by a series of stages that correspond to their maturity and development. There are 4 stages that are often cited: seed, early stage, mid (growth) stage and later stage. Metrick and Yasuda (2010) provide a description of these stages, summarised as follows:

- *Seed capital* – a relatively small amount of capital is provided to the inventor or entrepreneur to provide proof of concept and may involve product development and the development of a business plan.
- *Early stage* - financing is provided to startup firms that are completing product development and are mostly in the testing or pilot production phase. Typically, firms have conducted market studies, assembled a management team, developed a business plan and are ready to or have started to conduct business.
- *Mid (growth) stage* – this stage involves applying capital to the initial expansion or growth of the company. Some of the uses of capital may include further plant expansion, marketing, or development of an improved product.
- *Later stage* – the stage is for firms that have reached a relatively stable growth rate, may or may not be profitable and are likely to be demonstrating positive cash flow. This also includes firms that are considering IPOs.

As shown in *Figure 3* below, as firms grow through the stages, they require different forms of financing. The sources of financing are dependent on the skills of the investor and their ability to meet funding needs and take on risk. As is clearly shown on the diagram, VC plays a dominant role in the provision of finance especially in the early to mid-stages of development. As the company reaches later stage maturity the prevalence of VC diminishes and is replaced by other investors that have greater reserves of capital and are able to operate at the lower risk levels.

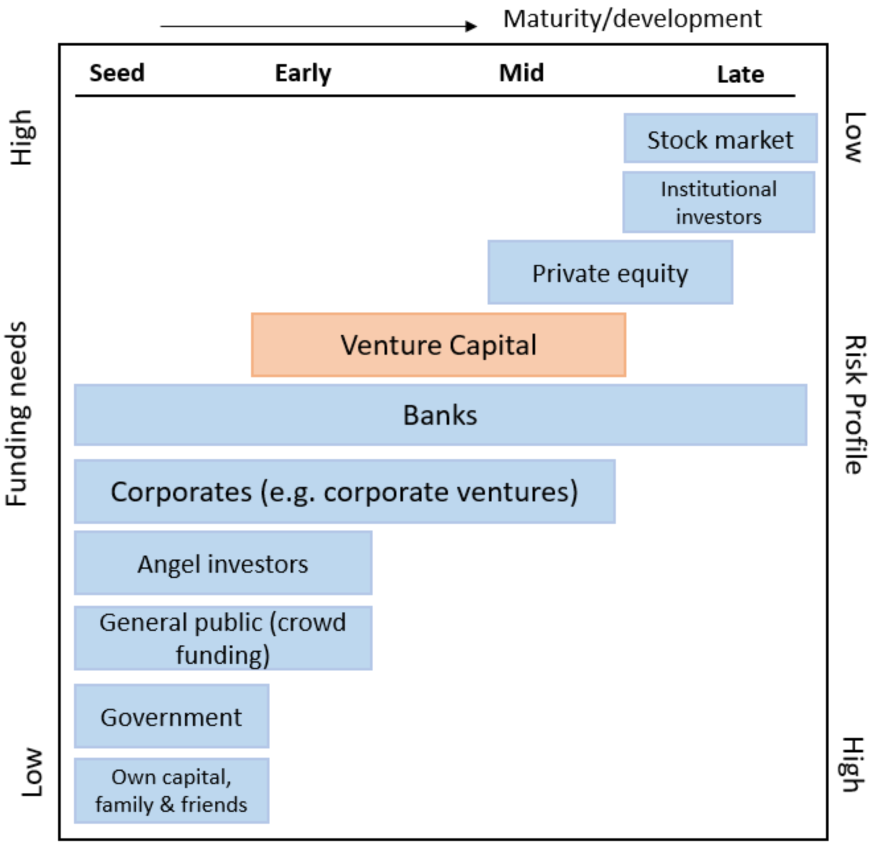

Figure 3: The positioning of venture capital and other actors in emerging business developments (adapted from Bocken, 2015 and Christofidis and Debande, 2001).

2.3 Investment in Cleantech

This section begins with an outline of the definitions of cleantech, followed by an overview of some of the drivers for investment and a review of specific characteristics inherent to cleantech investments.

2.3.1 Definitions of cleantech

To develop a better understanding of the applications and scope of cleantech, it is important to first review how the term has been defined. Since emerging in the early 2000s, the definition of cleantech has been shaped by a network of actors including firms, executives, policy makers, nongovernmental oraganisations and industry bodies (Caprotti, 2012). Initially, cleantech was used by the investment community alongside the development of early renewables. During this time, the term - which expanded to a wider range of environmental technologies and processes – began to establish itself as a new sector and investment category (Caprotti, 2012). As the use of the term has grown, defining exactly what cleantech is for all applications of the term has proved challenging. This has led scholars to discuss cleantech at a broader, more conceptual level to encompass the full scope of its application. Georgeson et al. (2014) stated that cleantech is framed as a technological, market oriented and ecologically modernising response to major issues such as climate change. Georgeson et al. (2014) also suggest that cleantech can be considered more of an investment theme or discursive sphere, rather than a distinct industrial sector. Additionally, through analysing the development of the term Caprotti (2012) described cleantech as "…an idea, a concept and an organising trope focused on the nexus between technology, finance, innovation and future transition pathway" (p. 371).

More granular definitions of cleantech have also been discussed in literature. Burtis et al. (2004), recognised that the application of cleantech across industries share a common thread; they "…use new, innovative technologies to create products and services that compete favorably on price and performance, while reducing mankind's impact on the environment" (p. 6). Beise and Rennings (2005) regard environmental innovations as modified processes, techniques, practices, systems and products that avoid or reduce environmental harm. Cooke (2008), provides a more extensive overview of the cleantech landscape, outlining categories that range from established industries (e.g. renewables) to more nascent technologies (e.g. nanotechnology). Pertinently, Cooke (2008) also discusses the *economic rationale* behind cleantech, stating that it must be competitive with conventional technologies and thus be *economically viable*. In this way, the development of new cleantech products and services should combine both economic and environmental factors, with the former often being prioritised.

2.3.2 Drivers of VC investment in the cleantech sector

This sub-section picks out some of the drivers of VC investment in cleantech, some of which were alluded to in the introduction, including integrating environmental factors, policy, supply side drivers and macro and micro factors.

Integrating environmental factors

Cleantech investments differ from traditional investments in a number of ways, including the way they accrue benefits in the form of a *public good*. Cumming et al. (2016) described this component in two ways. First, the investments are *non-excludable* for all stakeholders meaning that once a cleantech investment has improved an environmental attribute (e.g. cleaner air) none can be excluded from receiving the benefits. Second, the consumption of benefits can be thought of as being *non-rival*, meaning that generation of benefits does not affect the other stakeholders doing the same. By general economic theory the existence of these two characteristics posits that cleantech investments will be undersupplied, since the benefits cannot be excluded there is no economically driven incentive for one stakeholder to pay the costs in undertaking an investment Cumming et al. (2016).

Moreover, there are characteristics of integrating environmental factors in relation to cleantech investment that differ from traditional investments. In the context of environmental policy, Mickwitz (2003) explains that environmental problems have special characteristics that make them difficult to solve including: long time frames and complexity. Knowledge around these environmental problems is also characterised with huge *uncertainty* (Mickwitz, 2003).

Macro and micro factors

Georgeson et al. (2014), study used a relational economic geography approach in conjunction with other frameworks to examine (amongst other things) the macro- and micro-level drivers of cleantech investment. The macro drivers discussed relate to cleantech being a market driven sector that is an expression of 'market environmentalism' demonstrated through a trend towards a greener economy (Georgeson et al. 2014). An example of micro factors driving factors was the existence of networks that were shown to be important at enabling access to contacts, venture partners and expertise from industries and sectors. Cumming et al. (2016) study covering 31 countries sought to analyse the determinants of cleantech VC investment. The results showed wide range of factors, notably a pronounced role of oil prices, as well as country specific factors such as media coverage, legal and institutional variables, governance and culture.

Policy

Public policy is often cited in literature as one of the most important drivers for stimulating the market development of cleantech, as it prompts adjustments to institutions and supports sectors through demand-pull and technology push mechanisms (Migendt et al. 2017). Policies in energy and climate have been shown to have a direct and indirect influence on the performance of cleantech VC, particularly in relation to energy sector (Bürer and Wüstenhagen, 2009). For example, in a UK based study, Demirel and Kesidou (2011) attributes multiple kinds of eco-innovations and investments to regulatory drivers. In relation to commitments to VC investment more generally, decreases in capital gains tax and increases in R&D expenditures by industrial firms have been associated with increased VC activity (Gompers and Lerner, 2001).

Supply of VC

Supply oriented factors are also discussed as being influential to VC investments. Supply of VC towards startups firms is determined by investor willingness to provide funds to the VC firms (Gompers and Lerner, 2001). In this way, investment from VC firms and their underlying investors supply is connected to the investor's *perception* of risk and expected returns, often subject to uncertainty for cleantech investments. Wüstenhagen & Teppo (2006) studies what drives the VC market to extend to new industries through studying risk return factors affecting environmental technologies. One of the drivers identified was the need for the VC to have *specialised* knowledge and experience. VCs that obtained these special skills and expertise are found to be better able to alter expectations of both risk and return on their investments (Wüstenhagen & Teppo, 2006). Indeed, Wüstenhagen & Teppo (2006), conclude that "…demonstrating that there are opportunities to make good returns, and understanding how to manage the risks will probably be a particularly promising way to increase energy VC investment levels" (p. 82).

2.3.3 Cleantech venture capital characteristics

Cleantech investment differs from traditional VC investment by virtue of a number of specific factors. In a study focused on clean energy investment, Marcus et al. (2013) determine that the time horizon for involvement in firms is longer, requiring an extension from early stage development through to later stage technology commercialisation. This *extended horizon* has implications to the exit expectations for VC investors. Ghosh and Nanda (2010) also confirm this, stating that "…the time to exit for the typical startup is much longer than the three to five-year horizon that VCs typically target" (p. 14), meaning investors must be more patient to receive a pay-out for their investments. Further, this 'weak' exit pathway creates a bottleneck in the innovation pipeline, inhibiting fast development of breakthrough technologies and discouraging further investment (Ghosh and Nanda, 2010).

The requirement for an extension of development timescales also has significant implications in relation to *capital intensity*. Cleantech investments typically require greater volumes of capital throughout their development lifecycle (Ghosh and Nanda, 2010). This was clearly shown by Gaddy et al. (2017) who aggregated investments across a range of cleantech sectors bridging the financial crash (2006-2011). The so called 'deep technology' investments in materials, manufacturing, hardware and chemical companies required significantly larger sums of capital in comparison to 'lighter' non-cleantech sectors (e.g. software). The most capital intense sectors were materials and chemical processes, which also demonstrated significantly lower return profiles in comparison to software and software appliances (Gaddy et al., 2017).

The risk profile for cleantech is also said to be higher than for other VC investments (Nanda et al., 2014). Energy production cleantech has been shown to exhibit greater technology risk associated with proving the functionality of the technology (Ghosh and Nanda, 2010). Cleantech is also highly dependent on government policy, introducing regulatory uncertainty and policy risk which is seen as a major barrier for investment (Foxon and Pearson, 2008; Marcus et al. 2013). Finally, VCs also have difficulty evaluating risk, given many cleantech products and processes operate on the production side of the economy, meaning consumer interest cannot be used as a signal for success (Cumming et al., 2016).

2.4 Venture Capital Investment Model

The following section covers some of the core elements of a VC model utilised by venture capitalists. It will start with an overview of how the traditional venture capital fund works and progress through other areas including: the investment process, strategic value added, exit expectations, capital input, syndication. Finally, the section will complete with a reflection on institutional factors.

2.4.1 How venture capital works

A traditional VC fund raises capital from a number of investors, known as limited partners (LPs), that supply capital to the fund. The fund is constructed and managed by general partners (GPs), which will draw from the capital when needed to cover costs, expenses and to cover its own management fees (Christofidis and Debande, 2001). A typical fund will take around 2 to 3 years to use the money invested to make between 10-20 investment companies, with the fund's life usually up to 10 years (Christofidis and Debande, 2001). Profit is achieved through an 'exit' whereby companies are either acquired by other investors or become tradable on a stock exchange through an initial public offering (IPO). Typically, around 80% of any capital gain from an exit is distributed to the LPs (80%) and the remaining 20% to the GPs (Marcus et al., 2013). A visual representation of the VC structure is shown in *Figure 4*. Given the high-risk nature of the investments, complete write-offs are not uncommon, with many investments unable to return more money than was initially invested. Around 60% of venture capital investments do not pay off (Ghosh and Nanda, 2010) and more than 70% of the return of the portfolio is derived from only 8% of the investments (Marcus et al., 2013).

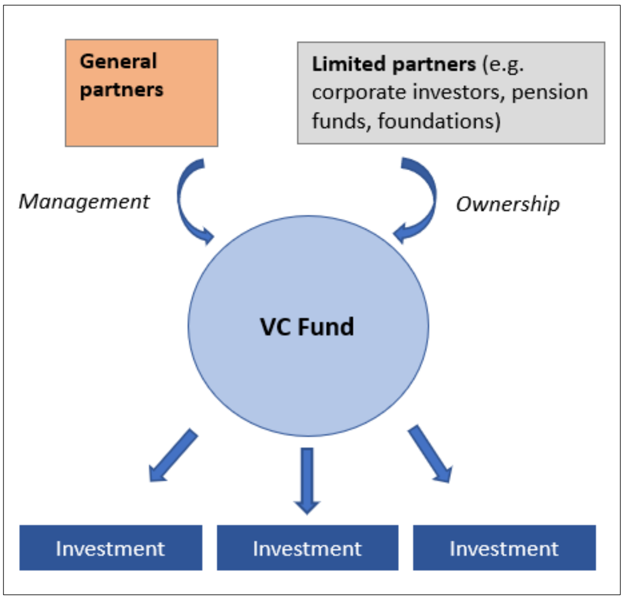

Figure 4: Structure of VC firm (adapted from Marcus et al. 2013).

2.4.2 Deal selection process

Acting as a financial intermediary, VC funds scrutinise startup firms intensively prior to investment through a screening and due diligence process (Hall and Hofer, 1993). Given that VC back firms are shown to have greater survival rates than non-VC backed firms (Davila et al., 2003), the selection process has understandably attracted attention in literature. Early work in this area describe the activities of VCs as an ordered and sequential process. Tyebjee and Bruno (1984) outline 5 main steps to this process outlined below:

1. *Deal origination* – process by which deals enter into consideration as investment prospects.
2. *Deal screening* – reviewing proposals to shortlist those which merit further consideration.
3. *Deal evaluation* - assessment of perceived risk and expected return based on a weighting of several characteristics.
4. *Deal structuring* - negotiation of the price of the deal, namely the equity relinquished to the investor.
5. *Post-investment activities* – the additional assistance provided beyond capital e.g. strategic planning, facilitating exit avenue.

The deal origination and screen phases are likely to involve some degree of market and scenario analysis in order to delineate high potential investment clusters from the market (Moore and Wüstenhagen, 2004). The VCs both actively source deals (e.g. attend industry events, research) and passively receive deal flow (e.g. firms sending proposals) (Moore and Wüstenhagen, 2004). The deal evaluation stage can be extensive and involves a range of assessment criteria. Commonly referenced criteria in this stage of the process include management skill and experience, product attributes, market growth and size, and expected returns (Hall and Hofer, 1993). Sharma (2015) provided a comprehensive overview of the evaluation criteria that are utilised by VC firms. The study highlighted that not all VCs follow the same investment decision process, with some placing more importance on entrepreneurial characteristics of the firm, whilst others focus more on the financial and marketing aspects (Sharma, 2015). The resulting firms that are selected are therefore a product of a relatively complex and subjective process.

2.4.3 Value-add

In addition to the provision of finance, VCs play a significant role in enhancing the value of their underlying investments through non-financial means. Together with deal selection, these factors have been shown to be influential to the success and development of the firm. This section focuses on three elements attributed to the additional value.

Performance

There is evidence in academic studies that show that firms that have been backed by VC are on average more successful than those that are not. This has been well documented in the US, with studies drawing from large samples of historical data (Gompers and Lerner, 2001). This trend has also demonstrated more broadly across Europe. Bessler and Seim (2012) provide evidence that venture-backed IPOs in Europe generate positive and superior returns to investors. Colombo and Grilli (2010) investigate new technology-based firms in Italy, finding that VC financing has a large positive effect on firm level growth and an is important source of additional resources. At an aggregate level, VC activity has been shown to positively impact economic growth (Samila and Sorenson, 2010).

Data asymmetries

The VC model is cited to overcome some of the inherent information asymmetries that are characteristic of young businesses, particularly in high-technology industries (Gompers and Lerner, 2001). Information asymmetries exist due to an inconsistent distribution of information between the firm and the wider market. There is a comparatively rapid reduction in information asymmetry between VCs and new firms at the outset of a relationship as the VC acquires new understanding of aspects of the firm's quality (e.g. management, technological capability) (Cumming and MacIntosh, 2001). In undertaking this process VCs reduce the chances of adverse selection and serve as information producing agents (Sahlman, 1990) on behalf of their investees (LPs) and to the wider market. Although, despite these steps early-stage ventures still exhibit risk and lack complete (quantifiable) financial and market data, with investment decisions vulnerable to unanticipated competitors, technological challenges, market shifts and financial cycles (Ruhnka and Young, 1991).

Strategic oversight

VC arrangements have demonstrated the capacity to build interpersonal relationships with their investment companies, from mentorship to more strategic oversight (Sapienza et al. 1996). Hellmann and Puri (2002) provide empirical evidence that VC firms play a broader role in the 'professionalisation' of start-ups including influencing decisions on human resources (e.g. new hires). This governance orientated role is often connected with active involvement on the board of company and strategic decisions (Sapienza et al., 1996). VCs also offer an extensive network of contacts, from administrative (e.g. lawyers, investment bankers, accountants) to personal industry contacts that may prove valuable as the company grows (Cumming, 2010). As a result, VC involvement has demonstrated positive impacts on growth and financial success. Hsu (2004) study found that offers made by high reputation VC firms to prospective start-ups were 3 to 4 times more likely to be accepted and were acquired at a 10-14% discount. Finally, it is important to note that there are regional differences in these more strategic aspects. Literature comparing differences between EU and US markets have highlighted notable differences in the level of strategic input as well as other aspects of the VC-firm relationship (Hege et al., 2009). These regional differences may impact the effectiveness of the VCs activities and are pursuant to the knowledge gap identified as part of this thesis.

2.4.4 Exit expectations

This section outlines the different exits avenues that are available for VC back startup firms. As investors seeking profitable return, this is a key element of the investment process. Expectation in the outcomes and the length of time in which an exit is achieved (e.g. duration) is therefore an important aspect of the VC model.

Exit strategies

As discussed in the introduction, VC firms will allocate capital to selected high-growth potential companies, with the expectation of a return on investment at some point in the future. To achieve this the VCs must decide at which point they should exit the investment to avoid loss and maximise gain. There are a variety of different exit strategies available to a VC as shown in *Table 1*. The optimal exit route depends on multiple factors including: the level of uncertainty of the investment, data asymmetries between actors involved, market conditions at the time of exit, and characteristics of the VC and underlying startup firm (Guo et al., 2015). Furthermore, Ghosh and Nanda (2010) describe how the type of exit has an important influence on upstream innovation processes in relation to pharmaceutical companies' willingness to invest in bio-chemical start-ups. A uniform and predictable buyer (often incumbent firms) establishes criteria for a successful exit, fueling further early stage activity and allowing VCs to work backwards to set their own investment milestones (Ghosh and Nanda, 2010).

Exit strategy	Description
Initial public offering (IPO)	Significant portion of the firm is sold into the public market via a stock exchange
Acquisition	Entire firm is bought by a third party (typically a strategic acquiror)
Secondary sale	VC's shares are sold to a third party (again, typically a strategic acquiror)
Buyback	VC's shares are repurchased by the entrepreneurial firm
Write-off	VC walks away from the investment.

Table 1: Exit strategies (Cumming and MacIntosh, 2001; MacIntosh, 1997; Cumming and MacIntosh, 2000).

Duration

The duration of time that a VC holds on to investments before exiting is influenced by many factors. Using data from 6000 venture backed US firms, Giot and Schwienbacher (2007) finds that the duration of investment was shorter for companies that reached IPO status in comparison to acquisitions, the authors suggesting this is driven by the higher profit potential of IPO candidates. Cumming and Macintosh (2001) consider a range of factors in relation to VC investment duration for different entrepreneurial firms on exit, based on *shifts in value and cost* of VC involvement – referred to as projected marginal value added (PMVA) and projected marginal cost (PMA). With respect to stage of development the study found (US data only) that earlier stage investments are more likely to be held for a short period of time. Reasons for this have been attributed to greater data asymmetry associated with early stage development (Wang et al. 2003) and adverse decision making leading to discarded investments (Cumming and MacIntosh, 2001). The availability of capital to the VC industry was also shown to affect the average duration of investment, with greater capital leading to shorter duration with increasing opportunity cost (Cumming and MacIntosh, 2001).

Cumming and Johan (2010) extend the work of Cumming and MacIntosh (2001), finding that entrepreneurial firm and VC characteristics, as well as institutional factors influence shifts in the value and cost of VC involvement, thereby impacting duration of investment. The also evidenced notable differences depending on whether firms were based in US or Canada. The authors posit that the inferior quality of the Canadian VC market pushed firms to seek capital from public markets sooner (Cumming and Johan, 2010). Further, duration was shown to be shorter for later (expansion) stage investments, large deal sizes and high-tech firms (e.g. software), and longer for life sciences firms. The study also presented cross comparative data for the average numbers of years to exit across three different regions, broken down by exit type. The results show marked differences in times to exit and the likelihood of each exit strategy depending on the region (see *Table 2* below). For example, Europe - in comparison to the US - exhibits a longer duration (EU 3.33 years vs. 2.95 years) to IPO and significantly less exits through this avenue (EU 17.02% vs US 35.65%).

Region	**IPO**	**Private Sales exit (acquisitions)**	**Source**
Europe (1995 to 2005)	3.33 years	3.38 years	Cumming (2008)
Canada (1991 -2004)	2. 45 years	4.11 years	Cumming and Johan (2010)
United States (1991 to 2004)	2.95 years	3.16 years	Cumming and Johan (2010)

Table 2: Time to VC exit across regions as per existing literature, adapted from Cumming and Johan (2010).

2.4.5 Capital contribution

As introduced in Section 2.2.4, firms require different amounts of capital depending on their stages of development. Investors must therefore be mindful of this when committing to an investment over time. There are also strategic aspects to this capital contribution that can provide distinct advantages for the VC fund, most notably the process of staging that will be discussed in this section.

Staging

VCs typically invest more than once during the life of a company, with the amount of finance typically increasing with each subsequent round (Sahlman, 1990). The capital invested at each distinct round should be sufficient to progress the company to the next stage of development, where additional funding will be required (Sahlman, 1990). According to Marcus et al. (2013), VC investors reserve 3 or 4 times their first investment for prospective follow up financing. In doing so, VCs are able to invest more money in the most promising firms, increase ownership stakes and improve overall performance of the fund (Gaddy et al. 2017). The main stages of follow up financing after the initial seed are early stage and later expansion, where VCs can set milestones and reassess the prospects of the investment (Marcus et al., 2013; Sharma and Tripathi, 2016).

Pertinently, staged funding gives the option for venture capitalists to abandon the project if it has not progressed as intended (Wang and Zhou, 2004). In this way the VCs can use the approach as a control mechanism (Sahlman, 1990) to keep investments in check, monitor for new information (Gompers, 1995) and help steer projects away from bad decisions (Gompers and Lerner, 2001). This in turn reduces the issue of moral hazard that occurs between the VC and firm when capital expenditure is not wholly observable following the allocation (Sharma and Tripathi, 2016). Wang and Zhou (2004) concluded that staged financing "plays a crucial role in controlling moral hazard" (p. 3), reducing risk through late investment and induces higher effort from the entrepreneur. Further, in a study sampling 794 companies, Gompers (1995) found that VCs concentrate investments in early stages and high technology companies where information asymmetries are likely to be most significant. Firms that exited through an IPO received more total financing and a greater number of rounds in comparison to other firms that liquidated, were acquired or remained private (Gompers, 1995).

2.4.6 Syndication

In addition to staged capital infusions, it is also common for VC funds to invest alongside each other in a process known as *syndication*. An equity syndication involves two or more VC firms (or other investors) taking equity in an investment for a share of any payoff (Manigart et al., 2006). There are several reasons why syndication takes place. First, syndication has been used for risk diversification across different investments (Schwienbacher, 2008) and to spread the risk of a single investment in high risk areas where the capital burden in larger (Hopp, 2010).

A second advantage of syndication relates to the pooling of experience and resources. Lerner (1994) study on biotechnology companies found that VC firms in early rounds of investing tended to form syndicates with other VC funds with similar experience to garner a second expert opinion. This process of seeking second (third and fourth) opinions on an investment opportunity limits the danger that bad deals will be selected and funded (Gompers and Lerner, 2001). This pooling of experience is also advantageous after initial investment through complementary monitoring, advisory functions and exploiting network contacts in the exit phase (Hege et al., 2009). Thirdly, syndication can be used to obtain the commitment from a corporate investor to secure distribution channels and offer a potentially valuable customer pool (Hellmann, 2002; Schwienbacher, 2008). Finally, syndication also provides validation of the technology through reputational effects if experienced or well specialised investors are involved (Gompers and Lerner 1999).

2.4.7 **Institutional Factors**

It is well recognised that the development of a strong institutional environment encourages entrepreneurship and innovation (Lerner and Tåg, 2013). Over the past couple of decades in particular, there has been extensive literature that has underscored the importance of these institutional factors in relation to VC activity (Jeng and Wells, 2000; Lerner and Tåg, 2013; Cumming and MacIntosh, 2001; Corsi and Prencipe, 2019). This literature field follows aspects of institutional theory that dictates that societal institutions have significant influence on organisations and their actions (Holmes et al., 2003). This section explores these institutional factors further.

Formal and information institutions

Institutional factors cover a broad range of areas which include financial market development, the legal environment, tax systems, labour market regulations, entrepreneurial culture and public spending on research and development (Lerner and Tåg, 2013). These factors can be split into two distinct groupings, namely formal and informal institutions (Corsi and Prencipe, 2019). Formal institutions are those that are governed by legally accepted rules or established laws such as capital market developments (e.g. stock markets) (Corsin and Prencipe, 2019). Conversely, informal institutions refer to "…stable but unwritten collective norms and conventions…" (Corsi and Prencipe, 2019, p. 2) that have been shown to influence entrepreneurial activity (Holmes et al., 2003). Institutional factors have been shown to make a significant difference to the expansion and development of entrepreneurial firms, including influencing the rates of success to exit (Cumming, 2010).

Capital markets

One of the key aspects of the formal institutional context is how well-developed capital markets are in the region that the VCs operate in, with specific reference to initial public offering (IPO) markets. Easy access to an IPO market allows firms to take greater risks as there is more certainty of reward that is potentially higher than other exit strategies (Bruton et al., 2005). Black and Gilson (1998) argue that the presence of a strong stock-market has been shown to correlate with greater early stage investing, since a mutually beneficial exit mechanism for both VC and firm is clear. Similarly, Lerner and Tåg (2013) state that the existence of an exit route like an IPO aligns with early-stage technology development, making best use of VCs skills in nurturing young firms until they reach a maturity level that attracts more traditional investors (Lerner and Tåg, 2013). Furthermore, the existence of liquid equity markets for IPOs is cited as being a key factor explaining regional difference in VC activity between US and the EU (Hege et al., 2009).

Type of investor

Another institutional aspect that influences the outcomes of VC activities is the type of investor that invests in the VC firm. It has been shown that the nature of the investor has a meaningful impact on the investment strategy of the VC firm. Mayer et al. (2004), show that there is a significant relationship between the sources of VC finance and their investment activities, stating: "banks, insurance and pension fund backed VC funds invest in later stage activities, whereas VC funds relying on private individual investors and corporations favour earlier stage activities" (p. 4). One of the major driving forces behind this occurrence is risk. Banks, for example, are not willing or are prevented by law from investing in young companies that have little to no tangible assets that can be used as collateral in the event of failure (Jeng and Wells, 2000). Sources of capital have also been shown to differ significantly between countries (Mayer et al., 2004), often with one source more prevalent that the others.

2.5 Preliminary conceptual framework

This section presents two theories that are often referred to in VC literature, namely signaling and agency theory. These theories introduce a number of principles and concepts that inform the relationship between VC and startup firms, thereby supporting the construction of a preliminary conceptual framework.

2.5.1 Signaling theory

Signaling theory posits that in the presence of asymmetric information between two parties, actions such as funding rounds or firm-related commitments can be interpreted as a potential signal mechanism for future value (Spence, 1974; Busenitz et al., 2005). In imperfect markets, asymmetric information exists where there is an inconsistent distribution of information between the startup firm, VCs and the wider market (e.g. investors). The absence of complete information thereby induces decision-makers to look to various indicators to signal what future outcomes are most likely to be (Busenitz et al., 2005). Moreover, in markets of high uncertainty, such as cleantech, the presence of a funding event can be significant in reducing perceived uncertainty about the future potential of a startup firm. Indeed, the credibility associated with a funding event by the VC is considered a strong signal of firm *quality* (Davila et al., 2003), given that VCs undertake a due diligence process that requires detailed analysis of the technology and numerous other criteria (Hall and Hofer, 1993; Sharmer, 2005). In this way, VC firms are incentivised to obtain as much information as possible to support this process. Similarly, it is in the interest of the startup firm to facilitate exchanges of information to the VC to provide proof of value, closing data asymmetries and attracting further investment (Busenitz et al., 2005).

2.5.2 Agency theory

Agency theory has been used to explain the relationship that is formed between VCs and startup firms after an agreement leads to an exchange of the portion of the firm's equity (Arthurs and Busenitz, 2003). An agency relationship develops between the VC and the firm when the VC operates as an external stakeholder who has a vested interest in the firm's future outcomes (Arthurs and Busenitz, 2003). This relationship is not without cost for the VC or the firm and introduces uncertainty through *agency risks* which arise when each actor pursues their own interests. Examples of *agency problems* that may incur costs include the *risk of adverse selection* in committing to an investment that may be unsuccessful and *moral hazard* whereby actions such as capital expenditure of the firm are not wholly verifiable by the VC following allocation (Sharma and Tripathi, 2016). These costs are shared between the VC and the firm and are predominantly based on the exchange of information and incentives (Smith and

Smith, 2000). In response to these costs, agency theory posits that VCs and firms act as rational individuals trying to further their own (economic) development, even if there is a misalignment of incentives and lack of efficient information exchange (Panda, 2018).

2.5.3 Preliminary conceptual framework

Concerning this study, there are key aspects of the theories described above that have been used to construct a preliminary conceptual framework, as shown in *Figure 5* below. The framework highlights some of the key concepts that drive VC investment behaviour. Considering agency theory, there are likely specific features of the information transferred between VCs and industrial cleantech startup firms that may demonstrate a *stronger* signal for value. Furthermore, signaling theory assumes that inside parties, in this case the VCs or startup firms, know more about prospects and future developments than other actors in the market e.g. investors (Keasey and Short, 1997). Therefore, industrial cleantech startup firms that have attracted investment (as per the data pursued in this study) reflect inside understanding and thus provide insight into prospective technologies in this sector. Regarding agency theory, the mechanisms associated with reducing agency risk and conflicts may be influential in explaining VC actions when investing in industrial cleantech (e.g. syndication, post-investment monitoring). Moreover, agency theory pertinently introduces the concept of economic self-interest with regards to the VC-firm relationship. This may be a significant factor, especially if the relationship is imbalanced in favour of the VC, thereby influencing the types of startup firms that receive support and funding.

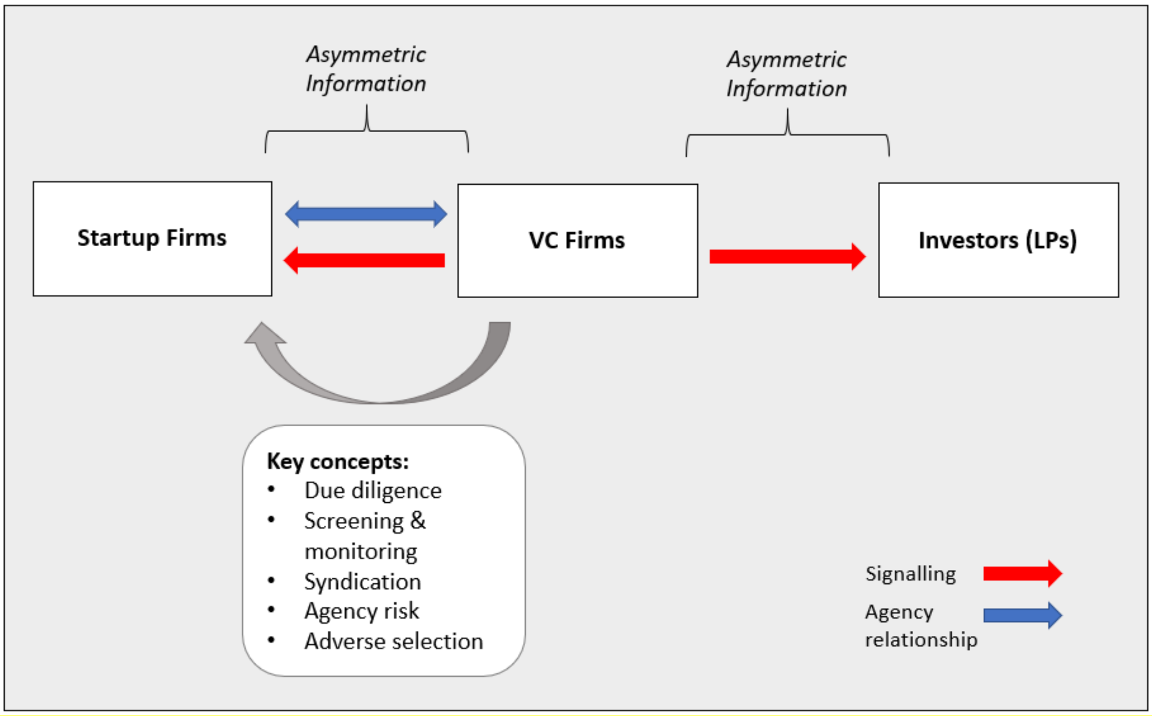

Figure 5: Preliminary conceptual framework for key actors involved in VC financing of industrial cleantech startup firms. Key concepts drawn from agency and signaling theory.

3 Methodology

This chapter outlines the study's research design and methodology. After describing the overarching research approach, the section will give an overview of the key steps that were taken during the research process. This will follow with a more detailed description of the data collection steps and conclude with an explanation of the steps taken during the data analysis.

3.1 Research approach

The research approach that this study most closely follows is an *explanatory sequential method*, whereby initial quantitative research is obtained and then supported and furthered by subsequent qualitative research; known as a *mixed methods* approach as shown in *Figure 6* below (Creswell, 2014). Combining quantitative and qualitative methods have a long history and have often been applied to social and behavioural or human sciences (Johnson et al. 2007). Campbell and Fiske (1959) first introduced the concept of *discriminant validation* in which more than one method is used to explain or validate the underlying phenomenon. In this way, mixed method approaches utilise a process of *triangulation*; which can lead to more comprehensive data sets, support the synthesis of multi theories and allow researchers to be more confident in their results (Jick, 1979).

The qualitative interviews were used in this study to help explain the findings derived from the quantitative method and to produce a richer data set than would have been achieved through one method alone. With respect to this research project, the quantitative data was comprised of *company level data* from the region covering key aspects of each company's funding history. The subsequent qualitative data was obtained through semi-structured interviews that mirrored key aspects of the quantitative data as well as going further in selected areas.

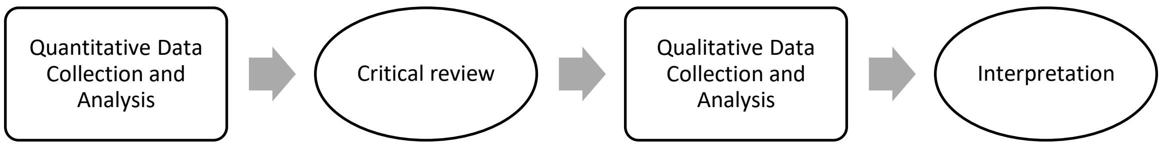

Figure 6: Convergent parallel mixed method (adapted from Creswell, 2014).

3.2 Key steps

As outlined in the opening section, the author interacted with industry practitioners intermittently throughout the project. Given the exploratory nature of the research, this required a flexible and dynamic approach, allowing for changes to be made as new information and understanding was obtained. A summary of the key steps during this process has been summarised below, in two stages.

3.2.1 Stage 1 – scoping and preliminary work

As has been discussed in the background section, *stage one* involved interactions with industry practitioners and an initial scoping of the project. The work was scoped to include VCs and the financing of cleantech companies in industrial subsectors and exclude other factors influential to innovation such as government intervention (e.g. policy, tax) and micro level attributes (e.g. firm level strategy). To help support the research in this area, it was agreed that some form of quantitative data would be helpful to support the outcomes of the project. This led to the arrangement of meetings with representatives from Cleantech Scandinavia who had granted access to industrial cleantech data that was available in their databases. Concurrent to this, the author undertook a literature review primarily focused on the VC field to strengthen knowledge in the area and provide the platform for later data analysis.

3.2.2 **Stage 2 – critical review of data**

Stage 2 of the process involved a critical review of the data that had been received in accordance with the literature review and objectives of the study. The data provided a high-level overview of industrial cleantech companies across the Nordic region between 2007-2018. An initial review of preliminary samples confirmed that further data would need to be collected to support analysis relating to VC financing. The data from this first foray was insufficient in providing details of all investors across all rounds of investment and did not always specify VC involvement. At this stage a research decision was made by the author to investigate additional data sources in order to build a more complete funding history for each company. This decision was taken because data in this area was the most accessible, allowing for some form of quantitative analysis and connected to literature by way of VC model attributes. It also provided key insight into cleantech companies that had generated investor interest which remained a valid interest to the industry practitioners when scoping the work. Additionally, this stage also indicated that the sample size would be relatively low (n<100), likely due to the relatively focused scope of research. More descriptive analysis techniques were therefore considered over those that relied on any statistical significance.

Finally, the insight into the data also prompted the author to consider follow up triangulation interviews to build on any results obtained from quantitative sources and allow for additional areas to be explored (which led to the formation of RQ1).

3.3 Data collection

This section provides an overview of the data collection methods used in this study, beginning with the literature review and followed with both elements of the mixed methods approach.

3.3.1 **Literature review**

A literature review was conducted with the aim of providing an overview of the relatively complex VC landscape and its specific application to cleantech. Insights from the extant literature were used to connect and position the project proposal within existing academic literature to ensure relevancy outside of the delivery of information to the industry practitioners. In addition to the literature review of the VC field, further research was conducted on the Nordic region and aspects of innovation to provide background and grounding to the project.

The VC literature was extensive and covered many areas of its application, particularly from a US setting. Alongside the critical review of data described above, the decision was made to focus on the literature that best aligned with aspects of the quantitative data. This directed the literature search to three main areas related to the VC model: capital contribution (including staging), syndication and exits and duration of VC support. These VC model attributes will be revisited throughout the remainder of this research project.

Conversely, the literature on cleantech and VC financing was less extensive and limited to a few core examples that were described in the problem definition section (Section 1.2). The decision was therefore made to review the references from these key sources in order to obtain the most relevant literature examples in these areas and increase the literature sampled.

To capture the full range of resources, this method of collection involved a key word search of Google, Google Scholar and the Lund University online library system. This was selected over a more systematic review with the aim of gaining a reasonably comprehensive assessment and critical reading of the key literature (Bryman, 2012). The key words for these searches are shown in the Appendix.

3.3.2 Quantitative data

The initial data set supplied by Cleantech Scandinavia included all companies that had been captured in their annual *deal flow* reporting between 2007-2018 fitting the classification of industrial cleantech which broadly covered manufacturing, materials and chemicals.[1] The list of companies that made up the deal flow were deemed to provide a good representation of industrial cleantech companies over the period, given the consistent approach that had been applied in consecutive years. Alongside the company names there was also other attributes recorded in the data including: the sub-sector categorisation, the amount of capital associated with funding events, the type of investor involved and the exit outcomes of certain companies.

Following the critical review of data (as discussed in previous section), extra data was searched for and sourced from publicly available sources. The initial company list provided by the deal flow (as above) was used to guide these searches. Two data platforms were identified and used to support this data collection:

- *Nordic9* – data platform offering deal flows, databases and reports specifically for Nordic countries (e.g. Sweden, Norway, Finland and Denmark).
- *Crunchbase* – large database providing a range of information for companies worldwide, including investment and funding histories.

This additional data collection step put pressure on the timeline of the project, therefore the author requested a data download from Nordic9 which was delivered in the form of excel data exports. This access to Nordic9 data exports allowed the author to introduce a secondary data set with the aim of providing a contrast or reference for the industrial cleantech sector sample throughout the analysis. This comparative element to the data analysis mirrors the work of Gaddy et al. (2017) who also used this approach using historic data from the US. The sector used for this secondary sample was derived from *software services* companies, as this was believed to provide the greatest contrast to the heavy industries focused in this study (e.g. light vs. heavy). Further, software services sample was selected as the sector closely aligns with traditional VC model structure e.g. where profit is derived over a shorter period and typically does not demand high upfront costs.

[1] Cleantech Scandinavia's data did not have a specific category for chemicals, however it was understood that chemical companies may be categorised in the other two categories.

A random sample was gathered from the Nordic9 search platform, taken from the period of 2009-2018.[2] Four to six companies from each year were selected to mirror the industrial cleantech data that also covered a similar time period. Companies were selected to be part of the sample based on the following criteria:

- Predominantly software services oriented (e.g. no hardware component)
- No relation to cleantech
- Funding size: unrestricted

The selections were chosen from the search results generated through Nordic9 platform (which were not alphabetised). If the company did not satisfy the criteria, it was skipped, and the next company was reviewed until sample was reached. The final sample size included 56 software services companies. The sample was not intended to be a comprehensive assessment of the sector, rather an indicative sample that could provide the basis for future research.

3.3.3 Qualitative data

The *semi-structured* interviews were conducted after the quantitative data had been collected and most of the analysis had been completed. In total, 6 interviews were conducted with the aim of validating key aspects of findings drawn from the quantitative data relating to VC model and providing further insight into industrial cleantech investment process to support RQ1. A semi-structured interview process was selected to allow for some flexibility in the interview to explore new areas, whilst remaining connected to the targeted question areas.

To elicit open, direct responses and to help facilitate the interview organisation process, the interviews were carried out anonymously; therefore, references and citations to interviewees have been documented in a way to reflect this. In total 6 interviews were conducted including 5 interviewees with VC firms and 1 interview with a large corporate investor. An overview of the guiding question areas for the VCs and the corporate investor are provided in Appendix.

Interview subjects were selected on behalf of the author largely through Cleantech Scandinavia's network, with the support of the industry practitioners. The remit for interviewee selection was discussed prior to contacting prospective informants. The two target criteria were as follows: (i) investor based in Nordic region or having exposure to Nordic markets, (ii) cleantech orientation of the investor, ideally with experience in industrial or heavy cleantech.

Each interview lasted around 30-35 minutes including an introduction and explanation of the project and an explanation of all stakeholders involved in the project. All interviewees granted permission to record the interview allowing for subsequent notes to be written up accurately.

3.4 Data analysis

This section will provide an overview of the data analysis steps undertaken during this research project. Most of the sub-sections that follow will describe the analysis of the quantitative data, given this was the most substantial process. The section will be broken down into 4 main sub-sections: pre-analysis, VC model characteristics, other analysis steps and triangulation interviews.

[2] This was the furthest back that records go through the Nordic9 platform

The data analysis steps were decided upon primarily based on the nature of the data and guided by supporting literature. The predominant aim of these data analysis steps was to provide descriptive analysis of the data that has been collected to best support the research questions outlined previously.

3.4.1 Pre-analysis

The pre-analysis stage involved a series of validation steps on the deal flow list received from Cleantech Scandinavia. This was to prepare data for later stages of analysis and ensure that the data best aligned with the outcomes of the study.

Data clean and activity check

The first analysis step involved a basic review of the list of companies from the Cleantech Scandinavia deal flow data. Each company was then checked to see whether it appeared on public data sources (Nordic9 and Crunchbase). This check informed whether the company had any additional available finding history and whether the company was still active. If the company did not appear on the public data sources, a Google search was undertaken to see if the company had an available and functional website in order to decide whether the company appeared active or not.

31 companies in the sample of 137 were also found to be listed on the Nordic9 platform. Additional data from each of these was exported and subject to additional analysis.

Definitions

The next step involved a review of the sub-sector categorisation. Whilst the raw data sources had already been classified into industrial subsectors, each company was subject to a further check to ensure all companies were representative to the intended sample. The author recognised from the review of literature that there would be no common or widespread cleantech definitions that would be easily transferrable (Section 2.3.1). Therefore, existing cleantech literature was used to develop working definitions to guide the final categorisation. The definitions shown in *Table 3* focus more on the kind of cleantech that is being developed, rather than explicitly defining the sub-sector. It is understood that these definitions are by no means comprehensive but help exclude companies that were not considered cleantech, heavy or industrial. In basic terms, this meant that the excluded companies did not have a hardware or tangible product component with associated technological development requirements.

Sub-sector	Definition description
Manufacturing	Manufacturing of tangible products or hardware that offer increased efficiency or reduced environmental impact in one or more environmental characteristic in comparison to existing industries or products in the market.
Materials (advanced)	The production of new materials or modification of existing materials that offer increased efficiency or reduced environmental impact in one or more environmental characteristic in comparison to existing industries or products in the market.
Materials (basic)	The processing of basic materials that offer increased efficiency or reduced environmental impact in one or more environmental characteristic in comparison to existing industries or products in the market.
Chemicals	The production of chemical compounds that offer increased efficiency or reduced environmental impact in one or more environmental characteristic in comparison to existing industries or products in the market.

Table 3: Industrial cleantech sub-category working definitions (based loosely on definitions from Burtis et al. 2006; Gaddy et al. 2017).

3.4.2 Analysis of VC model attributes

The literature review highlighted key areas of the VC model that most closely fitted the data that was available for this study. As mentioned earlier, the VC model attributes that were focused on were capital intensity (e.g. how much was invested), staging (e.g. how often and how much was invested over time), exits and duration (e.g. exit avenue and time taken to achieve it) and syndication (e.g. how many and what type of investors contributed to the investment). These focus areas were explicitly aimed at answering RQ2.

Each of the VC model attributes involved relatively straight forward data analysis steps that assisted subsequent descriptive analysis. All steps were calculated using Microsoft Excel and support formulas. A combination of formulas and manual steps were combined to obtain all the information. In many cases, the 'analysis' simple involved a targeted extraction from the existing data, rather than any calculation that altered the original data. An overview of each focus area is described below followed by a summary of the calculation steps taken.

Capital contribution and intensity

The total amount of capital for each company across all funding rounds was summed against the year it was invested to give an overview of total amount invested across all sub-sectors. The amount was also broken down by sub-sector. The total amount include investment from *all* investors (not just VC) as the data did not show the relative contribution of each.

The capital intensity measure was relatively rudimentary and calculated simply by dividing total amount invested by the number of companies in the sample. Capital intensity measures are widespread and often draw in different forms of information into the calculation. The finance industry for example calculates capital intensity by determining the amount of investment needed to generate 1 unit of sales revenue. However, for the purposes of this study and given the lack of additional data available, the simple calculation used in this study was deemed an adequate and indicative measure.

Summary of analysis steps:

- Total amount of funding across all investors across the all the sample, broken down by year.
- Total amounts by the year invested.
- Total amounts by sub-sector.
- Total amount divided by the number of companies in the selected sample (estimated capital intensity).

Staging

As stated in the literature review staging relates to consecutive funding rounds over time. Accordingly, the total number of funding rounds was counted for each individual company against the amount raised in each of the funding rounds. The percentage change across each of the rounds was also calculated for those companies who had been subject to multiple rounds of funding. This gave a high-level picture of the magnitude and frequency of the investment rounds across the data samples.

Summary of analysis steps:

- Total number of rounds recorded across all sample.
- The round number for each company and amount raised per round.
- The percentage change across each round (for those companies exceeding one round of funding).

Syndication

To understand the picture of syndication, all investors were recorded within the sample sets. Each investors connection to the investment round was also calculated in order understand the activity levels of each investor. Subsequent investment rounds were often supported by the same investor; therefore, care was needed to consider this in the calculation of results to avoid duplication.

Summary of analysis steps:

- Calculated the total number of investors, the rounds they were invested in and the percentage representation for each.
- Calculated a syndication rate across the samples by identifying companies that only had the support of only one investor type.

Exits

This analysis step sought to understand how industrial cleantech compares to exit literature (e.g. Cumming and MacIntosh, 2001; MacIntosh, 1997; Cumming and MacIntosh, 2000) and specifically whether it is clear whether exit opportunities are evident, given they are said to be less favourable for cleantech (Ghosh and Nanda, 2010). The known exits types identified through the literature review (Section 2.4.4) were as follows: initial public offering (IPO), acquisition, secondary sale, buyback and write-off. Confirmation of the exits were detectable in the raw Cleantech Scandinavia data which showed whether a company had raised money through a stock exchange, and confirmed by a separate search through Nordic9 platform.

Summary of analysis steps:

- Number of exits recorded through the sample data sets.
- The exit rate based on the sample selected.

Duration

This analysis step connected with literature regarding duration of investment support (e.g. Cumming and Johan, 2010). The length of time was calculated from the first VC investment recorded until the successful exit, as per the methodology followed by Cumming and Johan (2010).

Summary of analysis steps:

- Length of time recorded from first VC investment until known exit.

3.4.3 **Other analysis steps**

In addition to the above steps outlining VC model attributes, a number of smaller analysis steps were drawn from the data. These were undertaken to support the descriptive analysis and were selected based on the

- *Stage of funding* - as the data was not able to specifically show the stage of development that the investment related to (e.g. seed, growth, expansion) an *estimation* was calculated based on the total investment received by the company. This did not take into account the company age and only provided an indication as to the stage of development based on the amount of capital it had attracted to date.
- *Company age* – the company founded date was used for this measure, mostly drawn from the Crunchbase platform.

3.4.4 **Triangulation interviews**

In line with the research approach the interviews were utilised in this study as a form of triangulation therefore the interviews were not subject to coding. Instead the analysis involved a write up that summarised the communications and highlighted the key messages, assisted by the interview recording. The results stating the influential factors to investment (RQ1) were drawn from the specific question that related to this as well as other responses from other questions during the interview if relevant. An basic analysis was undertaken to group the responses into key themes, which will be described in the next section.

4 Results

This chapter reveals the results that have emerged from both the quantitative and qualitative elements of this research project. The sections will follow in sequential order in accordance with the research approach, starting with the quantitative analysis and then moving onto the qualitative analysis. The latter section builds from the former and attempts to mirror the themes where relevant.

4.1 Quantitative results

The following sections will describe the outcomes of the quantitative analysis, based on the 2007-2019 data set obtained for this research project. The subsequent subsections will include an overview of industrial cleantech and VC financing in the Nordic region, a review of exits and development support timescale and complete with a review of the cleantech company attributes.

4.1.1 Overview of industrial cleantech and VC financing in the Nordic region

This opening section will begin with an overview of the data set in relation to its composition and alignment to this research study.

Sample overview

In total, there were 137 companies that were broadly categorised as industrial cleantech over the period. After a second critical review, involving the pre-analysis steps described in the methodology (Section 3.4.1), 75 companies were removed from the sample. Of the companies removed from the original sample, 59 were due to misalignment with the working definitions, 11 were due to company closure or inactivity and 6 with a lack of visible funding history.

The 61 companies that progressed to the analysis stage were then split into two groupings based on the availability of data from the Nordic9 platform. The first group (A) was made up of 31 companies from Cleantech Scandinavia historical data that generated data from the Nordic9 platform. This data was used for all data analysis steps in the study. The second group (B) of 30 companies that did not generate data from the Nordic9 platform was also used, but only for later result sections relating to the remaining sub-sections of this section (e.g. sectors, development, age) and exit duration (Section 4.1.3). The funding history for these companies was not deemed complete enough to contribute to early stages of analysis.

The data set relating to software services was based wholly on Nordic9 platform data. This sample data set included 56 different startup firms and was included in all analysis steps. As mentioned in the methodology (Section 3.3.2), the software services sample was used to provide greatest contrast to the industrial cleantech sample and aligns more closely with the traditional VC model structure.

Sub-sectors

As stated earlier, there were 4 sub-sectors that were categorised as part of this study, namely manufacturing, materials (basic), materials (advanced) and chemicals. The distribution of the companies across these sub-sectors was uneven. Manufacturing and materials (advanced) represented the majority of the sample with 33 and 16 respectively. Companies categorised as chemical and materials (basic) represented 8 and 3 companies respectively. An overview of the distribution is shown in *Table 4* below.

Category	Sub-sector
Manufacturing	33
Materials (advanced)	16
Materials (basic)	3
Chemicals	8

Table 4: Breakdown of industrial sub-sectors of total sample (including dataset A and B).

Stage of development

The stage of company development was estimated based on the total funding received through all avenues to date. This is a basic estimation of the maturity and development of the firm based solely on the total invested amount to date is shown in *Table 5* below[3]. These groupings were broken down into 4 main stages: seed, early stage, mid stage and late stage. The results show a greater weighting of seed stage companies for the industrial cleantech sample, in comparison to the software services data set.

Funding stage	Industrial Cleantech	Software Services
Seed ($1M or less)	13	7
Early ($1M to $2M)	8	8
Mid ($2M to $15M)	25	26
Late ($15M+)	7	15

Table 5: Stage of funding based on total capital invested to date (fund stage value ranges taken from Reiff, n.d.).

Company Age

The founded year data available in the data collected for this study was used to provide an estimate for company age. The results are presented below in *Table 6*, showing that most of the companies were founded after 2006. An average year was calculated to assist with an interpretation of company maturity.

Sector	Pre 2000	2000-2005	2006-2010	2011-2015	Post 2015	Average year
Industrial Cleantech	5	9	18	11	8	2009.1
Software Services	4	4	16	23	3	2009.5

Table 6: Founded year of companies across each sector, including data set A and B for the industrial cleantech sample.

[3] The companies that had exited were mitigated from this analysis as the funding amounts from IPO sources could not always be isolated.

4.1.2 VC Model attributes

This section provides more in-depth results relating to how the VC model has been deployed including syndication, capital intensity and staging. The control sample set relating to software services data will be utilised throughout to compare and contrast with the results generated from industrial data sets.

Capital contribution and intensity

This sub-section will provide an overview of the total capital contributed to industrial cleantech across all the sub-sectors, alongside the software services sector sample.

The overall investment in industrial cleantech covering all the sub sectors analysed was $345.58 million, spread across the 31 companies in the sample between 2005 to 2019.[4] In comparison, software services generated $679.53 million of investment between 2010 and 2019 across the 56 companies in the sample. This data was then differentiated by year of investment and plotted against investment amount, as shown in *Figure 7* below.

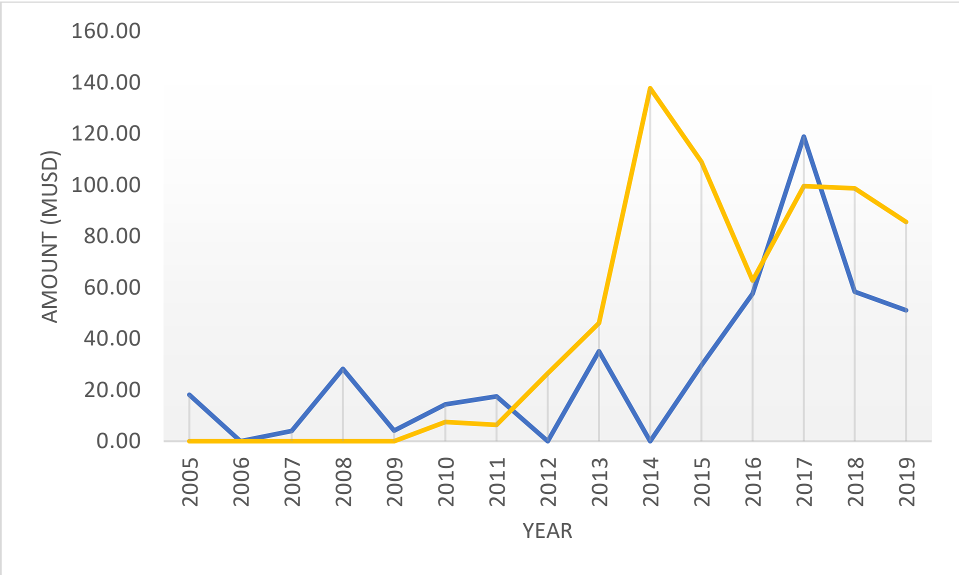

Figure 7: Total industrial cleantech investment between 2005 and 2019. Industrial data (Blue), software data set (yellow)

This total was then broken down by sub-sector for the industrial sub-sectors, to show the relative spread across the areas. The manufacturing sub-sector generated the most investment across the period ($154.19). This was followed by advanced materials ($149.1m), basic materials ($22.50) and chemicals ($19.78m). The total amount invested in software services sample data over the period was $679.53 million. To account for the differences in sample sizes an average capital intensity measure per company was derived by dividing the total amount by the number of companies in the sample. The results are shown in *Tables 7* and *Table 8* below, showing a *lower* capital intensity estimate for industrial cleantech in comparison to software services. This calculation was omitted for the basic material category due to lack of sample size (e.g. only 1 company).

[4] Date range of investment events within the sample.

Sub-sector	**Total Amount (m)**	**No. of companies**	**Average capital contribution (total amount/no. companies)**
Chemicals	19.78	5	3.96
Materials (advanced)	149.10	10	14.91
Materials (basic)	22.50	1	n/a
Manufacturing	154.19	15	10.28
Total	345.58	31	9.72

Table 7: *Total investment and average intensity of industrial cleantech across.*

Sector	**Total Amount (m)**	**No. of companies**	**Average capital contribution (total amount/no. companies)**
Software Services	679.53	56	12.58 (m)

Table 8: *Total investment and average intensity of software services data set.*

Staging

The results in this section give a high-level overview as to how investment has been staged throughout the funding history of the companies studied. This will provide some detail on number rounds and the nature of these investment across the rounds (e.g. relative increases or decreases). Such information gives an indication as to how investors are deploying their capital over time, which is useful because investors use this mechanism strategically to manage investments.

The first results evaluate each of the companies in terms of how many funding rounds they have received. Whilst this is influenced by the age and stage of development, it will also provide an indication to the nature of the funding process in relation to staging. For the industrial cleantech sample, this shows that most companies have received 1 or 2 stages of funding, represented by 11 (35%) and 12 (39%) companies respectively. From the sample of 31, only 3 (9%) companies had received 4 or more rounds of funding (*Table 9*) The software services companies demonstrated a similar pattern, but most of the companies have progressed to receive 2 and 3 rounds of funding. A greater proportion of the companies have also received 4 or more rounds of funding, at 23.2% of the sample. The distribution of these funding events is shown in *Figure 8*.

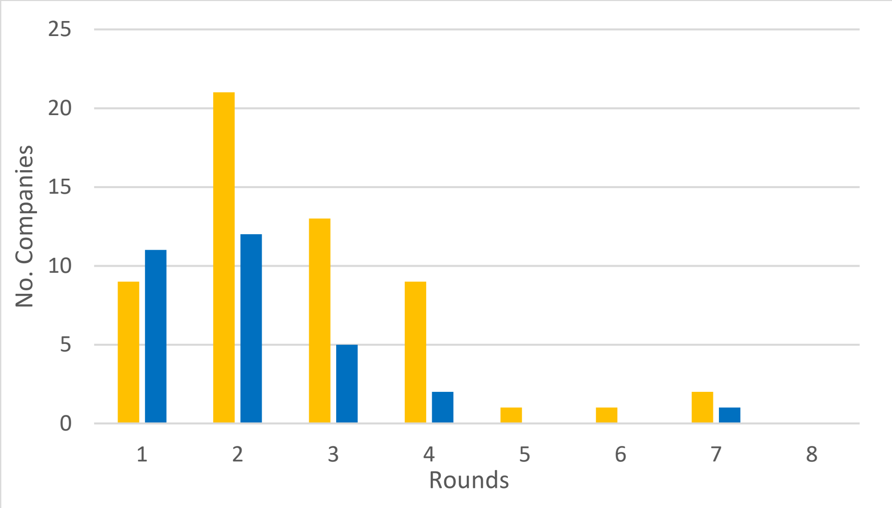

Figure 8: Industrial cleantech and software companies showing number of funding rounds. Industrial data (blue), software data set (yellow)

Industry Category	**Investment Round**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Industrial cleantech companies	11	12	5	2	0	0	1	31
Percentage of total	35%	39%	16%	6%	0%	0%	3%	100
Software services companies	9	21	13	9	1	1	2	56
Percentage of total	16.1%	37.5%	23.2%	16.1%	1.8%	1.8%	3.6%	100

Table 9: Number of funding rounds by VC across both sample sets.

Syndication

This subsection presents the syndication (e.g. co-investment) results across the samples. As discussed in the literature review syndication is used strategically by VCs during the investment process. The results here also reveal the wider investment landscape, including other investors that are involved in support the startup firms in the samples.

Table 10 shows a breakdown of the investors involved in the 31 companies within the industrial cleantech sample. The total number of investors and their relative activity across all investment rounds are presented. In total there were 91 different investors and 137 rounds of investment across the period. The results show that VC was the most prominent through both measures, representing 51.1 % of all investors and being involved in 56.6% of all funding rounds. Corporate investors (24% of total) were the next most active investor, followed by private equity investors (7.7% of total). The presence of pension funds and banks should be noted as these investors were absent from the software services sample.

Type	**Number of investors**	**Investor % (no./investor total)**	**Involvement in Rounds**	**Involvement in Rounds % (no./round total)**
Venture Capital	47	51.6	77	56.5
Corporate Investor	24	26.4	29	21.2
Private Equity	7	7.7	10	7.3
Pension Fund	3	3.3	3	2.2
Others	3	3.3	4	2.9
Angel Investor	4	4.4	4	2.9
Bank	2	2.2	3	2.2
Accelerator	1	1.1	6	4.4
n/a	0	0	1	0.7
Total	91	100	137	100

Table 10: Total number of investors and involvement in investment rounds for industrial cleantech sample.

The same analysis was also undertaken on the software services data set, made up of 56 different companies. In total, there were 131 different investors and 322 rounds of investments across the period. As shown in *Table 11* below, VCs also were again most active across both measures, representing 62% all investors and being involved in 59.3% of investment rounds. Angel investors were the second most active, representing 41.2% of the total, with corporate investors following after at 6.9% of the total.

Type	**Number of investors**	**Investor % (no./investor total)**	**Involvement in Rounds**	**Involvement in Rounds % (no./round total)**
Venture Capital	62	47.3	191	59.3
Angel Investor	54	41.2	92	28.6
Corporate Investor	9	6.9	17	5.3
Private equity	1	0.8	6	1.9
Accelerator	2	1.5	9	2.8
Crowdfunding	1	0.8	4	1.2
Others	2	1.5	3	0.9
Total	131	100	322	100

Table 11: Total number of investors and involvement in investment rounds for software services sample

The results presented above give a high-level picture of the syndication process across the sample set. In addition to these results, further analysis was undertaken to determine the percentage of companies within the samples that were demonstrating a syndicating process. The results are presented in *Table 12* below show that the syndication rate across both of the samples. Overall both samples demonstrated syndication rates of over 80%.

Attribute	Total in sample	No. companies syndicating	No. companies not syndicating	Syndication rate
Industrial Cleantech	31	26	5	83.9%
Software services	52*	46	6	88.5%

*Table 12: Syndication rates across the companies in each sector. *(4 companies in the sample did not show investor type history).*

4.1.3 Exits and duration

This results section builds off the research that investigates exits and the VC support timescales (e.g. support duration) of startup firms (Guo et al. 2015; Cumming and MacIntosh, 2001; Cumming and Johan, 2010). Both characteristics will be compared with the software services sector. Exit and timescale are important because they provide a picture of the rate of development and influence VC involvement through the expectation of return.

Exits

As outlined in earlier (Section 2.4.4), there are several exit avenues that a company may end up taking at later stages in the development including: initial public offerings (IPO), acquisitions, secondary sales and write offs. This sub-section evaluates the exits that have been observed in the each of the sample data sets.

For the industrial cleantech data sets (included both A and B data groups), which covered 65 companies, there were 10 known exits. These exits were comprised of 6 IPOs and 4 acquisitions, with one of the industrial cleantech companies in the sample subject to 2 separate exits (an acquisition followed by IPO). All IPOs recorded were admitted through the Nasdaq First North stock exchange, a *multilateral trading facility* operating in the region.

For software services, there were 9 known exits made up of 7 acquisitions (including mergers) and 3 secondary sales. The exit rate calculation is relevant only as a comparison to the samples shown and is not representative of the sector. *Table 13* summarises the figures for both samples.

	No. of companies	Known exits				Exit rate (%)
		IPO	Acquisition	Second.	Total	
Industrial cleantech	62	6	4	-	10	16.13%
Software Services	56	-	7	3	9	16.07%

Table 13: Exit avenues and exit rate.

Duration

This sub-section will review the length of time in which companies have received VC funding support during their development lifetime. The results recorded the time taken from the first known VC funding event until known exit or an ongoing date for companies that had not yet exited (e.g. August 2019).[5] Duration shows how much time a VC has to wait until an exit has been reached which in some cases could mean potential substantial return.

The results for the known exit dates for industrial cleantech companies are shown below (*Table 14*). The data entry points labelled n/a, either did not have any recorded VC funding history or had gaps in data that prevented analysis. The highest duration of support in the industrial cleantech sample was *Company A*, that received its first VC funding date in February 2005 and exit event nearly 12 years later in January 2017. The lowest duration was for the *Company I*, which received its first VC funding in August 2011 and then exited 5.33 years later. The average exit duration across the 6 companies that had available data was 8.32 years.

Company	**First recorded VC funding date**	**Exit date 1**	**Exit duration 1 (years)**
A	Feb-05	Jan 2017	11.92
B	Aug-07	Sep 2018	11.08
C	Jun-09	Apr 2016	6.83
D	n/a	Jun 2015	n/a
E	Jun-08	May-15	6.92
F	n/a	Dec-04	n/a
G	Oct-10	Aug-18	7.83
H	n/a	Jan-14	n/a
I	Aug-11	Dec-16	5.33
J	n/a	Apr-14	n/a
			8.32 (av.)

Table 14: Exit duration for industrial cleantech companies based on data obtained.

The same analysis was undertaken for the software services data set (*Table 15*), yielding lower duration values. The highest duration for this data sample was 7.25 years for *Company EE.* The lowest duration was only 1 year for Company II. The average duration across the 8 companies was 4.56 years.

Company	**First recorded VC funding date**	**Exit date 1**	**Exit duration 1 (years)**
AA	Jan-10	Dec-16	6.92
BB	Jul-13	Apr-19	3.42
CC	Jun-12	Jul-18	6.08
DD	Sep-12	Jun-18	5.75
EE	Apr-12	Jul-19	7.25
FF	Aug-15	Oct-18	3.17
GG	n/a	Mar-19	n/a
HH	May-15	Apr-18	2.92

[5] The date at which the analysis was undertaken.

II	Aug-16	Aug-17	1.00
			4.56 (av.)

Table 15: Exit duration for software services companies based on data obtained.

4.2 Qualitative results

The following section presents the findings from the triangulation interviews obtained for the research. The findings were generated through semi-structured interviews with VC firms and one corporate investor. These interviews were positioned to strengthen and further understanding of the quantitative results discussed in the previous sections, in support of RQs 1 and 2. In particular, the input from industry pundits at this stage provided a mechanism *for discriminant validation* of the quantitative results and gave the opportunity for the author to explore and test additional areas of understanding. The interviews also allowed for a reflection on the trends found and, importantly, provided the likely *motives* behind these trends that was not possible to gain through quantitative analysis alone.

This section is broken down into themes. These themes mirror the aspects described in the quantitative results section (e.g. VC model characteristics) and also other areas discovered during the interview process. As mentioned previously, to ensure anonymity the respondents are referred to as interviewees 1-8.

4.2.1 **Overview**

To begin, this section will give an overview of the VC firms that were interviewed. As is summarised in *Table 16*, 4 of the 6 interview firms were specialist cleantech VCs (2 of which government backed), with the other 2 interviewees (corporate and traditional VC) having some exposure to cleantech or industrial based investments. Most firms doing business in this area had a broad encompassing definition in relation to cleantech with two exceptions, notably interviewee firm 3 focused on renewable energy generation and infrastructure and interviewee firm 2, that specifically included a carbon dioxide reduction requirement. Further, all firms interviewed were invested in the Nordic markets in some capacity, with all but one situation in the region. The stage of investment varied between early seed, right the way through to later-stage growth investment. Finally, the known assets under management ranged between 55.5m (USD) and USD 300 (USD).

Interviewee	**Firm Type**	**Assets under management (USD / m)**	**Market orientation**	**Investment stage**	**Sector focus**
Interviewee 1	Venture Capital	50-100	Sweden	Early	Cleantech (focus on carbon reduction)
Interviewee 2	Venture Capital	50-100	Sweden	Late Seed, A round	Cleantech (various)
Interviewee 3	Venture Capital	300+	Nordics, EU	Late seed, A round (0.5 – 5 million normal range)	Cleantech (renewable energy generation and infrastructure)

Interviewee 4	Venture Capital	n/a	EU, Nordics	5 to 10 million	Cleantech (various)
Interviewee 5	Venture Capital	n/a	Sweden	n/a	Traditional (but some history investing in cleantech)
Interviewee 6	Corporate Investor	n/a	Global	Early to mid	n/a

Table 16: Characteristics of VC firms and corporate investor interviewed.

Deal flow

The data described in the quantitative section related to a collection of companies that had proven value to investors and received various forms of external funding. A question related to the deal flow process was therefore posed to all interviewees to provide greater context to the sample evaluated in this study.

Most interviewees described both *active* and *passive* processes of deal selection. Active deal selection processes included online searches, attending cleantech fairs and email outreaches. Passive processes included receipt of inquiries of interest from companies without a formal prompt from the firm themselves. Reputation was cited as a key factor that influenced the balance of these deal flow processes, with well-known entities relying more on passive investment rather than active avenues (Interviewee 1, 2019; Interviewee 3, 2019). Interviewee 1 (2019), stated that ~90% of early-stage companies in Sweden had contacted them at some point in their early development given their position in the investment landscape.

Each of the interviewees was also asked to provide a ballpark figure on the total deal flow that they receive on an annual basis and how many of those deals they committed support to. Overall, the percentage of committed deals ranged from circa 0.3 % to 5.6%. A breakdown of the figures is shown in *Table 17* below.

Interviewee/firm	**Deal flow (annual)**	**Deals Committed**	**Circa conversion rate (%)**
Interviewee 1	88	5	5.6%
Interviewee 2	Several hundred	5 to 10	n/a
Interviewee 3	300	1 to 3	0.33% to 1%
Interviewee 4	1000	3	0.3%
Interviewee 5	n/a	1 in 100	1%

Table 17 Estimation of total deal flow vs. committed deals with supporting details for VC firms interviewed.

4.2.2 **VC Model for industrial cleantech**

This section presents the results from the interviews that mirrors the aspects of VC model discussed in the previous section, namely capital contribution (intensity), staging and syndication.

Capital contribution

All interviewees made clear that investment in cleantech and industrial cleantech was capital intensive, requiring greater investment over a longer time period before seeing revenue growth. However, this was often followed up with some dependencies. First, the *stage* of investment was understandably an influential factor, with different capital demands for early compared to later stage investments based on the company's level of development (Interviewee 2, 2019). Second, the *company-specific case* must always be considered with regards to capital needs, as every company will have slightly different requirements. In the case of industrial cleantech the need for high capital expenditure (capex) is often associated with the need for additional processes such as a pilot plant to manufacture and test the technology (Interviewee 2, 2019).

Staging

The interviewee's responses to questions related to staging were generally more widely spread. Interviewee 2 (2019) stated that it is difficult to say that capital is deployed differently for industrial cleantech, with some software services strategies, for example, also being just as costly. Although a noted difference cited related to the *control* or potential lack of control of costs for industrial investment, for example concerning the need for factories and proof by piloting (Interviewee 2, 2019). Another respondent stated that for some particularly heavy, capital intense projects they will utilise a strategy (reviewed every half year) that helps guide investment and ensure that there is sufficient capital reserve to provide the support the company needs (Interviewee 3, 2019). Moreover, the deployment of capital is also impacted by the size of the fund in question and the need to balance to meet certain objectives (Interviewee 2, 2019). For example, a smaller fund will not be able to be involved in high capex companies and projects as they do not have the resources to support the venture through multiple rounds of funding (Interviewee 2, 2019).

Interviewee 4 (2019), a later stage investor, provided further detail into the rationale behind the decision to invest capital over time, stating several general ways that VCs manage the process, such as performance targets and milestones and the option for convertible loans.[6] Interviewee 4 (2019) instead assuring that: "we're either in or not in", that some cash requirements are planned (e.g. aligned with expected growth) and sometimes the amount reinvested is purely related to the defaulted pro-rata[7] rate rather than any specific strategy. In the case where they have invested and the company's growth prospects have lowered it was generally considered favourable to follow the money to protect the investment (e.g. continue to invest), rather than pull out straight away (Interviewee 4, 2019).

Syndication

There was a range of views about co-investment across the different actors involved. Generally, syndication was considered very important and often a pre-requisite for involvement in industrial cleantech investment. Interviewee 6, a corporate investor, stated that VC involvement in a company is an important sign. They provide "proof of quality" in some respects or, conversely, signal that something is not good if they are looking to exit or are

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[6] A form of short-term debt that converts into equity, typically in conjunction with a future financing round

[7] In proportion to the investors existing equity stake

holding back further investment (Interviewee 6, 2019). Interviewee 6 (2019) also stated the value of the skills and expertise of the VCs involved as providing a stronger signal for value. Furthermore, it was noted that if joining in later rounds it is also important to see how the company has developed during the preceding period of syndication with regards to key attributes such as efficiency improvements and any key milestones that may have been expected (Interviewee 6, 2019).

Moreover, one of the common points discussed across most of the interviewees was the importance of *aligning motives* across the investors. With regards to VCs this may relate to the timing of the exit, with some investors pushing an earlier exit, with other investors wanting the company to grow further (Interviewee 4, 2019). With regards to corporate investors, it is pertinent as part of the due diligence process to differentiate whether their involvement is for *strategic* purposes (for example having greater control of the product or technology) rather than simply financial (Interviewee 2, 2019), and if there are any exclusivity orders or other agreements that may otherwise hinder the growth of the business (Interviewee 4, 2019). Specifically relating to industrial cleantech, it is important to know that syndicating partners have *sufficient funds* to carry the investment through multiple rounds and to avoid being stranded alone with later stage capital demands (Interviewee 1, 2019). Further, given the increased caution of industrial cleantech there is particular importance in getting the syndication partnerships set up "right" from the beginning (Interviewee 2, 2019), meaning the composition of investors is carefully considered from the outset.

The involvement of corporate investors in industrial cleantech also yielded additional results that were perceived to be an important precursor for success. The pronounced role of corporates was also recorded in the quantitative results that saw an increased representation of corporates compared to other investors involved. Interviewee 2 (2019), who ideally prefers at least 2 corporates involved in an investment, stated that when it comes to industrial cleantech it is "even more important" that you have corporate investors involved. Several reasons were cited for this. First, it is often more difficult for VCs to evaluate the validity of the technology, especially when it comes to material science and other technical areas (Interviewee 2, 2019), with corporates often adding this expertise. Second, corporate involvement is seen as a "stamp of trust", especially if they are committing money (Interviewee 2, 2019). Third, corporates bring "credibility" with their networks of potential customers and value provided in the previous points (Interviewee 4, 2019). Finally, corporates may end up acquiring the business thereby providing the necessary exit avenue (Interviewee 4, 2019).

Conversely to the above, Interviewee 3 (2019) stated that they did not want to enter into syndication where a corporate investor is included as it goes against their own strategy. Generally, they co-invest in about 25% of their investments (much lower than the average provided in this research) and prioritise practicality of the partnership over any particular technical expertise.

4.2.3 Exit and development expectations

Generally, there was no particular preference on exit avenue for industrial cleantech, with most of the interviewees stating that this was mostly decided on a case by case basis. Interviewee 4 (2019), the later stage investor, was the exception to this with a preference for strategic acquisitions. It was noted that IPOs for cleantech are generally rarer, as the companies tend to operate under a business-to-business (B2B) sales model and so generate less interest than internet or software-based businesses (Interviewee 4, 2019).

Interviewee 1 (2019), discussed general development timelines of 5 to 7 years, regarding estimated multipliers that fit this development horizon (e.g. the need for approx. 5 times return for the fund). Interviewee 3 (2019) in earlier days of their business considered 4 to 7 years as expected development timescales, but later re-adjusted this to 7 to 10, with 10 or more years not being uncommon. Interviewee 6 (2019), discussed the rationale behind the expectation horizons, specifically relating to the proximity of the company to market and the *structure of the value chain*. An example was expressed with reference to *qualification times* (e.g. the time taken to move material or product from one stage to the next) which can take a lot of time and includes a multi-step process involving: piloting, scale up of production, customer evaluation and adjustments, product acceptance and a repeat and scale up of production.

4.2.4 Factors influencing investment

This section presents the results that relate to key influencing factors in the decision-making process for industrial cleantech, to better understand the quantitative sample that was collected in this study and directly support RQ1. A number of themes emerged from the data during the analysis process. It has been chosen to group these into 6 working titles, as described below.

Business fundamentals

One common theme across all of the interviews was the requirement for a *traditional* assessment of the company relating to *business fundamentals*. Interviewee 2 (2019) for example, stated that “they do not look at cleantech differently to other investments” and rather look at them in terms of their business and the value attributes that are expected from that business. Similarly, Interviewee 4, states that the “business and economic outlook are most important”. Interviewee 1 (2019) listed some key requirements (of a wider list) that any investment must satisfy, including: scalability, attributes of the company’s team, the technology and other conventional performance drivers. Positive cash flows and EBITA[8] calculations fall into this assessment and were cited as one of the first steps of the decision-making process for interviewee 5 (2019).

Technology

Another prominent theme related to attributes of the *technology*. Interviewee 3 (2019), made several comments on this point first, stating that “in principal when you go into the heavy (industries) you really need to be confident that the technology is super” and ensure that the technology is the best in the market. Further, the technology is considered something that is under the control of the investors, with one of the guiding rules being that the prototypes have been running and are thoroughly tested (Interviewee 3, 2019). Interview 1 (2019) also states that they “look hard” at the technology, whether the idea is protected and how difficult or cumbersome it is to apply to existing market processes. Interviewee 6, (2019), built on the latter point emphasising the importance that early stage companies should be clearly “bolted on” to existing processes, meaning that a whole new facility and supply chain does not need to be financed which reduces the need for high capex expenditure. Further, it was stressed that any technology (at least from the perspective of this corporate investor) should be simple, possessing the ability to be presented in an understandable way and ideally avoiding high capex and complex processing steps (Interviewee 6, 2019).

[8] Earnings before interest, taxes, and amortization (EBITA) is a measure of company profitability used by investors.

Markets

Markets or market conditions was another common discussion point throughout. The relative maturity of the technology in relation to the prevailing market was considered very important (Interviewee 3, 2019). Interviewee 3 (2019) stressed this point by stating that they haven't failed on technology (selection), rather poor timing of the technology in the market. Investor 4 (2019) also discussed the importance of market, particularly in respect to industrial cleantech, stating a need to carefully evaluate where the company's key markets are how they are performing. An assessment of whether the market is undergoing any changes and if these changes allowed for scalability was also cited as one of the key factors of the initial deal selection process (Interviewee 1, 2019).

CAPEX

Overcoming high capex were another key talking point when discussing factors influencing investment. For industrial cleantech, this is linked to the need for pilot plant as previously mentioned. Interviewee 2 (2019), stated that it is "essential" for the company to have a good plan for overcoming some of the unattractive attributes of investing in them (e.g. high capex) notably on the piloting of the technology, which may need to be funded in differently. When asked to expand on this point, other (non-VC) avenues of funding were suggested including support through public money or corporate investors, which have in some cases financed pilot technologies (Interviewee 2, 2019). Related to this, Interviewee 1 (2019) cited that one of the reasons for industrial cleantech failure is that they run out of patient capital, even if they are not bad companies.

Government involvement

The reference to public involvement came up intermittently across the interviews. Given the acceptance that industrial cleantech companies are more capital intensive and take more time, it was mentioned that there is a need for state backed, *patient capital*. This capital source is especially needed in industrial areas to overcome likely "hiccups" and possible reworking of the development process (Interviewee 1, 2019). Similarly, more public support was called upon in a more structured way to overcome high capital needs of some projects (Interviewee 2, 2019). Soft or non-financial aspects of public involvement were also said to be extremely important for young companies in preparing them for later investment such as support with aspects such as control documents, financials, legal requirements, reporting and a well-formed board of directors (Interviewee 1, 2019).

Mandate of the VC firm

Finally, through the interview there were a few occasions where the mandate of the fund dictated the companies the VC fund was able to commit to. Interviewee 1 (2019), described and aspect of its mandate to only include companies that focus specifically on the reduction or potential reduction of carbon dioxide emissions. This was considered a "gatekeeper" criterion that guided which companies were selected and supported. There were also resemblances with regards to the longevity of the fund structure. Interviewee 1 (2019), fund spanned a 12-year period with the option to extend by 2 years. Interviewee 2 (2019), stated that they were an evergreen fund meaning the fund has an indefinite life and is not pressured to exit or close in a given amount of time. Similarly, Interviewee 4 (2019) firm is independent, giving them more autonomy on investment decisions, and Interview 5 (2019) had no supporting LP investors and rather sourced funding through preferential and ordinary (unlisted) shares.

5 Analysis and Discussion

The penultimate chapter brings together the findings obtained from both qualitative and quantitative sources as described in the previous sections. These findings will be used to address the RQs, leaving space to explore new insights where possible. This will follow with a revisit of the preliminary conceptual framework, a reflection on methodological choices and suggestions for future research.

5.1 Analysis of results - RQ1

This section combines analysis and discussion related to RQ1, derived from the results of the qualitative interviews only. Each of the themes identified in the results described in the previous section (4.2.4) will be revisited and expanded upon, followed by a direct address of RQ1 to conclude the section.

5.1.1 Business fundamentals

Specific criteria relating to environmental aspects were more seldom discussed as key factors for investment, suggesting that these considerations were more *secondary* within the decision-making process. Integrating environmental aspects into investment decision making processes is an inherently difficult task. One fundamental barrier for investors is being bound by fiduciary duties to meet two-dimensional obligations e.g. financial risk and return (Brandstetter and Lehner, 2015). Adding a third environmental component interferes with this two-dimensional dynamic meaning the investors must actively weigh all three elements which add complexity in the decision-making process. Only one of the VC interviewees incorporated both quantitative and qualitative assessment in relation to reduction or potential for the reduction of carbon dioxide emissions.

The focus and prominence of business fundamentals of the target company (e.g. financials, product, team, market) were not unexpected, given that the VCs interviewed were competitive investors on the market. The interviews evidenced that investment in industrial cleantech follows the same or comparable process to more traditional investments, confirming that business fundamentals are a key driving factor behind investment in these areas. Whilst it was not possible to obtain detailed information on the criteria evaluated in the triangulation interviews, it was evident from most respondents that this represented a first step when selecting prospective companies. This confirmation mirrors earlier literature that identified principle evaluation criteria in the VC decision making process including product attributes, market growth and size, team management and expected returns (Tyebjee and Bruno, 1984; Hall and Hofer, 1993). Industrial cleantech companies seeking investment must, therefore, meet these threshold criteria, in conjunction with (and likely above) their proposition of environmental improvement.

5.1.2 High Capex

There was little doubt that capital intensity was one of the primary barriers for investment in industrial cleantech and as such was a dominant factor influencing both initial selection of an investment and the management of the investment over time. This falls in line with literature that has highlighted capital intensity as a common characteristic of cleantech (Ghosh and Nanda, 2010). In the case of industrial cleantech, the financial demands associated with the pilot plant was frequently referred to in the interviews as an inhibiting factor. The *timing* and *magnitude* of these high capex activities are likely to be influential in whether or not VCs commit. If high capex is required during the early stages of company development this may discourage support for potentially disruptive technologies. This was also noted by Marcus et al. (2013)

who made the case that more investment is needed in early (explorative) stages as well as later commercialisation (exploitation) stages. This presents a dilemma for investors that want to take advantage of being early movers, as an early investment in these areas is likely to require significant investment commitment. Furthermore, respondents from the interview also cited that providing a plan to overcome this expenditure would be a positive signal for involvement. The exact details of this plan were not explored, although one interviewee discussed the need for *non-VC* sources of finance to support the process (e.g. government, corporates) suggesting limitations for VCs in supporting aspects of industrial cleantech development.

5.1.3 Market conditions

The prevailing and future market opportunities for industrial cleantech represent another important factor for industrial cleantech investment. The requirement for a market in which to sell the product or service is (of course) important for any new venture, however, there is a case that it is even more *sensitive* for industrial cleantech. First, there is a significantly higher downside risk given the higher demands of capital to support industrial cleantech investment, meaning more will be lost if the market does not align with the emergence of the technology. Second, the VC's ability to assess the risks associated with market growth is tested as many cleantech firms operate on the production side (e.g. B2B) of the economy, away from consumer-led signals and media attention (Cumming et al., 2016). Third, VCs investing in cleantech must extend market predictions further into the future given the technology will take longer to emerge given the longer development timescales. Finally, aside from technological maturity, the aspect of market acceptance was also discussed, suggesting this may also be influential in the successful maturation of industrial cleantech, a point also raised in by Marcus et al. (2013).

5.1.4 Technology

Ensuring that the technology was sound and market-leading was cited as a key factor impacting investment in cleantech. For similar reasons mentioned above, the extended capital and resources mean that any bet on a company's technology requires full commitment and confidence. Existing literature has discussed the pertinence of technical challenges and complexity in conjunction with cleantech in the form of higher technical risk (e.g. Cumming et al. 2016). However, the existence of technical complexity did not seem to be a significant concern the investors interviewed, even though this was described as a highly scutinised aspect of deal selection. It is likely therefore that each investor combines individual specialist expertise in evaluating technical complexity and operates under their technical tolerances to ensure confidence in any commitment and avoid technologies that are outside of these parameters. This point was specifically addressed by the corporate investor who stressed the importance of simplicity and the avoidance of additional complexity where possible. Additionally, the reference to *bolted on* technologies by one interviewee was significant, highlighting a preference for alignment of emerging innovation with existing incumbent processes, infrastructure and supply chains. As highlighted in the literature review, this process of complementary technological transitions has been recognised in the existing literature. In a study looking at the horticulture industry, Berkers and Geels (2011) for example, describe a process of *stepwise reconfiguration* where a transition pattern begins with the adoption of modular innovation that subsequently reconfigures the basic architecture by combining both new and old elements of technology.

5.1.5 Mandate of the VC firm

The mandate of the VC firm is undoubtedly a significant factor when investing in industrial cleantech. The results revealed that there were three distinguishing attributes to the VC mandate which facilitated investment in industrial cleantech. The first was an extension in the fund's longevity. Three interviewees attributed fund structures that exceeded 10 years, which included an *evergreen* fund that had an unrestricted lifetime. Whilst the *traditional* VC structure is commonly described as following a 10-year partnership, the reality is often far shorter, with years to exit averaging less than 5 years according to existing academic findings (see more on this in the next section). The second attribute related to autonomy in making investment decisions. Again, this was highlighted by three interviewees, with one explicitly identifying autonomy as a supporting factor for investing in cleantech. This ability to further particular goals in relation to social or environmental attributes has been described in the literature as an "additive objective" (Rubin, 2009). The final attribute relates to definitions of cleantech and the subsequent specialisation of the fund in question. The discursive nature of cleantech definitions was certainly reflected in the relatively wide interpretation of cleantech across each of the firm's mandate, with some exhibiting narrow focuses (e.g. carbon dioxide reduction potential) and others being relatively unrestricted in potential investment areas.

5.1.6 **Government involvement**

The topic of government involvement was a notable feature of the interview's responses. In the face of significant market barriers such as high capital expenditure, this perhaps was to be expected. This was especially likely given this research was focused on Nordic region countries, that have historically been active in support of VC markets and environmental agendas. The role of government featured in the results of this study in the form of government-backed VCs known as GVCs[9]. According to Grilli and Murtinu (2014) GVCs can be used to tackle low supply of private VC and help overcome the typical chicken-egg paradox characteristic of nascent-markets in which "…the deal flow is scarce because of a shortage of VC and, at the same time, VC is poorly developed because there are few potential viable targets."(p. 1524). One of the interviewees also discussed the role of soft-financing aspects in conjunction with GVC involvement, indicating that this is another important aspect of their role on top of the market interventions role described above.

5.1.7 **Addressing RQ1**

Drawing from the above analysis and qualitative results, this section attempts to directly respond to RQ1:

- *What are the key factors influencing VC investors when investing in industrial cleantech in the Nordic region?*

As identified in the problem definition of this study (Section 1.2), much of the foundational work on VC is based on the US context, and there are relatively few studies that have overlapped VC and the cleantech field. For this reason, there is value in this studies research for providing insight from the Nordic region when investing in this area. The findings highlighted a number of themes that reflect the challenges and considerations encountered by VC investors when evaluating prospective investments in industrial cleantech. For the most part, the factors identified corroborate with existing literature, as described in earlier sections of this study. For instance, the themes or key influencing factors connect to the literature that discusses processes of investment or deal selection (Section 2.4.2) which are addressed during the deal origination, screening and evaluation phases. Through exploring these factors, it was clear that each VC had their own multi-criteria process with varying preferences and priorities. The business case for investing in a prospective company was a key influencing factor.

[9] Two of the five VCs interviewed were government-backed

Considering agency theory, this supports the view that VCs *and* GVCs act as rational individuals trying to further their own development. Capital intensity and development timescales were also prominent influencing factors frequently referred to throughout the interviews, aligning with existing observations in cleantech literature (e.g. Ghosh and Nanda, 2010; Marcus et al. 2013; Gaddy et al. 2017). Concerning industrial cleantech the timing and magnitude of capital intense (high capex) activities was a notable aspect and a likely influential in the VCs decision to commit to an investment. This aspect of capital intensity has not been explicitly discussed in existing cleantech literature, providing nuance to discussions around this investment barrier.

Moreover, the importance of market (prevailing and future) was discussed, with some indication that this was a particularly sensitive aspect when investing in industrial cleantech given higher demands for capital (e.g. sunk costs) and longer development horizons. Again, this aspect did not consistently feature in the preceding literature yet remains a prominent consideration for the investors interviewed in this study. Technological complexity was a highly scutinised aspect of deal selection which required investor expertise to ensure that confidence was obtained from the selection of the technology. There was some evidence that this risk was managed by higher degrees of scrutiny in the decision-making process, expertise within the VC firms themselves and the reliance on other investment partners e.g. corporates (the latter point is discussed with RQ2). Regardless of the method for managing the risk, it was clear that the specific expertise of VC investment team was influential in decisions relating to technology. Finally, flexibility in the VC firm's mandate was also recognised as being an important aspect of investing in areas such as cleantech, with examples of the interviewee firms operating towards independent and evergreen structures. Given the development timescales and additional challenges associated with investment in industrial cleantech, these mandate adjustments are likely a pre-requisite for involvement in most investment opportunities within the sector.

5.2 Analysis of results – RQ2

This section will begin with an analysis of the results related to the VC model attributes, drawing from both quantitative and qualitative avenues of research. This will provide the reader with a basis for the more direct response to RQ2 that follows.

5.2.1 **Capital contribution**

This sub-section interprets attributes of the VC model related staging and supplements with analysis of total capital contributed and capital intensity across the period.

Staging

The quantitative data available relating to staging provided a high-level overview of the amount and frequency of capital deployed to each company across each of the samples. The most significant finding related to differences in the number of rounds between industrial cleantech and software services; only 25% of the industrial cleantech companies progressed further than the second round, in comparison to 46.2% for software services. Interpreting these results in isolation suggests that either the demand for capital from the industrial cleantech startup firms operates on a lower frequency (e.g. lower demand) or the VCs are more conservative with follow up investments (e.g. lower supply). The triangulation interviews provided some additional insight into the likely rationale behind the staging process for industrial cleantech including greater control of expenditure, strategic deployment for high capex investments and simply meeting the demands from the startup firm (e.g. accepting pro-rata rate). Together, these responses suggest that staging is case specific and in practice not necessarily being used in ways that existing literature has stated, for example, to overcome data asymmetries and controlling moral hazard (e.g. Gompers, 1995; Gompers and Lerner, 2001). Although it must be noted that the interview question relating to staging was more directed to differences between cleantech and traditional investments, rather than identifying specific processes.

Capital intensity

The results showing the total investment over the period for both the industrial cleantech and the software services data set show a clear upward trend. Both the sample sets, although representing different sample sizes, roughly mirror this upward trajectory. This is likely an indication of the overall VC activity in the region over the period, seeing as it also reflects the total VC activity that was presented in the literature review section (Section 2.1, Figure 2). When breaking the total amounts by each subsector, there was a clear weighting on manufacturing and advanced materials sub-sectors, which attracted the majority of the investment across the period. The chemicals sector attracted the least investment. The distribution of investment between the sectors indicates the relative deal flow in these areas. Although, it is noted that many technologies could be assigned to more than one category and therefore the final sub-sector numbers are only indicative.

The quantitative results that estimated capital intensity (Section 4.1.2) were unexpectedly lower for industrial cleantech in comparison to the software services sample. At first inspection, this goes against the precluding literature that indicated that cleantech sectors are significantly more capital intensive. Notably, the results of Gaddy et al. (2017) showed that over 4 times the amount of capital was needed for growth-stage investments for cleantech material and chemical processes in comparison to software services. Regarding the sample data in this study, the differences are likely to be due to relative maturity or stage of development of the company. The results relating to the estimated development stage (Section 4.1.1) partly confirm this, showing a greater number of industrial cleantech companies at seed stage in comparison to the software services sample. Marcus et al. (2013) also observed this trend in their study relating to early-stage clean energy investments, observing that "…VCs have done more clean energy deals at early stages but have feebly financed them" (p. 54). Investigating this further using the company founded date (Section 4.1.1), shows that both sample groups were of a similar age (e.g. year 2009 ± 6 months). Therefore, it can be said (at least for the sample evaluated) that the software services companies attracted more capital over a shorter period, which provides indicative evidence that they are developing at a faster rate than the industrial cleantech. It is also possible that the anticipated high capex activities associated with industrial cleantech companies had not yet been encountered or recorded in the data sampled.

5.2.2 Syndication

The picture of syndication through both avenues of analysis provided some insight into the motives behind the process. It was evident that one of the primary reasons for syndication by the VCs was to spread the risk of high capital burden and potential loss by pooling capital resources, as per findings in existing literature (Hogg, 2010). In this regard, ensuring that the syndicate partners were large enough to provide sufficient capital was deemed important and that they were aligned with the timing of the exit. In general, the involvement of syndication partners was considered standard to the investment process. This was reflected in the syndication rates which were over 80% for both samples (Section 4.1.3). Furthermore, these rates from a European context were markedly higher than those found in existing literature. According to survey results from Schwienbacher (2008)[10], mean syndication rates in Europe

[10] Total sample of the study was 171. 104 for EU (Belgium, France, Germany, the Netherlands, Sweden and the United Kingdom) and 67 from the US (Schwienbacher, 2008).

were 54%, whilst in the US it was much higher at 80%. It is difficult to pinpoint exactly why this is different to the results of this study alone. Either the rates have increased over time since the previous study, the samples gathered are misrepresentative of a wider trend or potentially, the Nordic region demonstrates a closer similarity to the syndication processes undertaken within the US.

Furthermore, the results provided valuable insight into the role of non-VC partners and why they are important for VCs in the syndication process. With regards to industrial cleantech, the role of *corporate investors* stood out as the second most active investor after VC. The presence of corporate contrasted markedly with the software services sample that showed only a 6.9% representation by this investor. The importance placed on corporates in conjunction with industrial cleantech was mirrored in the responses from the interviews. Most VCs saw corporates as a positive signal, with some seeing their presence as a pre-requisite for involvement. With regards to corporates and industrial cleantech in this study, there were two broad areas where VCs sought further confirmation, namely: *technical validation* (as corporates were said to at times possess a greater expertise in this area) and *support in commercialisation* (through networks, offering a customer base and acting as potential end acquirer of the business). This falls in line with VC literature that has described the process of gaining secondary opinions on an investment choice (e.g. Gompers and Lerner, 2001). Aside from corporates, the industrial cleantech sample highlighted other investors that were not present in the software services sample. Notably, the presence of institutional investors in the form of pension funds showed that there is *potential* for these investors to be involved in sectors that are considered high risk, such as the cleantech sample analysed in this study.

Finally, an outlier to the above was one of the VC funds that avoided corporate involvement and only syndicated in a quarter of its investments. This strategy is likely based on taking a high equity stake, that is less diluted by other investors, with the guarantee of a higher return. This firm was highly specialised in the renewables sector, so it is interpreted that this enables the company to take on greater risks through this strategy. It was also exhibited the largest known fund size from the small sample which would be needed to carry investments more independently through multiple stages of the development process.

5.2.3 Exits and duration

The results evaluating the exits provided some additional understanding of the exit environment for the samples evaluated in the Nordic region. One of the first aspects observed was the comparable number of exits across both the industrial cleantech and software services samples. This was an unanticipated result, that contradicts some background research that suggested that there are less favourable exit opportunities for cleantech (Ghosh and Nanda, 2010). Breaking down the results showed that more exits (6) were recorded through an IPO for industrial cleantech than any other exit avenue over the period sampled. The presence of an IPO exit avenue, in this case, may be providing the *incentive* for investing in these typically higher risk areas, a driver that has been discussed in previous literature (Bruton et al. 2005). This also suggests that VC skills in the region are being used to support young companies to reach a level of maturity and development that prepares them for institutional investment involvement.

All IPOs recorded were admitted through the Nasdaq First North stock exchange. Further investigation revealed that Nasdaq First North is regulated as a *multilateral trading facility* and thus does not have legal status as an EU-regulated market (Nasdaq n.d.). This means the exchange is subject to its own rules of trading and as a result, the risks of investment may be *higher* than on main markets that are regulated through the EU (Nasdaq n.d.). Revest and Sapio

(2013) study focused on the influence of alternative financial instruments in promoting growth and innovation based on the results from the UK's Alternative Investment Market (AIM). They find that whilst there is a positive impact on employee growth, this is not matched by superior growth in company value. Therefore, whilst the data from this study provides preliminary evidence that the IPO market is accessible for industrial cleantech, confirming the viability of this avenue within the region will require further research.

The results relating to the duration of time that a VC holds on to investments before exiting was also derived from the data. The industrial cleantech duration was significantly higher (8.32 years) than the software services sample (4.56 years) and highly pronounced when compared to the exit averages cited in the literature review that ranged between 2 and 5 years for non-cleantech focused data (e.g. Cumming and Johan 2010). This supports the earlier point raised in this section (5.2.1) that industrial cleantech is evidencing longer development timescales. These findings also complement the results provided by the triangulation interviews, with some interviewees citing support timescales of 5 to 10 years and over.

5.2.4 **Addressing RQ2**

Multiple stages of research were undertaken to build up to answering RQ2, including: an extant literature review of VC and cleantech literature, quantitative data analysis of two contrasting quantitative data sets, triangulation interviews industry practitioners and an analysis of these results (presented above). The discussion now seeks to bring these stages together to provide an informed and direct response to RQ2:

- *(RQ2) Is there potential for the VC model to be adjusted to enable more effective support of industrial cleantech development?*

The exploratory findings in this study provided preliminary evidence that VCs in the region have adjusted aspects of their operating model to accommodate the demands of industrial cleantech. The first adjustment involved the extension of support timescales for industrial cleantech companies in comparison to more traditional VC structures. This was evident in the duration data and was communicated in the triangulation interviews, with timescales of 5 to 10 years and over being cited. This shows that VCs have the potential for *greater patience* with their capital when investing in demanding areas such as industrial cleantech, a change that was also observed by Marcus et al. (2013) concerning clean energy investment. Adjustments to the time horizons will also impact the expectation of return from underlying investors, although it was outside the scope of this study to determine whether this ultimately resulted in a lower return profile. Second, VCs have the potential to influence the syndication process. As has been discussed in the previous sections the composition of co-investors is highly important and is used to overcome key challenges associated with investment in these areas, particularly with regards to high capital demands and technical complexity. The interviews with VCs confirmed that there are specific criteria that are considered before committing to an investment with others. The quantitative data for industrial cleantech also showed a distinct investor composition profile when compared to the software services sample. Third, the triangulation interviews (as discussed earlier) highlighted examples of structural adjustments to VC firm mandates including independency and evergreen structures, suggesting these changes provided more effective support for industrial cleantech. This is likely through greater autonomy in selecting and maintaining a commitment to cleantech investments and the reduction of exit pressure through the uncapped timescales of the evergreen structure. Lastly, the presence of an IPO exit avenue through a subsidiary exchange was observed within the quantitative data. Whilst this component does not directly link to changes to the VC model, it is a potential driver for investment in the region given IPO avenues has been shown to influence investor behaviour (e.g. Bruton et al. 2005).

Whilst the above does highlight some examples of some degree of adjustments, the potential for *radical* changes as called upon by Ghosh and Nanda (2010) faces fundamental barriers. As discussed in earlier sections of this work, the VC model is built to support high-risk ventures under the condition that a proportion generates enough return over a given period to meet the needs of their investors (LPs). This core aspect of the VC model will restrict investments in technologies or companies that do resemble a risk and return profile that is competitive in the market. In this way, the *bandwidth* for VC investment is always going to be capped to a certain range, and thus excluding some potentially impactful emerging ventures at either end of the spectrum. Moreover, the constraints placed on investors with regards to characteristics like capital intensity and long-term horizons mean that VC involvement is more likely to be taken on by specialised independent firms and government-backed VCs (e.g. the interviewees of this study), which are more able to make adaptions to their mandates that go against traditional market practice. Finally, given the pressures that VCs are under to generate a return, alternative investments in other sectors (e.g. software services) represent a constant opportunity cost for VC investment. As was shown by Gaddy et al. (2017) signs of underperformance in the cleantech sector prompted changes in investor behaviour by shifting cleantech investments to software and software appliances.

Additional to the above, a clearer picture has emerged during this research with regards to the role of government has in supporting VC investment in industrial cleantech. First, the most direct support would be in the form of subsidies, targeted at high capex aspects of industrial cleantech development, such as the pilot plant. As has been described, these high demands for capital are very difficult for most VC investors to account for, especially in earlier stages of development, therefore support in this area may provide the stimulus needed to draw in VC investment. A recent example of where government has supported cleantech through early stages of development is the Swedish biofuel company Renfuel. In 2013, the Swedish Energy Agency provided SEK 16m (~USD 1.6m) for technology verification, followed by SEK 71m (~USD 7.3m) in 2015 for a pilot project (Noden, 2018). This investment was made primarily to support national strategy related to cuts in transport emissions. Second, aside from direct subsidies from government, the continued presence of GVCs is important given they can influence investment in areas of low deal flow and where VC support is scarce such as cleantech. This indirect form of government intervention has also been shown to create a more favourable environment for private VCs in comparison to more aggressive approaches to intervention (Grilli and Murtinu 2014). Lastly, in relation to the environmental impacts of cleantech, the sector would benefit from *standardisation*. As discussed in the literature review, cleantech is a discursive sector and is therefore particularly prone to wide interpretation and thus would benefit from a more formal process of classification. In the area of standardisation there is a new regulation that was adopted by the European Commission in 2018, that outlines a classification framework or *taxonomy*. The taxonomy targets investors (including VC funds) who market a sustainable product to disclose and relate their investment to the taxonomy framework and use the tool to "enable capital markets to identify and respond to investment opportunities that contribute to environmental policy objectives."(European Commission, 2019a, p. 10).

5.3 Theoretical and methodological choices

This subsection builds on the conceptual framework presented earlier in the work and offers some reflections on the methodological choices, including limitations and generalisability of the results from this study.

5.3.1 Reflections on conceptual framework

The conceptual model presented in Section 2.5 was used to help explain the dynamic between VCs and startup firms to support the analysis of the results and discussion. This discussion revisits the framework, adding insight derived from the results and analysis of the study and offering further areas of theoretical consideration.

To recap, signaling theory was used to interpret actions such as funding events or other commitments as a potential signal mechanism for future value. It is held that the results of this study have provided valuable insight into the nature of the signal between the industrial cleantech companies and VC investors, particularly in terms of what signals VCs are looking for to prove value. The factors discussed in relation to RQ1 confirmed that VCs operate as rational individuals to further their own development through the prioritisation of business fundamentals, representing aspects that are controllable to the company (e.g. team composition, product) and those which are outside of control (e.g. market conditions). Another important signal specific to industrial cleantech companies is their ability to present awareness and provide a strategy around addressing high capex aspects of their development. This study has highlighted the particular importance of this factor within the decision-making process for industrial cleantech, therefore the business proposition would benefit from prioritising this point in any early exchanges of information. Moreover, the triangulation interviews confirmed that investments by other VC firms or other investors were key signals of value and in most cases supported the decision to invest. The signal of quality was also shown to differ depending on the type of investor involved particularly for corporate investors who provided a signal of credibility, support in commercialisation and technical validation.

There are also aspects of the theoretical assumptions that can be questioned with the strength of value signal between VC and startup firms. Firstly, the exchange of information from startup firm may not always be representative or accurate, as there is an incentive for startup firms to convey *positive* aspects of their development to secure future funding. This introduces the concept of *imperfect information exchange,* where data asymmetries are potentially inaccurately closed. Secondly, firms engaged in innovation tend to have a high percentage of intangible assets (Kerr and Nanda, 2014), for example in human capital, which brings in elements of subjectivity when evaluating value signals. Thirdly, there is no easy way to guarantee whether the financing round has met the development needs of the underlying startup firm, especially when you consider that each firm has different needs to enable development (Mazzucato, 2014). Therefore, there will be variations in signal strength that are difficult to measure.

As noted in Section 2.5, *agency theory* has been used to explain the relationship between VCs and the startup firm. The theory outlined a range of aspects associated with the formation of a relationship that helped explain the actions and the reasons behind the actions. The results of this study principally informed the actions of the VC. The notion of economic self-interest was confirmed as a key influential factor in the agency relationship between the VC and startup firms. This aspect is considered in the screening of investments and reduces the risks associated with adverse selection. The triangulation interviews provided some indication that VCs were *trusting* in their startup firms in the form of commitment and willingness to follow the money to protect the investment. The trusting behaviour of the VC was also found in a study by Christensen et al. (2009) largely observed between different rounds of investments. Lastly, it was evident in the results of this study that the deal selection process was heavily relied upon in controlling agency risks such as moral hazard and adverse selection. These risks were also shared through the mechanism of syndication.

Regarding key actors in addition to the three presented in the preliminary conceptual framework (e.g. VC firm, startup, investor), government and market should be incorporated into any subsequent expansion of the framework. Both of these actors were shown to have specific and influential roles in relation to industrial cleantech investment; *government* being required to help overcome common barriers for investment and *market* influencing the technological demand over time.

Supplementary to the above, *lock-in theory* supports an additional understanding of the framework and interpretation of the results osf this study. *Lock-in* arises when the adoption of a selected technology is subject to positive feedback loops or increasing returns (Arthur, 1994). As a result, incumbent technologies retain a distinct advantage over emerging technologies, not because they are necessarily better, but rather they are more widely used and accepted. Arthur (1994) provided 4 main explanations for increasing returns for adopted technologies: (1) scale economics (e.g. economies of scale where costs are spread across greater product volume); (2) economies of scope (e.g. cost advantages associated with widespread use of the technology); adaptive expectations (e.g. increasing adoption decreases technology uncertainty) and network effects (e.g. accrued advantages for using the same technologies as others). The prevailing conditions from incumbent regimes subject to lock-in processes favour incremental changes rather than radical, as large investment costs have already been made and small follow up investment is often considered enough to improve processes and products (Klitkou et al., 2015). Concerning this study, lock-in dynamics are likely to shape the type of technologies that are being created by startup firms, as well as influencing the decision-making process for VCs and their underlying investors. Specifically, this relates to the point raised in the triangulation interviews on *bolt-on* technologies, that offer the incremental changes that market actors in the form of incumbents are demanding. Alignment with incumbent locked-in technologies may also improve the value proposition for VC investors through lower the risk profile given there are clearer exit avenues and existing markets for the product.

5.3.2 Reflection on methodological choices

A research study is always subject to some form of limitations for which this project was not an exception. One of the limitations related to data availability. Given that startup firms are private entities the information that is made public is not consistent or standardised. The public data platforms showed this, often showing discrepancies in the information or missing data entirely. This was also an issue when seeking to understand the relative influence of each investor in relation to funding history. In all cases where syndication was involved, it was not possible to see the breakdown of the contribution by an investor. This was because only a total amount was shown per investment round rather than splitting the total across each of the investors. By reviewing other public sources (and confirmed in triangulation interviews) it became apparent that public availability of this information was seldom available and not easily attainable. This aspect has implications as to the validity of the results when making conclusions based solely on the influence of one investor. However, concerning this study given the focus was on VCs which were the dominant investor in most cases, this aspect would have been less impactful. Another limitation relates to the confidential nature of VC business practice. Concerning the decision-making processes, collecting data on the details of strategy and criteria evaluation is understandably inhibited given the risk of the VC sharing information that is valuable to competitors and reveals internal processes. Therefore, getting a close understanding of the investment process including its barriers will always be subject to shortcomings and may not represent practical applications occurring in the market.

6 Conclusions and recommendations

This final chapter provides a summary of the concluding remarks drawn from the findings, analysis and discussion. First a reflection on each of the research questions is provided with reference back to the aim and introduction of this project. This is followed by some recommendations for the industry practitioners and suggestions for further areas of research.

6.1.1 Concluding remarks

The research aimed to explore the role of VC financing in supporting the development of industrial cleantech innovation in the Nordic region. This research was pursued to better understand the challenges and constraints associated with an investment in this area and provide supporting research to industry practitioners active in this space. This aim was first explored through RQ1 which sought to identify the key factors influencing VCs when investing in heavy areas such as industrial cleantech. The results returned six themes that highlighted the main challenges and considerations encountered by VC investors when evaluating prospective investments in industrial cleantech. The themes identified covered business fundamentals, high capital expenditure (capex), market conditions, technology, the mandate of the VC firm, and government involvement. Most of the factors identified aligned with those highlighted in existing cleantech literature, with close references to capital intensity, technological complexity and extended development timescales. Within each of the factors identified, this study's findings added greater depth and detail such as the timing and magnitude of capital intense events, market conditions, technical expertise of VC professionals and government involvement. The results also connect to literature that discusses processes of investment or deal selection, providing some valuable insight into investment decision processes for cleantech in the Nordic region.

Concerning RQ2, the research sought evidence of whether there is *potential* for adjustments to be made to the VC model; in essence, to determine whether changes can be made to enable more effective support of industrial cleantech development. As discussed in the introduction to this study, the VC model for cleantech presents some significant challenges, with some scholars calling for a *radical* reworking of VC fund structures and terms (Ghosh and Nanda, 2010). When addressing this question, four elements of the VC model were identified and addressed, namely: capital contribution, syndication, exits and duration. The results obtained provided preliminary evidence that VCs in the region have already adjusted aspects of their operating model to accommodate the demands of industrial cleantech in comparison to more traditional approaches. These adjustments covered four main areas. First, the extended development timescales of industrial cleantech have led to *greater patience* by investors in this area, with expectations of return on capital being stretched above 5 years and at times beyond a 10-year horizon. Second, the role of syndication was a prominent feature of the results and offered an area for potential VC influence and adjustment, notably with the presence of corporate investors who provide *technical validation* and *support in commercialisation*. Third, triangulation interviews highlighted examples of structural adjustments to VC firm mandates; these including *independency* and *evergreen* structures. Lastly, whilst not a direct adjustment to the model the presence of an IPO exit avenue through Nasdaq First North was identified in the quantitative data.

Whilst there was evidence in the findings that adjustment had been made within the region by some specialist private and public actors, the application of the VC model still dictates that certain investments will be out of the scope if they exhibit risk and return profiles that are non-competitive in the market. In this way, the *bandwidth* for VC investment is capped to a certain range and may overlook potentially impactful technologies. The constraints highlighted in the

VC model have significant implications for supporting delivery of the high-level sustainability goals discussed in the introduction to the project. Specifically, whether the VC-backed startup landscape is the best-placed venue to deliver the far-reaching changes that are needed in industrial sectors. In response, there is a call for government action to provide further support for private VC actors when investing in these challenging industrial sectors. The discussion related to RQ2 highlighted some proposed changes, referring to direct subsidies, continued support through GVCs and regulation by standardising what is classified as sustainable for investment purposes.

6.1.2 Recommendation areas for industry practitioners

As was outlined at the outset of this project, the pursuit of research in this area was prompted by external industry practitioners. Accordingly, the author set out to construct a project to support the industry practitioners with future-oriented work in this space, whilst situating and furthering the research in the relevant academic fields. Overall, the outcomes provided valuable supporting background to industrial cleantech investment in the Nordic region. Through the engagement of a range of active investors, this research has highlighted key challenges and considerations relevant to any investor in this space. A summary of the recommendation areas, drawing from the findings of this research, are presented below.

Firstly, there are valuable insights as to the nature of the syndication process provided in both the quantitative and supporting qualitative elements of this study (Section 4.1 and 4.2). Based on the experience gained in this work, it is held at a minimum, that any future investment activity should include an evaluation of the syndicate partners in relation to the composition data presented in this study. The data provided shows companies that have reached some measure of maturity through attracting multiple rounds of funding; therefore, the syndicate structure can be considered part of this successful development. Secondly, the findings of this study highlight valuable aspects of corporate investment behaviour as mentioned in the previous section. If an investment is considered in industrial cleantech then the involvement of corporates in some capacity should be a key consideration and reviewed in terms of the potential value (e.g. technical expertise) and potential risks (e.g. misaligned motives). Thirdly, selecting cleantech startup technologies that have the potential to be *bolted-on* to existing processes, supply chains and infrastructure appear to offer advantages to corporate investors in the region. This advantage can be maximised if there is closer compatibility to existing incumbent processes, which lowers the cost and ease of integration. Establishing mechanisms that assist cleantech startups with this alignment process is recommended. Fourth, regarding historical investment activity in industrial cleantech, there should be a consideration of the size of the deal flow in these sub-sectors within the region. The exploratory findings from this work indicate that there is a low number of tangible product-based startup firms that have generated any substantial investment over the 11-year period, as shown by the sample size obtained in this study ($n<100$). Whilst this sample omits potential startup companies that have not been able to secure funding (e.g. the full deal flow spectrum), the low sample does indicate that deals that have attracted interest from existing investors have historically been infrequent.

6.1.3 Areas of further research

Given this research was exploratory, ample opportunities for further research were recorded, three of these are considered of immediate importance are presented here. First, as outlined in literature earlier in the study the sources of the VC finance are significant and influence VC behaviour and investment activities (e.g. Mayer et al. 2004). To explore this further in the context of industrial cleantech, further research could be directed at an assessment of the underlying investors (LPs) that are active in cleantech to understand expectations of return in this area and their relative influence on VC investment operations. This assessment would also provide more of an indication as to the capital resources that are aligned to cleantech, referencing back to the investment gap highlighted in the problem definition of this study (Section 1.2). Secondly, further research could look at the full spectrum of industrial cleantech firms, including those that had *not* been successful in attracting some form of VC investment. As was indicated earlier in the study these deals represent over 95% of the total deal flow (Section 4.2.). Understanding this piece of the puzzle could better highlight the barriers for investment in this area and provide a comparison to the more 'successful' companies that have already gained investment support. Such research could follow a case study approach that has been used in the field (e.g. Migendt et al. 2017), to gain access to deal flow data that is not public, coupled with supporting interviews to understand the motives behind the process. Thirdly, additional analysis could be undertaken to understand the *relative success* of the industrial cleantech companies within a given sample. As discussed in relation to the conceptual framework there is no easy way to guarantee whether the financing round has met the development needs of the underlying startup firm, given all financing needs are different. Some measure of success would be needed such as an evaluation of financial progress (e.g. internal rate of return, cash flows), as was demonstrated by Gaddy et al. (2017), or an external framework that evaluates technical readiness or relative maturity of technologies through their development cycles. This would provide greater clarity as to the financing conditions that supported these companies in reaching some measure of success. Finally, as has been discussed in earlier sections of this study industrial cleantech requires expertise for both the startup firm and the financiers that evaluate these investments. For this reason, further research could be directed at understanding the individual characteristics of entrepreneurs and financing professionals that operate in this area (e.g. academic backgrounds, connected to research institutions, industry experience). This further research would shed light on the pathways and institutional mechanisms that have supported technological development in this challenging area.

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7 Appendix

7.1 Literature review search criteria

Venture capital key search words in preliminary search:

"Venture capital"; "venture capital funding"; "venture capital structure"; "venture capital model"; "venture capital role"; "venture capital innovation"; "venture capital technology development"; "venture capital investment".

Venture capital key search words in follow up search:

"Venture capital staging"; "Venture capital syndication"; "Venture capital deployment of capital"; "Venture capital syndication"; "Venture capital exits"; "Venture capital duration"

Cleantech key search words:

"Cleantech investment"; "Cleantech venture capital"; "cleantech development"; "cleantech financing"; "cleantech factors development"; "cleantech innovation"; "investment in cleantech"; "factors effecting cleantech development"; "drivers of cleantech investment";

Cleantech and the Nordics key search words:

"Cleantech venture capital Nordic region"; "Cleantech Nordic region"; "Cleantech Nordic region"; "cleantech financing Nordics"; "cleantech financing Sweden"; "cleantech financing Finland"; "cleantech financing Denmark"; "cleantech financing Norway";

7.2 Triangulation interview questions

7.2.1 Questions to VCs

1. **Decision process and deal selection**

- What factors are considered in the screening process of cleantech investments?
- In general, how many cleantech deals do you receive as compared to deals you actually commit to?

2. **Capital deployment**

- Is capital deployed differently for cleantech investments compared to traditional? (e.g. total amount, number of rounds)

3. **Syndication**

- How important is the involvement of other investors (public, VCs, corporates) when committing to an investment in cleantech/industrial cleantech?
    - How does the involvement of other investors influence your investment decision process or your decision to commit to another company?

4. **Exits expectations**
- Is there a preferred exit for cleantech/ industrial investments?
- Are there altered expectations in terms of development and exit timescales for cleantech/industrial cleantech investments?

5. **Industrial cleantech expectations**
- What are the key factors considered when investing in heavier industrial sector cleantech such as manufacturing, materials and chemicals?

7.2.2 Questions to Corporates

1. **Role of Corporate investors in cleantech**
- What would you say is the role corporate engagement when investment in cleantech?
  - Generally, a leading role or less active co-investor? Or is this dependent on the investment?

2. **Syndication**
- How important is the presence of other investors notably VCs when committing to an investment in cleantech/industrial cleantech?
  - How does the involvement of VCs influence your investment decision process or your decision to get involved with a company?

3. **Development timescales**
- Are there altered expectations in terms of timescales and nature of development for cleantech/industrial cleantech investments?

4. **Industrial cleantech expectations**
- What are the key factors considered when investing in heavier industrial sector cleantech such as manufacturing, materials and chemicals?