Valley of Death for European Cleantech Startups

Multi-Case Study

Master Thesis

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Executive Summary

This thesis explores the strategies used by European cleantech startups to navigate the Valley of Death. This critical stage in the development of startups is characterised by a funding gap that hinders commercialisation efforts. Cleantech startups, however, with their focus on sustainable innovations addressing global issues such as climate change and energy transition, often experience a Valley of Death longer and deeper than other startups due to significant additional barriers in this phase. The additional barriers are high capital intensity, long development time, high technological risk, and ecosystem dependence. Thus, understanding how these startups overcome these barriers is crucial, given their potential to drive environmental and energy solutions. Therefore, this study seeks to uncover the strategies that allow cleantech startups to successfully navigate this challenging period. Through a multi-case study involving semi-structured interviews with eight cleantech startups and four investment stakeholders, the research seeks to identify the strategies used to navigate the Valley of Death. To ensure the strategies are grounded in a shared understanding, the timeline and barriers encountered by cleantech startups are first compared to the literature. This comparison is important because the timeline and barriers strongly influence the strategies that startups adopt. After establishing this foundation, the study then identifies the specific strategies used by cleantech startups to overcome these barriers.

The findings reveal that cleantech startups generally experience the onset of the Valley of Death around Technology Readiness Levels (TRL) 4-5. However, the exact timeline is highly dependent on the sector, market conditions, and type of technology being developed. Compared to other deeptech sectors, cleantech startups experience a delayed onset of the Valley of Death, largely due to the greater availability of government grants and strong public support that help mitigate early financial constraints. The Valley of Death typically ends around TRL 8, when startups begin to generate revenue and achieve financial independence.

In terms of barriers, the findings are strongly aligned with the existing literature, confirming the multifaceted nature of the challenges cleantech startups face. However, the interviews provide additional practical nuances that are less emphasised in the literature. For instance, while the literature touches on the limitations of grants, interviewees pointed out specific challenges such as grant application biases and restrictive conditions, the scarcity of skilled personnel was highlighted as a significant barrier to team-building, adding a practical layer to the more general discussions in the literature.

Another key difference is the strong emphasis placed on product-market fit by both startups and stakeholders during the interviews, which is underrepresented in the literature. Once startups progressed into the Valley of Death, tech risk appeared to diminish in importance, with startups shifting their focus to commercialisation and market challenges. These practical insights provide a deeper understanding of how cleantech startups navigate the VoD and highlight areas where existing research may need further exploration.

To overcome these barriers, European cleantech startups implement a combination of strategies that address both immediate financial constraints and the inherent risks of their ventures. The key strategies identified include non-dilutive funding, blended financing, alternative revenue streams, bootstrapping, investor engagement, deployment-led innovation, customer discovery, market demand signals, strate-

gic partnerships, consortia-building, semi-commercial deployment, and early commercialisation.

Non-dilutive funding, such as grants, plays a crucial role, particularly in the early and intermediate stages, allowing startups to retain ownership while advancing development. The reliance on non-dilutive funding is one of the distinguishing features of cleantech startups, as they often use grants extensively, even until late stages, due to high capital intensity and the regulatory support available for climate and sustainability solutions. This reliance sets them apart from startups in other sectors, which may not leverage grants to the same extent.

In terms of managing inherent risks, cleantech startups employ strategies such as deployment-led innovation, customer discovery, and strategic partnerships to validate technology, establish credibility, and demonstrate market fit. By engaging with investors and pursuing blended financing, cleantech ventures can reduce perceived risks and secure the capital needed for scaling. These strategies are most effective when integrated, providing both short-term solutions for bridging funding gaps and establishing a foundation for long-term stability.

While the strategies employed by cleantech startups to overcome the Valley of Death align broadly with general entrepreneurial practices, the reliance on government support and the nature of addressing urgent global issues such as climate change and sustainability distinguish cleantech ventures from other sectors.

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Contents

Nomenclature

Abbreviations

Abbreviation	Definition
VoD	Valley of Death
VC	Venture Capital
UNEP	United Nations Environment Programme
TRL	Technology Readiness Level
R&D	Research and Development
PoC	Proof of Concept
MVP	Minimum Viable Product
FOAK	First-of-a-Kind Plant
OPEX	Operational Expenses
LOI	Letter-of-Intent

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Introduction

Despite another period of record-breaking levels of greenhouse gas emissions and increasing temperatures, climate action has proven to be slow and often insufficient. Therefore, United Nations Environment Programme (2023) urgently calls for adequate climate action. A multifaceted approach is needed that includes policy reforms, societal transformations, and most importantly, technological innovation. Recent studies align with this view on the climate crisis and highlight a growing consensus that technological solutions will prove vital to address current climate challenges (Bianchini & Croce, 2022; Engel-Cox et al., 2022; Guzmán et al., 2023; Holzner & Wagner, 2022). These recent developments have led to the rise of 'Cleantech', offering technological solutions to environmental challenges (Shakeel, 2021).

To provide context, Pernick and Wilder (2007) state that "cleantech refers to any product, service, or process that delivers value using limited or zero nonrenewable resources and/or creates significantly less waste than conventional offerings." The sector is categorised into four main fields: energy, transportation, water, and materials, with sub-sectors such as energy efficiency, biofuels, and waste recycling (Cumming et al., 2016).

Driven by the increasing demand for climate-focused innovation, the cleantech sector has seen a rapid growth over the last decade. This is highlighted by the continuous growth of investments in cleantech. Global investments in clean technologies increased by 17% in 2023, reaching a historic high of 1.8 trillion US dollars (Tiseo, 2024). Nevertheless, significantly more investment will be needed in the upcoming years to meet global climate objectives. Although investments are projected to approach two trillion US dollars in 2024, these investments must nearly double by 2030 to limit global warming to 1.5 °C above pre-industrial levels and to achieve net zero emissions by 2050 (Tiseo, 2024).

Despite this growth, there is still a substantial gap between the capital that is available and the amount needed to sustain cleantech startups. The lack of required capital leads to a phase in which startups face significant difficulties in bridging the gap between a concept and a commercially viable product (Engel-Cox et al., 2022). This phase is generally characterised by a high risk of failure due to the depletion of financial resources before reaching profitability (Al-Shaikh & Siddiqui, 2021; Meijer et al., 2019; Mkhize, 2023; Otto, 2020). This difficult stage in the development journey is often encapsulated in the concept of 'the Valley of Death' (VoD). The concept of the Valley of Death is a widely discussed phenomenon and occurs in many sectors, however, cleantech startups face additional barri-

ers. Other barriers that further hinder the progress of these startups comprise technological, regulatory, and market barriers (Engel-Cox et al., 2022; Hartley & Medlock, 2017; Meijer et al., 2019; Yadav et al., 2006). More specifically, the startups have a capital-intensive nature and a long technology development, which often require significant investment sizes and lengthy timelines before any returns can be achieved (Bianchini & Croce, 2022; Cumming et al., 2016). Besides high technological risks (Duriaux et al., 2021; Romme et al., 2023), market entrance is considered to be challenging due to the disruptive nature of the technology (Shakeel & Juszczyk, 2019). These challenges add to the increased risk perception of investors (Bianchini & Croce, 2022). As a result, investors show investment reluctance, often favouring sectors with lower capital intensities and quicker returns (Chassot et al., 2014; Nanda & Ghosh, 2010; Polzin, 2017). This risk aversion is further exacerbated by the fact that cleantech products typically lack the immediate consumer appeal or visibility enjoyed by other high-tech innovations, limiting their ability to secure funding (Cumming et al., 2016). These combined factors complicate the financing opportunities for cleantech startups (Cumming et al., 2016; Polzin, 2017). Moreover, these complexities are further exacerbated by a lack of industry standards, consumer scepticism, and a scarcity of investors willing to commit to the long-term horizons required for cleantech ventures to reach maturity (Engel-Cox et al., 2022; Hegeman & Sørheim, 2021; Meijer et al., 2019; Muscio et al., 2023; Romme et al., 2023).

Although these barriers faced by cleantech startups are universal and global, the landscape in Europe presents additional barriers that further complicate their path to success (Botsari et al., 2019). One of the additional complexities of the European ecosystem is an even more financially constrained market. This is highlighted by the fact that Europe struggles to match the levels of venture capital investment seen in the United States, especially in sectors that require substantial initial investments and longer development times for technologies such as the cleantech sector (Cumming et al., 2016). In comparison to other leading markets, Europe is falling behind. This is illustrated by the fact that US tech startups are 40% more likely to have secured venture capital funding after five years than their European counterparts (Atomico, 2023). Another additional barrier is the fragmentation of the European market, with its diverse regulatory environments and varying levels of government support between countries; it further complicates the landscape for cleantech ventures (Botsari et al., 2019). This fragmentation contrasts sharply with the more unified investment strategies seen in the USA, where federal and state policies have been more aligned to support the growth of these sectors (Aernoudt, 2017).

The literature offers extensive discussions on the Valley of Death (VoD) across different sectors, highlighting critical areas such as funding challenges, the importance of regulatory frameworks, and the role of innovation ecosystems in supporting technology commercialisation (De Noronha et al., 2022; Engel-Cox et al., 2022; Harrer & Owen, 2022; Hegeman & Sørheim, 2021; Meijer et al., 2019; Muscio et al., 2023; Otto, 2020; Romme et al., 2023; Van Den Heuvel & Popp, 2022). Although there is a considerable amount of literature discussing these issues, there remains a lack of academic-based frameworks tailored specifically to the needs of European cleantech startups. Unlike other industries where established frameworks provide guidance, the cleantech sector lacks a framework to help startups navigate the unique barriers described above. This lack of structured support leaves many cleantech entrepreneurs navigating the Valley of Death on their own, often without the necessary tools or knowledge to overcome these hurdles.

Given these unique challenges, creating an adequate support framework for cleantech startups in Europe is urgently needed. This requires a comprehensive understanding of the entire ecosystem, encompassing all actors, barriers, drivers, and supporting elements specific to the region. A key missing component in this understanding is insight into the strategies deployed by the startups themselves. By first mapping the strategies used by European cleantech startups and clustering them through ex-

ploratory qualitative research, this research establishes a foundation for assessing their effectiveness. The next step will involve quantitative analysis to determine the success rates of these strategies. This will offer data-driven insights essential for developing a robust framework.

This research focuses on the initial phase of framework development by identifying and categorising these strategies. Given the scope and duration of the project, the study is limited to mapping strategies to lay the groundwork for further quantitative analysis. Ultimately, this will serve as a basis for future research aimed at building an Europe-focused support framework that enhances the ability of cleantech startups to successfully navigate the Valley of Death and contribute to mitigating the climate crisis.

This discussion leads us to the following research question:

Research Question

What strategies do European cleantech startups implement to overcome the barriers encountered in the Valley of Death?

This question aims to map the strategies the European cleantech sector employs to overcome the Valley of Death. To achieve this, the main research question is supplemented by three sub-questions designed to help answer the main question.

First, it is necessary to understand the timeline and barriers of the Valley of Death for cleantech startups, as the strategies are strongly anchored in the specific stage and to specific barriers. Although the literature discussed the timeline of the Valley of Death (see 2), the timeline is applied to the wider field of deeptech and therefore nuances and differences can occur with the sub-sector of cleantech. By mapping the stages of the Valley of Death and identifying when key barriers arise, the proposed strategies can be properly contextualised, as different barriers might emerge at distinct points within the VoD. Moreover, each stage may present unique opportunities that shape the strategies startups employ. This understanding helps establish a clearer view of how barriers evolve over time, which is crucial for tailoring strategies to overcome them effectively. Concerning the barriers, the literature extensively discusses the barriers occurring in the Valley of Death, specifically to the cleantech field, however, startups may experience nuances or variations compared to what the literature suggests. By identifying these potential differences, the research will highlight whether cleantech startups encounter unique or previously unexplored challenges. This is important because the nature of these barriers directly influences the strategies employed to overcome them. Thus, exploring the specific barriers cleantech startups face, and when they emerge, is key to understanding how these ventures navigate the VoD. This leads to the first sub-question:

Sub-Question 1

At what stages does the Valley of Death occur for European cleantech startups, and what barriers do they encounter?

The literature highlights that the primary barrier cleantech startups face is financial constraints, which makes the Valley of Death particularly challenging (Frank et al., 1996; Muscio et al., 2023). Additionally, the high-risk profile of cleantech ventures, driven by uncertainties related to the nature of cleantech and external barriers such as market adoption and regulatory environments, is another significant challenge these startups must navigate (Hartley & Medlock, 2017). Given these factors, the sub-questions are divided into two key elements: addressing the immediate financial constraints that pose acute chal-

lenges to survival and exploring how startups manage and de-risk their ventures to ensure long-term sustainability and growth.

The second sub-question specifically focuses on how cleantech startups manage acute financial constraints during the Valley of Death, looking at strategies such as bootstrapping, generating early revenue streams, and securing alternative funding sources. This is crucial for understanding how startups overcome the financial challenges that are central to their survival. By exploring how cleantech startups tackle these immediate financial constraints, this sub-question will help identify the crucial strategies they employ to navigate the most critical phases of the VoD and ensure their continued operation. Therefore, the second sub-question is:

Sub-Question 2

What strategies do European cleantech startups employ to address immediate financial constraints during the Valley of Death?

The third sub-question shifts focus to the broader issue of risk management, exploring how cleantech startups mitigate the inherent risks of their ventures. By addressing these risks, startups can ensure their long-term viability and growth beyond the immediate financial pressures. Together, these sub-questions cover the critical aspects of both immediate survival and long-term success by tackling the most pressing challenges faced by cleantech startups. The third sub-question is:

Sub-Question 3

What strategies do European cleantech startups use to manage the inherent risks of their ventures?

1.1. Research Gap

The previous discussion underscores a significant gap in the literature on the strategies of cleantech startups in Europe as they navigate the Valley of Death (VoD). Although academics have covered other elements of the ecosystem, there has been a limited coverage of the strategies that enable them to survive the VoD. Kräussl and Krause (2012) and Veugelers (2011) have highlighted the disparities in funding between Europe and the United States, but have not explored the specific strategies that startups use to overcome these funding challenges. Similarly, Gaddy et al. (2017) discusses the difficulties of securing venture capital but does not address the strategic responses of startups. Furthermore, while Engel-Cox et al. (2022) and Muscio et al. (2023) have examined the impacts of regulatory environments, market uncertainties, and technological complexities on the cleantech sector, they have not investigated how individual startups navigate these challenges through innovative practices and strategic pivots.

As noted by Dean et al. (2022), the existing literature on the VoD offers little guidance on how to overcome this gap. This highlights the need for new knowledge to improve current strategies. This gap is not merely a lack of insight into business practices, but a deeper absence of a framework for European cleantech startups to navigate the VoD effectively. The first step to creating such a framework is understanding the strategies currently employed by startups to overcome the VoD's challenges.

1.2. Relevance to Master's Program

This research on the strategies employed by European cleantech startups to overcome the ”Valley of Death” is highly relevant to the MSc Management of Technology (MOT) program. It aligns with the program’s focus on understanding how technological innovations can be effectively managed to achieve strategic goals in challenging environments. By exploring how cleantech startups navigate barriers such as financial constraints, regulatory challenges, and market fragmentation, the research creates a deeper understanding of managing technological innovations.

The study also examines strategic approaches that startups use to bridge the Valley of Death, which relates directly to key themes in the MOT program, such as innovation, entrepreneurship, and technology strategy. Insights from courses like ”Technology Strategy and Entrepreneurship” are applied, offering real-world examples of how startups can utilise strategies to overcome barriers in a fragmented and competitive market landscape.

The study’s use of qualitative research methods, including data collection and analysis techniques, showcases the use of the matters discussed in courses like ”Research Methods” and ”Preparation for Master Thesis.” By mapping strategies specific to the European cleantech sector, this research lays the groundwork for building a comprehensive support framework for technological ventures. This aligns with the program’s objective of fostering technology-driven growth and sustainability.

1.3. Thesis Outline

This thesis begins with the literature review (2), which seeks to define key themes such as ’Startup’ (2.2), ’Cleantech’ (2.3), ’Valley of Death’ (2.4), and ’Technology Readiness Levels’ (2.1). These definitions establish a common understanding of the subject matter. Furthermore, the literature review explores existing research on the cleantech sector and highlights the unique challenges faced by cleantech startups while navigating the Valley of Death (VoD), including high capital requirements, long development timelines, and market and regulatory barriers. This chapter also examines the European landscape, focusing on characteristics such as market fragmentation, diverse regulatory environments, and financial constraints that impact cleantech startups.

The methodology chapter (3) provides a comprehensive overview of the research design used in this study. It describes the qualitative research approach, emphasizing semi-structured interviews conducted with European cleantech startups and investment stakeholders to explore strategies for overcoming the VoD. The study employs a multiple-case approach, involving interviews with 8 cleantech startups and 4 investors, using purposive, snowball, and convenience sampling. Thematic analysis was applied to the interview transcripts to identify key challenges and strategies for overcoming the VoD.

Chapter 4 presents the results of the qualitative data analysis, offering an in-depth exploration of the Valley of Death timeline (4.1), the barriers faced by cleantech startups (4.1.2), and the strategies they use to navigate these challenges (4.2). The findings reveal that cleantech startups generally experience the onset of the VoD around Technology Readiness Levels (TRL) 4-5 and end around TRL 8 as they approach commercialisation. Key barriers identified include high capital intensity, long development times, team-building challenges, and investor reluctance. The strategies used by startups to navigate the VoD include non-dilutive funding, blended financing, alternative revenue streams, bootstrapping, and investor engagement, among others.

Following the presentation of results, the discussion chapter (5) synthesises the findings in relation to the existing literature and addresses the research questions. This chapter highlights that while many

strategies employed by cleantech startups align with general entrepreneurial practices, there are unique aspects to cleantech, such as heavy reliance on government grants and the challenges associated with addressing climate and sustainability issues. It also discusses the broader implications of these findings, emphasises the similarities and differences between cleantech and other sectors, and offers insights into the effectiveness of the identified strategies. Limitations of the research, including sample size and scope, are also discussed, with suggestions provided for areas of further investigation.

Finally, the conclusion chapter (6) synthesises the key research findings to answer the main research question, which centres on the strategies implemented by European cleantech startups to overcome barriers in the Valley of Death. The conclusion highlights the importance of combining short-term financial strategies, such as bootstrapping and grants, with long-term risk management strategies such as strategic partnerships and customer discovery. It also provides practical recommendations for stakeholders, including policymakers, investors, and startup founders, to effectively support cleantech ventures. Additionally, suggestions for future research are offered to further explore and refine strategies that support cleantech startups in achieving commercial success and sustainable growth.

The outline of the thesis follows the approach depicted in the Research Flow Diagram below (see Fig. 1.1). It begins with problem identification and review of the literature to establish a foundational understanding, proceeding through the research design, data collection, data analysis, and concluding with the presentation of results, discussion, and recommendations.

Figure 1.1: Research Flow Diagram

2

Literature Review

To provide meaningful insights into the timeline, challenges and strategies cleantech startups face, it is crucial first to establish clear definitions of key concepts such as 'Startup' (Section 2.2), 'Cleantech' (Section 2.3) and the 'Valley of Death' (2.4). Understanding these terms is essential because they frame the discussion and ensure that the analysis is grounded in a shared understanding of the subject matter. In addition, 'Technology Readiness Levels' (TRLs) will be discussed and defined as it is a vital tool for assessing the technology maturity throughout the paper (see Section 2.1).

Furthermore, an overview of the current state of the cleantech sector in Europe is provided to give context to the discussion and highlight the specific regional challenges that influence the trajectory of these startups (Section 2.6). By synthesising these themes from the literature, a conceptual framework is developed to offer insights into the barriers and drivers affecting cleantech startups in the Valley of Death (Section 2.8). This framework enables a structured comparison between the views of the literature and the interviewees on the challenges faced by cleantech startups. In Section 2.7, an overview of all key findings is presented.

2.1. Technology Readiness Level

Technology Readiness Level (TRL) offers a tool to assess the maturity of a technology, as it spans from fundamental research to full operational deployment (Mankins, 2009). The TRL scale, originally developed by NASA, spans from TRL1 to TRL9. Each level represents a different stage in the technology development cycle, which was further developed by Mankins (1995) by adding definitions to each level.

At TRL1, basic principles underlying the technology are observed, laying the foundation for applied research. Upon progression to TRL2, the concept of the technology and potential applications are formulated. TRL3 marks the stage where analytical and experimental efforts begin to validate the concept, with proof-of-concept tests carried out. This also marks the end of the research phase as seen in Fig. 2.1. As development continues, TRL4 involves validating components in a laboratory setting, where key technological elements are tested in a controlled environment. TRL5 continues by validating these components in a relevant environment, typically under conditions that simulate actual operational settings. TRL6 focuses on demonstrating a system or subsystem model or prototype in a relevant environment, often bridging the gap between laboratory testing and real-world application marking the

end of development demonstration (see Fig. 2.1). TRL7 involves demonstrating the prototype in an operational environment, such as a space mission for space technologies, where it operates under expected conditions. TRL8 sees the technology fully integrated and tested in its final form and intended operational environment. Finally, TRL9 signifies that the technology is mature, fully operational, and ready for production or deployment. The deployment phase encompasses TRL7 until TRL9, as shown in Fig. 2.1. (Mankins, 1995). Nowadays, this framework is widely used not only in aerospace but also across various industries. The tool is used to assess the risks associated with different technologies as investments are done (Moorhouse, 2002). An adapted TRL scale applied to sustainable technologies is shown below in Fig. 2.1.

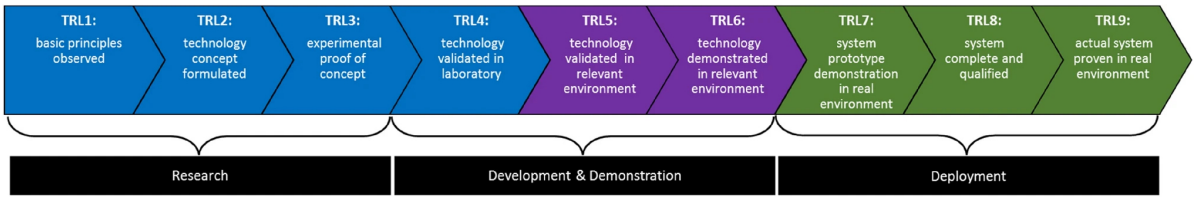

Figure 2.1: TRL scale (blue-laboratory environment; purple—relevant, i.e. simulated, environment; green-real environment) (White et al., 2022)

2.2. Startup

Startups are generally characterised by their innovation, potential for rapid growth, and ability to navigate uncertain environments. Ries (2011) defines a startup as "a human institution designed to create new products and services under conditions of extreme uncertainty", emphasising the inherent unpredictability and need for flexibility. Hernández-Cenzano and González (2017) describe a startup as a company with high growth potential due to its intensive use of technology, aiming to innovate in its products or services for customers. Similarly, Krejcí et al. (2015) highlight that startups are new and temporary companies with business models grounded in innovation and technology, possessing the potential for rapid growth and scalability.

Startups are also defined based on their lifespan, often considered a temporary phase. Steigertahl et al. (2018) specify that startups are companies established within the last 10 years, characterised by innovative technologies or business models. Cho and Mclean (2009) further define them as temporary organisations that create innovative products or services through high technology, often operating in risky and uncertain scenarios.

Pardo-del-Val et al. (2024) describes startups as young and innovative companies whose purpose is to achieve rapid and significant growth through a scalable business model. This aligns with Ehsan (2021), who defines startups as rapidly growing firms due to innovation in products, services, and processes, particularly facilitated by IT or ICT-enabled services. The startup status, as per Ehsan (2021), is also contingent on the age of incorporation according to each country's regulations.

Furthermore, startups typically operate in industries driven by technological or digital innovation. They adopt informal organisational structures with flat hierarchies and collaborative environments, with a key focus on rapid scalability. This is often fueled by external funding, such as venture capital, and the aim to either disrupt existing markets or create entirely new ones (Cockayne, 2019). The combination of innovation, agility, and a focus on high growth differentiates startups from traditional small businesses.

2.3. Cleantech

Cleantech represents an important sector within the global economy. The term 'Cleantech' dates back to the mid-1990s, emerging from North America's venture capital communities. It became widely recognised in the mainstream media and professional discourse in the early 2000s (Caprotti, 2012; O'Rourke, 2009). Multiple academic articles define cleantech, highlighting its growing importance. Shakeel (2021) view cleantech as innovative approaches that reduce the environmental impact by enhancing efficiency, minimising waste, and advocating the use of sustainable resources. Harrer and Owen (2022) refer to cleantech companies as "Cleantechs" and state that they are pioneering ventures that stand at the forefront of innovation by developing commercial products, services, and technologies to minimise environmental impact and foster a sustainable future. The EU (2020) offers a broad definition, encompassing any intervention that mitigates negative ecological effects, promotes environmental protection, or employs goods modified to be less energy or resource-intensive than industry standards (EU, 2020). Cleantech companies span across diverse sectors including renewable energy, energy efficiency, water management, and waste reduction, and are characterised by their commitment to reducing the reliance on non-renewable resources and producing significantly less waste than conventional businesses (Cumming et al., 2016; Giudici et al., 2017; Pernick & Wilder, 2007). However, Shakeel (2021) note that cleantech practices are not newly emerged; they represent a collection of technologies that have existed for years but have only recently been categorised under the umbrella term 'Cleantech'.

The cleantech sector's uniqueness lies in how it differentiates itself from other industrial sectors, this becomes apparent in several characteristics of the sector. The most influential characteristics of cleantech startups are the high capital intensity and long development times (Bianchini & Croce, 2022; Cumming et al., 2016; Harrer & Owen, 2022; Hegeman & Sørheim, 2021). These characteristics also specifically contribute to reduced investment opportunities (Polzin, 2017). Other factors are government dependence, public good, and disruptive nature.

The significant role the government plays by intervening via regulations, policies, and incentives designed to foster growth and innovation in the sector (Aagaard et al., 2021). Therefore, cleantech startups must navigate a complex landscape involving multiple stakeholders. Alongside private investors, governmental bodies, and others, these startups also need to consider international bodies of environmental policies and regulations, which pose additional challenges compared to more traditional technologies (Giudici et al., 2019). Cumming et al. (2016) and Shakeel (2021) state that this dependence is exacerbated by the disruptive nature.

Many cleantech develop and commercialise products with public good nature such as clean air, water, and reduced carbon emissions. As these technologies are difficult to monetise directly, this could lead to undervaluation by the market (Bianchini & Croce, 2022).

Most clean technologies are disruptive, introducing novel solutions to existing markets. This leads to the need for new systems and structures, making market acceptance difficult (Christensen et al., 2016; Shakeel, 2021; Woschke et al., 2017). Another result of the disruptive nature is that these ventures struggle to mobilise other essential resources such as human resources (Brown et al., 2007). On top of that, startups tend to lose sight of the functionality due to the inability to mobilise resources (Shakeel, 2021). Since only a small share of the market is willing to pay for the environmental benefits, functionality is key in successful commercialisation (Balachandra et al., 2010). Therefore, again, support mechanisms such as grants, incubators, and accelerator programs are essential for the survival of such startups (Sarzynski et al., 2012; Shakeel, 2021).

2.4. Valley of Death

The term ”Valley of Death” (VoD) was initially used to describe the difficulties in transferring agricultural technologies to developing countries (Merrifield, 1995). Later, the term was used to describe other innovation difficulties, specifically the resource gap between R&D laboratories or units and the commercialisation process within organisations (Branscomb & Auerswald, 2001; Markham, 2002). The concept refers to a critical phase in the early stages of science-based innovation, characterised by a lack of funding and support stalling the technology's progress. This concept, well documented across various disciplines, has been described in multiple ways, initially as “an inability to advance from a technology's demonstration phase through the commercialisation phase” by Frank et al. (1996). Other articles described it as ”the transition between invention and innovation” (Auerswald & Branscomb, 2003) or “the gap between the technical invention or market recognition of an idea and the efforts to commercialise it” (Markham, 2002). It is important to note that the VoD happens at an inflexion point where the research has not been concluded yet and the commercialisation of the technology is not yet in full effect (Ellwood et al., 2022). In Fig. 2.2 below, the VoD is schematically shown as a gap between existing research resources and existing commercialisation resources.

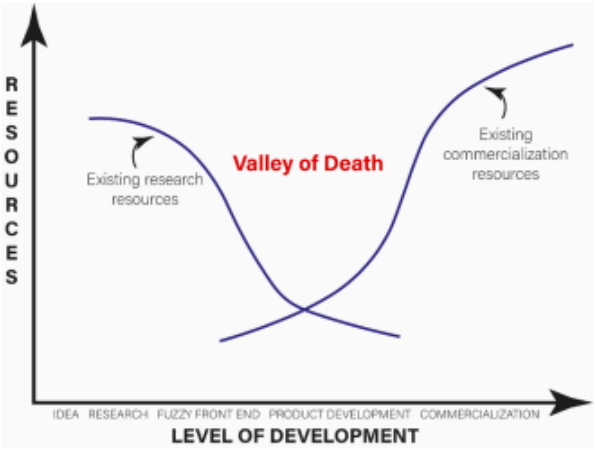

Figure 2.2: Valley of Death (Gbadegeshin et al., 2022)

It arises when a technology developer has proven the effectiveness of a particular technology but cannot secure financing for scaling up and manufacturing. The government typically views the technology as too advanced to continue funding as their focus is more on basic research. Meanwhile, the private sector is hesitant to invest because the technology has not yet been commercially implemented. (Frank et al., 1996) Published research typically describes the VoD as the transitional chasm between the initial research phases in academic institutions and the subsequent phases of product development by firms (Dean et al., 2022). Moreover, Frank et al. (1996) sees the VoD as a funding gap but adds that this lack of funding can be exacerbated by market, regulatory, and technological barriers. These additional barriers result in: ”scaring off potential buyers or venture capitalists and unnecessarily delaying commercialisation” (Frank et al., 1996). In contrast, Murphy and Edwards (2003) identified high risk as the main barrier to commercialisation.

2.5. Valley of Death for Cleantech

The VoD, characterised by a lack of sufficient funding, is a challenging period for all startups (Frank et al., 1996; Muscio et al., 2023). However, Cumming et al. (2016) point out that ”cleantech start-ups also tend to be more susceptible to the 'Valley of Death' than start-ups in other industries,” highlighting

a distinct vulnerability due to the innovative nature and scale of challenges in cleantech. This results in a VoD that is deeper and longer than regular startups (Romme et al., 2023).

This phenomenon can be explained by several unique characteristics of cleantech. As clean technology entrepreneurs, as numerous conventional entrepreneurs, often seek to partner with VCs to overcome this funding gap (Shakeel & Juszczyk, 2019), Harrer and Owen (2022) observe that cleantech investment usually remains too risky for private investors. This high-risk perception can be addressed to additional barriers cleantech startups face.

2.5.1. Unique Barriers

Compared to other startups that rely on external funding, cleantech startups face significant additional challenges that restrict their growth and ability to reach profitability to due to three different risks: technological risk, financial risk, and collaborative risk (Romme et al., 2023). First, the high technological risk contributes to a high perception of overall risk (de la Tour et al., 2017; Romme et al., 2023). Second, the financial risk comprises two factors, high capital intensity and long development time (Balachandra et al., 2010; Bianchini & Croce, 2022; Cumming et al., 2016; Hegeman & Sørheim, 2021; Powell et al., 2015), making cleantech ventures less attractive to venture capitalists due to the large investment sizes and the long return timelines (Gaddy et al., 2017). Furthermore, there are two external factors contributing to the longer and deeper VoD for cleantech specifically. These factors can be encapsulated under the concept of collaborative risk, a strong dependence on a collaborative innovation ecosystem, creating a risk if essential partners do not commit (Romme et al., 2023). The two different factors consist of the market and government dependence. Cleantech ventures present disruptive solutions to existing markets, resulting in difficult market entrance (Christensen et al., 2016; Shakeel, 2021; Woschke et al., 2017). Therefore, not only revenue generation is doubtful (Frank et al., 1996), investment in such ventures is also considered risky (Hartley & Medlock, 2017). The second part of collaborative risk relates to the strong dependence on government support. This dependence is established in two different manners, directly and indirectly. Cleantech startups offer disruptive technologies that are usually not price-competitive and experience significant market resistance, therefore, government policies and subsidies are vital to support these technologies and enable them to be competitive (Christensen et al., 2016; Woschke et al., 2017). Indirectly, all the aforementioned factors lead to investor reluctance which drives the funding gap characteristic to the VoD, which increases the dependence on alternative funding sources such as government support (Harrer & Owen, 2022).

2.5.2. Team

In addition, there is another important risk barrier relevant to the VoD of cleantech startups: the team-building risk. While team-building is not unique to cleantech (Romme et al., 2023), it is particularly critical in cleantech ventures, where founding teams need a diverse and complementary set of skills to manage the scientific and technological challenges of the industry (Paola Garrone & Mrkajic, 2017). Cleantech startups often require more specialised technical and work experience compared to other sectors such as Internet-based startups (Sawhney & Kahn, 2012). This need for complementary skills frequently forces cleantech entrepreneurs to look beyond their existing social networks to form teams with broader expertise (Ruef et al., 2003).

The team's quality is a key factor for investors, often outweighing other factors such as the technology itself when it comes to venture capital (Zacharakis & Meyer, 2000). A well-rounded team with technical, commercial, and legal expertise enhances the startup's chances of crossing the Valley of Death by securing funding and navigating complex challenges (Singh & Subrahmanya, 2023). Forming strong, complementary teams in cleantech helps mitigate risk perceptions for investors and improves the like-

lihood of obtaining the necessary capital to scale and succeed (Ye & Zheng, 2023). However, if the team is not well-rounded, it significantly increases the perceived risk of the venture, making it harder to secure investment (Zacharakis & Meyer, 2000). Since cleantech startups often struggle to form such teams due to the sector's complexity and the need for complementary skills (Paola Garrone & Mrkajic, 2017; Ruef et al., 2003), this presents an additional barrier (Romme et al., 2023).

In summary, Cumming et al. (2016) state that "Cleantech VC is more capital intensive, riskier, less likely to scale up, and more difficult to exit than VC investments in other risky industries like biotechnology or information technology". Due to the high risks, VCs prefer to invest in sectors less capital intensive or at later stages (Cumming et al., 2016). These high risks can be assigned to the five factors discussed above, as they contribute to a deeper and longer VoD unique to cleantech startups.

2.5.3. Timeline

Furthermore, the timeline of when the barriers occur is essential to give the necessary context to the barriers. Romme et al. (2023) provide a structured approach to understanding this gap through the lens of technology readiness levels (TRLs), identifying specific stages at which innovations are most vulnerable. The period between TRLs 2 and 3 is said to be the start of the chasm, and it ends at TRLs 7 or 8 (Romme et al., 2023). Venture capital firms invest primarily when startups have reached a TRL of 8 or higher to eliminate technology and market uncertainty (Romme et al., 2023). To close this gap and sustain innovations strategic support mechanisms are needed, underlined by Romme et al. (2023), who discuss the depth and duration of the VoD in deeptech ventures, where the beginning and complex nature of the innovations involved amplifies the risks. See below the adjusted VoD timeline for cleantech startups in Fig. 2.3. The figure illustrates the VoD for cleantech ventures, where startups struggle with funding between the demonstration and commercialisation stages. It highlights the role of government interventions and various sources of financial investments, such as grants, venture capital, and private equity, in helping the startups bridge the VoD.

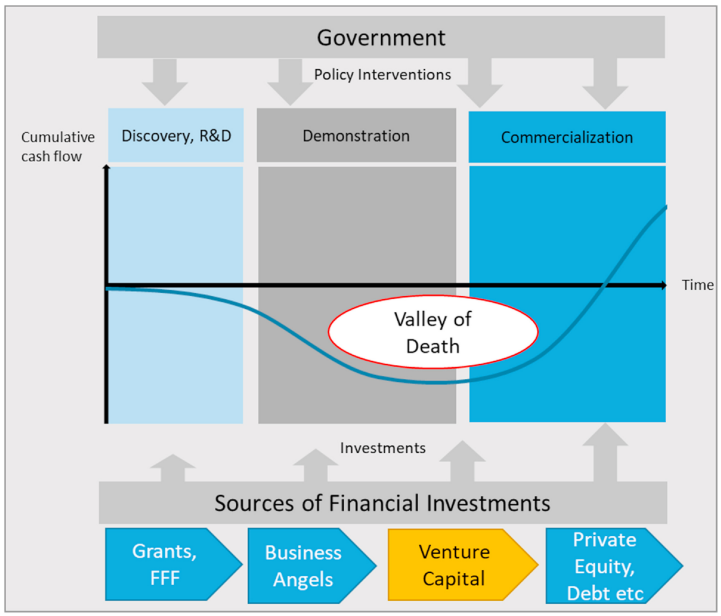

Figure 2.3: Valley of Death for Cleantech Startups (Hegeman & Sørheim, 2021)

2.6. State of Europe

In Europe, universities and research institutes produce an abundance of scientific breakthroughs and innovations, but many of these advances do not translate into societal solutions (Romme et al., 2023). This shows that Europe presents a fertile foundation for the growth of science-based ventures; however, the ecosystem fails to redeem the availability of talent and research. Europe's efforts to improve capacity in this area include programs such as entrepreneurial education, incentive schemes for entrepreneurs, the creation of technology transfer offices, and initiatives such as the European Scale-up Action for Risk Capital (ESCALAR) and InvestEU, which aim to bridge the investment gap and foster a conducive environment for deeptech and cleantech ventures (Baglieri et al., 2018; Ndou et al., 2018; Publications Office of the European Union, 2021; Quas et al., 2022; Román et al., 2013). Nevertheless, Romme et al. (2023) argue that these efforts have minimal results, further stating that the misuse of Silicon Valley as a benchmark has biased these initiatives. Thus, Europe faces a unique and complex challenge that requires long-term strategies and collaboration among various stakeholders (Romme et al., 2023). This complex problem can be further highlighted by comparing investment numbers with other ecosystems. Compared to the United States, which has long been recognised as a powerhouse in VC funding, particularly in Silicon Valley, Europe has struggled to match this level of investment (Cumming et al., 2016). The European Commission (2016) reported that the total amount of venture capital available to companies is significantly lower in Europe than in the USA, a disparity that extends in deeptech and cleantech.

Recent studies indicate that while Europe is making strides in early-stage financing for deeptech and cleantech startups, it falls behind the United States in financing (Romme et al., 2023). For example, European Innovation Council (2021) highlights that despite increasing investments in the sector, European deeptech ventures received only a fraction of the VC funding than their American counterparts did in recent years. This investment gap is particularly pronounced in deeptech and cleantech, where the need for extensive R&D and long time-to-market timelines exacerbate the financial barrier faced by startups (Duriaux et al., 2021; Kurowski, 2024). This is highlighted by the fact that US tech startups are 40% more likely to have secured venture capital funding after five years than their European counterparts (Atomico, 2023). Another study suggested that the global equity gap in Europe is double that in the US, and the funding gap in the early stages is five times greater (Kräussl & Krause, 2012; Veugelers, 2011).

Alongside the lack of financial resources, the fragmentation of the European market, with its diverse regulatory environments and varying levels of government support across countries, further complicates the landscape for VC investment in deeptech and cleantech (Botsari et al., 2019). This fragmentation contrasts sharply with the more unified and aggressive investment strategies observed in the USA, where federal and state policies have been more systematically aligned to support the growth of these sectors (Aernoudt, 2017).

In conclusion, European cleantech startups face unique additional challenges such as fragmented markets, lower VC availability, and complex regulatory environments (Aernoudt, 2017; Botsari et al., 2019; Cumming et al., 2016).

2.7. Overview Findings Literature

The following table summarises the key findings from the literature reviewed in this chapter, highlighting the characteristics of cleantech startups and their VoD (Table 2.1).

Table 2.1: Overview of Key Literature Findings

Focus Studies	Key Findings	Authors
Definition TRLs	TRLs measure technology maturity from initial concept (TRL1) to full-scale application (TRL9).	(Mankins, 1995, 2009; White et al., 2022)
Definition Startup	Startups are young, innovative companies focused on rapid growth, leveraging technology and external funding to develop new products or services under uncertain conditions. Startups typically aim for scalability within their first 10 years.	(Cho & Mclean, 2009; Ehsan, 2021; Hernández-Cenzano & González, 2017; Krejcí et al., 2015; Pardo-del-Val et al., 2024; Ries, 2011; Steigertahl et al., 2018)
Definition Cleantech	Cleantech aims to minimise environmental impact and promote sustainability across sectors like renewable energy and waste management.	(Caprotti, 2012; Cumming et al., 2016; EU, 2020; Giudici et al., 2017; Harrer & Owen, 2022; O'Rourke, 2009; Pernick & Wilder, 2007; Shakeel, 2021)
Unique Characteristics Cleantech	Unique characteristics are heavy reliance on government policies and incentives; commercialise public goods; disruptive nature; high capital intensity and long development times; and a critical dependence on raising customer awareness	(Aagaard et al., 2021; Bianchini & Croce, 2022; Brown et al., 2007; Christensen et al., 2016; Cumming et al., 2016; Giudici et al., 2019; Harrer & Owen, 2022; Hegeman & Sørheim, 2021; Polzin, 2017; Sarzynski et al., 2012; Shakeel, 2021; Shakeel & Juszczyk, 2019; Woschke et al., 2017)
Definition VoD	"Valley of Death" denotes a funding gap preventing technology from advancing from R&D to market readiness.	(Auerswald & Branscomb, 2003; Branscomb & Auerswald, 2001; Ellwood et al., 2022; Frank et al., 1996; Markham, 2002; Merrifield, 1995)
Barriers VoD	The VoD is marked by a funding gap exacerbated by market, regulatory, team-building and technological barriers.	(Dean et al., 2022; Frank et al., 1996; Mkhize, 2023; Muscio et al., 2023; Nemet et al., 2018; Romme et al., 2023)
Barriers Cleantech	The main barriers for cleantech startups in the VoD are technological, financial, collaborative, and team-building risks. More specifically, high capital intensity, long development times, technological complexity, dependency on a collaborative innovation ecosystem, and human capital barriers.	(Botsari et al., 2019; Cumming et al., 2016; de la Tour et al., 2017; Duriaux et al., 2021; Frank et al., 1996; Gaddy et al., 2017; Harrer & Owen, 2022; Hartley & Medlock, 2017; Kurowski, 2024; Muscio et al., 2023; Polzin, 2017; Romme et al., 2023)
Timeline	The VoD for deeptech startups typically occurs between TRLs 2 and 8.	(Romme et al., 2023)
Barriers Europe	European deeptech startups face lower VC availability, larger investment gaps, fragmented markets, and diverse regulations.	(Aernoudt, 2017; Botsari et al., 2019; Cumming et al., 2016; Duriaux et al., 2021; European Commission, 2016; Kräussl & Krause, 2012; Kurowski, 2024; Veugelers, 2011)

2.8. Conceptual Framework

As the literature review is completed and the key findings are summarised in Section 2.7, a conceptual framework can be constructed. The barriers, drivers, and dependencies are synthesised and illustrated in below in Fig. 2.4. A version with all relevant references can be found in Appendix A, Fig. A.1.

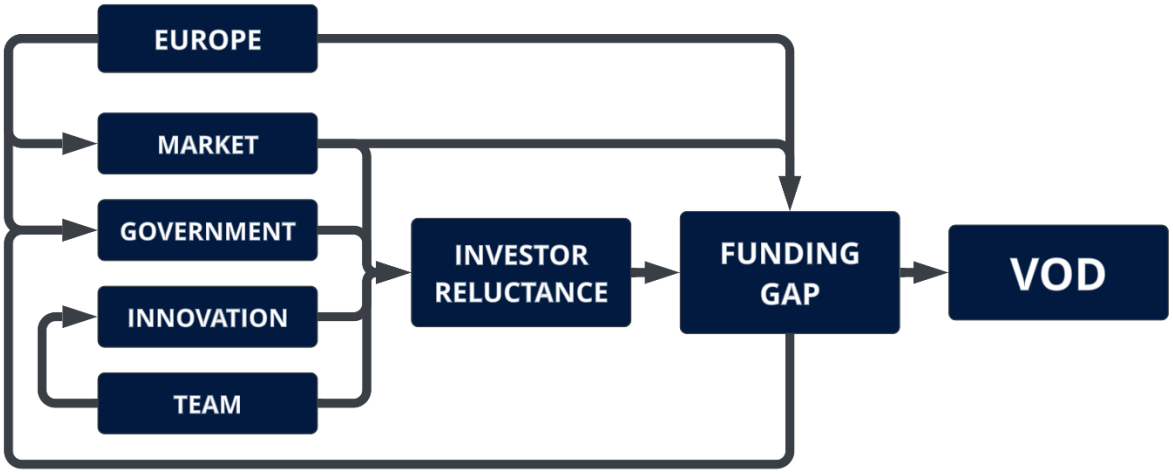

Figure 2.4: Conceptual Framework

The VoD is particularly challenging for cleantech startups due to six key barriers. The first three are high technological risk (de la Tour et al., 2017; Romme et al., 2023), high capital intensity (Balachandra et al., 2010; Bianchini & Croce, 2022; Cumming et al., 2016; Harrer & Owen, 2022; Hegeman & Sørheim, 2021; Powell et al., 2015), and long development time (Bianchini & Croce, 2022; Cumming et al., 2016) which are encapsulated under innovation risks. Furthermore, there are government dependence (Cumming et al., 2016; Sarzynski et al., 2012; Shakeel, 2021) and difficult market entry due to the disruptive nature of their technology (Hartley & Medlock, 2017). Lastly, team building risks present an important barrier, however, there are not exclusive to cleantech ventures (Romme et al., 2023).

Innovation barriers, including technological uncertainty, capital intensity, and long development cycles, make cleantech ventures particularly risky and increase investor reluctance (de la Tour et al., 2017; Gaddy et al., 2017; Harrer & Owen, 2022; Polzin, 2017; Romme et al., 2023). Furthermore, the introduction of novel disruptive technologies into established practices results in market resistance (Christensen et al., 2016; Shakeel, 2021; Woschke et al., 2017). This challenging market position exacerbates the funding gap indirectly by discouraging private investment (Hartley & Medlock, 2017) and directly by complicating revenue generation possibilities (Frank et al., 1996). Government support plays a critical role in mitigating these risks. Due to uncertainties in private funding, cleantech ventures become highly dependent on government grants and subsidies to survive (Cumming et al., 2016; Harrer & Owen, 2022; Sarzynski et al., 2012). However, this dependence adds further uncertainty, as fluctuating government policies can either de-risk or increase the perceived risk of cleantech ventures (Harrer & Owen, 2022; Hartley & Medlock, 2017). Inadequate government support worsens financial constraints, extending and deepening the VoD for cleantech startups (Frank et al., 1996; Muscio et al., 2023). Moreover, team building is a critical barrier, as its importance often outweighs the technology (Zacharakis & Meyer, 2000). The lack of a well-rounded team does not only cause investor reluctance (Zacharakis & Meyer, 2000) but it also hinders overall development of the startup (Singh & Subrahmanya, 2023). Despite the fact that barrier is not unique to the sector, the relevance is high and therefore included in the framework. On top of the barriers, the influence of the European context is

also added to the framework, where the fragmented market and regulations feed uncertainties regarding government support and market position. However, more importantly, the scarcity of funding drives the already existing funding gap (Botsari et al., 2019; Duriaux et al., 2021; Kurowski, 2024).

3

Methodology

This chapter describes the qualitative research methodology. This research employs semi-structured interviews to explore strategies used by European cleantech startups to navigate the VoD. The research design, participant selection, sampling strategy, data collection, and analysis techniques are discussed.

3.1. Research Design

This section outlines the methodological approach for this study, aimed at exploring the timeline, perceived barriers, and strategies. The study adopts a qualitative research design using semi-structured interviews to gather rich, descriptive data, offering direct insights into the experiences and perspectives of participants (Yin, 2009). This qualitative approach is particularly suited to this research because it allows for in-depth exploration of a relatively under-researched topic. Since these strategies are not well-documented in the existing literature, a qualitative method is essential for uncovering the diverse business practices in this context.

This research utilises a multiple-case study approach, as advocated by Eisenhardt (1989), to leverage the power of comparative analysis across different cases. Each case serves as a separate experiment that helps confirm or refute emerging patterns. This enables the development of a theoretical framework grounded in empirical evidence. Given the current lack of a strategic framework to support cleantech startups, this study serves as the first stepping stone in developing such a framework.

Mapping and categorising the strategies these startups use through qualitative research provides a foundation for understanding which strategies are being deployed and how they operate in practice. This is the first step towards building an evidence-based framework that can guide future research.

To achieve this, the study involves interviews with 8 cleantech startups in Europe currently in the VoD or beyond, as well as 4 investment stakeholders focusing on cleantech. Participants were selected based on their oversight of business operations, ensuring they could provide informed perspectives on strategic decisions, investments, regulations, and challenges. A similar approach was applied to investment stakeholders, selecting participants with key roles in overseeing the development and strategic management of cleantech startups in their portfolio. This multiple-case study method facilitates cross-case analysis to identify commonalities and differences. Ultimately, laying the groundwork for future research to build a support framework tailored to the unique needs of cleantech startups (Eisenhardt,

1989).

3.1.1. Selection Criteria Startups

The following four criteria are used to select the participants for this research.

- **Technology Sector**
- **Geographical Location**
- **Technology Readiness Level**
- **Position Participant**

Technology Sector

The first criterion for selection is the specific technology sector in which the startup operates, with a focus on cleantech. Focusing on the cleantech sector is essential because these companies face unique challenges, such as high capital intensity, long development time, and stringent regulations. By narrowing the scope to cleantech, the study aims to examine the barriers that influence the success and growth of startups and provide insights into the strategies that are employed to overcome them.

Technology Readiness Level (TRL)

The second criterion for selecting participant startups is the TRL. Startups with a TRL of at least 5 were chosen. This range indicates that the technologies are beyond the conceptual or prototyping stages. This criterion ensures that startups have progressed beyond the initial development phase and are at a stage where potential scalability and commercial viability can be assessed. Although one of the challenges in this study was the difficulty in finding companies that have already survived the VoD, interviewing those currently navigating this critical phase offers valuable insights. By selecting companies at TRL 5 or higher, the research captures real-time challenges and strategies these startups face while still within the VoD. This approach provides a unique opportunity to understand the dynamics of this challenging stage and gather firsthand perspectives on what factors may influence their success or failure.

Geographical Location

The third criterion for selecting cleantech startups is their geographical location. This focus is crucial to identify the unique barriers startups face in Europe, where the startup climate is generally more complex and challenging than in other ecosystems. European cleantech startups often face significant additional hurdles in their journey to profitability due to factors such as lack of funding and fragmented markets. By examining European startups, the study aims to understand the barriers these companies face in the European ecosystem. Moreover, the study seeks to uncover the strategies that startups employ to overcome the complex environment in Europe.

Position Participant

The fourth criterion for participant selection was the position of the participant within the company, specifically targeting individuals who possess comprehensive oversight of business operations. As it requires an in-depth understanding of various aspects such as investments, regulations, human resources, and day-to-day operations. Ideally, the participant should occupy the position of a CEO, co-founder, or senior executive who has an intimate knowledge of the company's operations. These positions can assess both the successes and challenges within the organisation, offering valuable insights into the strategic decisions that drive the business. By focusing on participants in such roles, the study aims to gather informed perspectives on the multifaceted nature of business management.

These criteria were designed to ensure a comprehensive understanding of the current landscape of cleantech startups. This is done by analysing startups that are not only technologically advanced but

also representative of the technology sector and regional characteristics. Moreover, the participant will be able to provide a complete overview of the startup's operations. This methodological approach aims to provide a detailed examination of how these selected companies navigate the challenges of the cleantech sector and leverage opportunities within their specific contexts.

3.1.2. Selection Criteria Investment Stakeholders

The following four criteria are used to select the investment stakeholders for this research.

- **Sector Focus**
- **Geographical Focus**
- **Engagement Stage**
- **Position Participant**

Sector Focus

The first criterion for selection is the sector focus of the investment stakeholders, particularly those focused on cleantech. Given the research's focus on cleantech startups, it is essential to include investors and supporters who specialise in this sector. Cleantech investments are often characterised by long return periods, high capital requirements, and significant regulatory hurdles. By selecting stakeholders who are familiar with these challenges, the study aims to understand the unique considerations that drive investment and support decisions in this sector.

Engagement Stage

The second criterion for selecting investment stakeholders is the stage at which they engage with startups. This research focuses on stakeholders involved in mid-to-late-stage engagements, as these phases are critical for startups transitioning through the VoD. Investors and partners at these stages provide the necessary capital, strategic guidance, and resources that can significantly influence a startup's ability to scale and achieve commercial viability. By selecting stakeholders involved in these engagement stages, the study aims to gain insights into how financial support, expertise, and collaboration contribute to overcoming the challenges associated with scaling cleantech innovations.

Regional Focus

The third criterion is the regional focus of the investment stakeholders, particularly those who invest in or support startups within Europe. Understanding the regional dynamics of investment or support is crucial, as the European climate is characterised by a lack of funding and fragmented markets, which can pose additional challenges for startups. By selecting stakeholders who are active in Europe, the study aims to provide a holistic view of the barriers that startups encounter and the strategies that are deployed.

Position Participant

The fourth criterion for participant selection is the role within the firm, with a preference for individuals who have experience in the cleantech sector. While senior executives such as partners or managing directors are ideal, the study also includes investment analysts and managers who possess a strong understanding of the challenges startups face. The key requirement is that the participant should be able to provide an informed overview of the barriers startups encounter and the strategies they employ to overcome them. This approach ensures that the insights gathered are well-rounded and focused on the strategies startups deploy to navigate challenges.

These criteria were designed to ensure that the research captures a comprehensive view of the investment landscape for cleantech startups. By selecting stakeholders who are strategically positioned in terms of engagement stage, regional focus, sector specialisation, and relevant experience, the study

aims to provide an complete overview of the barriers startups face and the strategies they employ to overcome them. The inclusion of perspectives from investment stakeholders ensures a holistic understanding of the challenges within the VoD and the strategies that are employed to navigate them.

3.1.3. Sampling Strategy

The sampling strategy for this study incorporates multiple methods to select 8 European cleantech startups and 4 investment stakeholders with a focus on Europe. The identification and approach of the participants happened in two different stages. In the initial stage, the recruitment of participants happened during the global technology event, HelloTomorrow, held annually in Paris. This prominent event serves as a gathering point for founders of various deeptech startups and a wide range of investors, facilitating a unique opportunity to recruit participants. The application of the event was utilised to filter with previously mentioned selection criteria (purposive sampling) and identify the right startups and investment stakeholders. Subsequently, the potential participants were approached at the event either at the stand (startups) or in the meeting areas of the event (investment stakeholders). The methodology aligns with the approach advocated by Aagaard et al. (2021), leveraging major events as fertile grounds for initial participant recruitment. In the second phase, startups meeting the specified criteria below were identified through portfolios of investment funds and Crunchbase. Consequently, these potential additional participants were approached through professional networking platforms such as LinkedIn. Moreover, additional participants were recruited through referrals of original participants. In total, 72 companies were approached of which 49 startups and 23 investment stakeholders. Of the 49 startups 15 responded leading to 8 successful interviews, and of the 23 investment stakeholders 13 responded leading to 4 successful interviews.

- **Purposive Sampling:** This method involves selecting startups that specifically meet pre-defined criteria aligned with the research objectives, as described above in the initial recruitment phase. This approach ensures that the participants are directly relevant to the research questions, providing focused insights into the challenges and strategies specific to cleantech startups.
- **Snowball Sampling:** In the second phase, the recruitment process expanded through referrals from original participants. This technique, where existing participants suggest additional potential participants, is characteristic of snowball sampling. Employed to leverage the networks of initial interviewees, this technique facilitated the identification of additional participants within the cleantech industry. As initial subjects recommend further contacts, this method helps in uncovering hidden layers within the sector and gaining access to a broader spectrum of experiences and perspectives, which might otherwise remain inaccessible.
- **Convenience Sampling:** The recruitment of participants at a specific event like HelloTomorrow suggests an element of convenience sampling, as the event provides easy access to a concentrated pool of relevant participants. HelloTomorrow, being a central hub for technology and innovation in Europe, provides a practical venue for conducting this research. Convenience sampling is utilised not only for its efficiency but also as a pragmatic solution to the difficulty of engaging startups, which may be limited by location and availability.

These sampling methods are designed to construct a robust dataset that captures a wide array of viewpoints and experiences within the European cleantech landscape, thus enhancing the depth and relevance of the study's findings. The combination of these strategies acknowledges the logistical challenges and leverages the opportunities presented by the proximity of Paris as a vibrant tech ecosystem. An overview of the participants with corresponding selection criteria is provided below in Tables 3.1 and 3.2.

Table 3.1: Overview of Startup Participants

Startup	Position	Background	Industry	Country	TRL
Startup 1	CMO	Business	Carbon Reduction	Eastern Europe	TRL6
Startup 2	Founder & CEO	Engineering	Renewable Energy	Netherlands	TRL8
Startup 3	Founder & CEO	Engineering	Sustainable Materials	Cyprus	TRL7
Startup 4	Co-founder & CEO	Business	Sustainable Foods	Netherlands	TRL7
Startup 5	Co-founder & Engineer	Engineering	Sustainable Construction	Netherlands	TRL8
Startup 6	Co-founder & CEO	Chemistry	Sustainable Materials	Malta	TRL7
Startup 7	Founder & CEO	Business	Sustainable Constructions	Poland	TRL8
Startup 8	Co-founder & CEO	Engineering	Renewable Energy	Netherlands	TRL5

Table 3.2: Overview of Investment Stakeholder Participants

Stakeholder	Position	Background	Focus	Type of Fund
Stakeholder 1	Head	Business & Engineering	Greentech	VC Initiative
Stakeholder 2	General Partner	Business & Engineering	Deeptech	Family Office
Stakeholder 3	Associate	Business & Engineering	Deeptech	Venture Capital
Stakeholder 4	Manager Deeptech	Engineering	Greentech	Impact Fund

3.1.4. Interview Script

This interview script was developed in several steps to ensure clarity, purpose, and engagement. This included the literature review discussed in Chapter 2 to ensure a comprehensive understanding of the current state of knowledge in the field. This step was crucial for identifying important elements and gaps in existing research, to be able to craft the questions that not only align with established findings but also build upon them to explore new insights. The script was tested in a trial interview, which helped refine the questions to ensure respondents understood them clearly. The main findings from the trial were that participants were keen to discuss the topic. However, the discussion could be significantly influenced by the way questions are phrased or by providing specific examples of potential challenges, thereby guiding the conversation in a particular direction. So, it became evident that questions should be framed in an open-ended manner without framing. Moreover, despite the willingness of participants to discuss the matter, they were initially reluctant to speak openly about investors or to address challenges. However, as they began to share about their company, technology, and experiences, they gradually became more forthcoming and comfortable, eventually revealing more in-depth insights. Having an opening introduction and a short chat was very helpful in establishing rapport and easing them into

the conversation. Another key insight was that questions should focus on one particular aspect of their business or strategy at a time. This approach, informed by the trial interviews, encouraged respondents to provide detailed answers about specific challenges and strategies rather than speaking in broad, general terms. The interview was continuously reviewed to ensure increasingly more insight in the interviews to come. The interview script is presented in Appendix B.1.

3.2. Data Collection

The data collection method for this research involves conducting semi-structured interviews, which allows for flexibility in discussing complex and nuanced aspects of the challenges and the strategies deployed by cleantech startups in the European context (Adeoye□Olatunde & Olenik, 2021). Moreover, this method is known to be particularly effective in uncovering detailed insights into the specific challenges faced by startups, thus improving the understanding of the unique dynamics of the sector (Kallio et al., 2016). Each interview was designed to last approximately 20-30 minutes and was conducted remotely using the MS Teams video conferencing tool due to the geographical spread of the startups. Based on the participants, the interview was conducted in Dutch or English.

The interview questions align with the sub-questions of the study, focusing on the challenges and the strategies of cleantech startups. These interviews are designed to provide insights into the experiences and challenges the startups face navigating the VoD. An interview guide is designed with open-ended questions to facilitate rich discussions on subjects like their experiences in the VoD, the various strategies for overcoming early-stage challenges, and the role of external support systems and networks in business progression.

Before the interview, a consent form is sent to participants for their review and signature. At the beginning of the interview, participants are asked if they have any questions and whether the consent form has been signed. Once their consent is confirmed, the interview commences, and the recording is initiated.

The interview begins by kindly asking the participant to introduce themselves, their role, and the company they work for. Following this brief introduction, the first part of the interview focuses on discussing the challenges encountered by the participant and their company. Both the timeline of these challenges and each challenge in detail are explored.

Once the challenges have been thoroughly discussed, the interview transitions to the second part, where the strategies employed to overcome these challenges are examined. In some instances, a specific challenge and its corresponding strategy may be discussed together before moving on to the next set of challenges and strategies.

After all prominent challenges and strategies have been addressed, the participant is invited to contribute any additional insights they perceive as valuable. This could include topics that may extend beyond the original scope of the interview.

3.2.1. Ethical Considerations & Data Management

The study was ethically approved by the TU Delft Human Research Ethics Committee. As mentioned previously, participants are informed about the study's scope, their rights, data management, and privacy. All interviews are conducted with consent obtained before conducting interviews. The Informed Consent Form can be found in Appendix A. The transcripts are not part of the public Appendix, to ensure compliance with data protection.

3.3. Data Analysis

Thematic analysis is used to examine the 12 interview transcripts, where the data will be methodically coded to identify prevalent themes and patterns that align with the research questions. Each transcript, resulting from interviews ranging between 15 and 60 minutes, was analysed using Microsoft Excel. This analytical approach aims to construct a detailed portrayal of the challenges and strategies cleantech startups face.

The coding process began with the segmentation of the data, separating quantitative and qualitative data. Although limited quantitative data was collected, it was systematically gathered and structured, as detailed in the previous section. Data on the technology sector, TRL, geographical location, and participant position were collected to ensure that the selection criteria were met.

For the second phase of the data analysis, the qualitative data was analysed. As mentioned previously, the transcripts were thematically analysed. The start of the coding process is extracting raw codes from the transcripts that are relevant to the research. Thus, the generation of initial codes stemmed directly from the data, followed by grouping the raw codes in code groups. Then an organised search for themes will be done. Stemming from the literature review, several themes emerged as main challenges for cleantech startups are addressed in the literature. Subsequently, these identified themes will then be reviewed and refined to ensure they accurately reflect the collected data points and are relevant to the research questions, thereby enhancing the robustness of the findings. The themes are paramount for both the challenges and strategies and the code groups will classified accordingly.

The themes emerged from both the literature and the transcripts, providing clarity on the timeline, barriers but predominantly, the strategies. The timeline of the VoD, as revealed by the analysis, will be examined and compared with existing literature, contributing to a comprehesive understanding of the timeline. Furthermore, the identified challenges will be compared with the literature to determine whether there is overlap, differences, or additional insights. From this comparative analysis, a conclusion will be drawn regarding the alignment or divergence between the timeline and barriers identified in this study and those documented in the literature. This will provide the necessary context for discussing the strategies.

Subsequently, the strategies employed by the startups will be discussed, highlighting commonalities and differences in approaches suggested by both sets of stakeholders. Finally, the strategies will be synthesised and examined, leading to a comprehensive conclusion that encapsulates the findings of the study.

4

Results

Understanding the journey of cleantech startups through the Valley of Death (VoD) requires a comprehensive analysis of both the challenges they face and the strategies they employ to overcome these challenges. This chapter is structured to first discuss the timeline and barriers, followed by the strategies implemented by startups.

The first part of this chapter (Section 4.1.1) focuses on mapping the timeline of the VoD and identifying the barriers experienced by cleantech startups and investment stakeholders. While the literature provides an overview of a typical timeline and barriers faced by startups, it is crucial to verify if these align with the actual experiences of the startups and stakeholders interviewed. Understanding when and why these barriers occur is essential for accurately assessing the strategies adopted by startups, as these strategies are strongly anchored in the specific stage of development and tailored to address particular barriers.

After establishing the timeline and barriers, the second part (Section 4.2) delves into the strategies that cleantech startups use to navigate these challenges. The strategies are divided into two main elements based on both the interviewees' perspectives and the literature: addressing immediate financial constraints and de-risking the business. Addressing financial constraints involves securing funding through various creative methods, while de-risking focuses on enhancing market appeal, validating technology, and ensuring a well-rounded team. Together, these sections provide a complete picture of the obstacles faced by cleantech startups and the strategies they employ to achieve short-term and long-term success.

4.1. Timeline & Barriers

Mapping the VoD timeline and barriers is essential for this research as it provides a detailed understanding of when and why cleantech startups face their most critical barriers. Identifying the specific stages where the VoD begins and ends, along with the associated barriers, highlights the phases where startups are most vulnerable and where targeted interventions are most necessary. This mapping sets the context for the subsequent discussion, as both the barriers and the strategies are closely tied to the particular development stages and barriers encountered.

4.1.1. Timeline

In this subsection, the timeline of when the most significant barriers begin and end, as perceived by both startups and investment stakeholders, will be identified. This section will highlight the specific points at which these barriers emerge and subside, mapped against the relevant stages of Technology Readiness Levels (TRL). These insights provide a timeline for the VoD, offering a clearer understanding of when cleantech startups are most vulnerable and in need of support from both perspectives. In the section several interviewees will be quoted, additional supporting quotes can be found in the appendix (See App. C.1.1).

The overall consensus from both startups and investment stakeholders is that the VoD typically begins when startups transition from early-stage development and validation to larger-scale commercial operations. Startups generally place the onset of the VoD around TRL4, during the seed stage, where funding needs increase significantly, and investor hesitation becomes a major barrier. As one startup founder noted:

> *"It is primarily the seed round that is difficult, especially in the Netherlands, but also more broadly in Europe, where they want you to have shown a lot already. And as I just mentioned, it is relatively capital-intensive. So you have to be very careful about what you do and don't do." (Startup 04)*

Investment stakeholders, however, tend to see the VoD starting slightly later, around TRL5, where companies have moved beyond lab-scale validation but have not yet achieved a profitable, at-scale product. One investment stakeholder explained:

> *"The Valley of Death is real. From my perspective, there's a good availability of early-stage funding. Then there's a lot of private equity and infrastructure capital for kind of really established technologies but it's that middle where you don't yet have a profitable at-scale product, but you're also out of the kind of lab scale. That stage is the hardest to fund." (Investment Stakeholder 01)*

Despite this general agreement, there are several additional views on the timeline that differ significantly from the aforementioned consensus. A startup in conservative industries such as construction experienced the VoD as early as TRL1, due to the challenges of introducing disruptive solutions to an already established market. As one startup founder in the construction industry pointed out:

> *"We had to overcome many obstacles, not even going from TRL3 to whatever, even from the inception, from the very beginning." (Startup 07)*

For another startup, the VoD does not emerge until the scaling phase, particularly during the transition from small-scale to large-scale operations, around TRL6 to 7. This challenge is highlighted by one startup founder who noted:

> *"Actually, it's starting now [the Valley of Death], the hardest part is going from small scale to large scale. You always encounter scale-up problems. I think that's really a pain point for many companies as well." (Startup 05)*

An investment stakeholder described a "double VoD," with an initial phase occurring early in the innovation process (TRL2 to 4), when startups struggle to secure their first round of funding, and a second phase occurring just before achieving product-market fit (TRL6 to 7). As the stakeholder explained:

> *"The first one is in the very early phase, just out of a university or research centre with a new technology until you can raise the first funding. There is a large Valley of Death there and the other one is just before the product-market fit piece on the chart." (Investment Stakeholder 03)*

Another stakeholder specialising in first-of-a-kind (FOAK) plants emphasised that the VoD is particularly pronounced between the demonstration plant stage (TRL6-7) and the first commercial-scale plant (TRL8), where capital requirements dramatically increase:

> *"Where it gets really tricky is to go from that plant, so from that installation to a commercial first-of-a-kind plant. Here the problem is suddenly you're not looking at five million or something that a VC could do, but you might be looking at 50 to 100 million depending on what kind of plant you're building, what contracts you might have with the government." (Investment Stakeholder 04)*

In summary, while there is a general consensus that the VoD typically occurs during the transition from early-stage development to scaling, around TRL3 to TRL4, there are significant variations in the timeline depending on the market, technology type, and sector. Startups in conservative sectors with a disruptive technology encounter the VoD earlier due to higher market resistance. In contrast, startups in the same conservative markets but with complementary technologies may experience a delayed VoD, typically during the scaling phase. Some investment stakeholders also noted different experiences, such as a "double VoD" or a VoD emerging later, particularly when transitioning to large-scale commercial operations. These divergences are shaped by market dynamics, sector conservatism, and varying capital requirements across industries.

4.1.2. Barriers

This section will identify the barriers cleantech startups face when traversing the VoD. Identifying the barriers is crucial for this research, as it offers an understanding of the specific barriers that hinder the startups' progress. Therefore, the sub-question that discusses the barriers in the VoD will be addressed in this section. Following the identification of the VoD timeline, the next step is to identify the barriers, which is essential setting the context for the strategies employed by cleantech startups. It provides insights into the internal and external factors that most significantly impact the startups' progress. By examining these barriers in detail, it can be determined how the startups face the greatest resistance and determine where support and strategic interventions are necessary. This section seeks to create an understanding of all barriers according to the startups and investment stakeholders. This sets the stage for the next section which addresses strategies as the strategies are strongly connected to the specific barriers that startups encounter.

Capital Intensity

One of the most frequently occurring barriers to cleantech startups' development is their high capital intensity. All startups interviewed mention this barrier, underscoring its significant impact on their growth. High capital requirements become increasingly more important and pressing as the startups progress, making it a dominant factor in cleantech ventures' journeys through the Valley of Death. As Startup 02 explains:

> *"The capital requirements for scaling our technology are substantial. It's not just about the initial investment; it's about maintaining that financial support throughout the development stages." (Startup 02)*

Investment stakeholders also consistently emphasise the challenge posed by high capital intensity, particularly when the startups move towards scaling operations. One stakeholder explains:

> *"The problem here is suddenly you're not looking at five million or something that a VC could do, but you might be looking at 50 to 100 million depending on what kind of plant you're building, what contracts you might have with the government." (Investment Stakeholder 04)*

Given the strong consensus on the critical role of capital intensity as a barrier, there are numerous supporting quotes from both startups and stakeholders, which can be found in the appendix (App. C.1.2). This shared understanding highlights how high capital intensity significantly increases the overall risk, making it challenging for cleantech ventures to secure the necessary funding for scaling and commercialisation.

Development Time
Long development time emerges as another key barrier that significantly contributes to the unique VoD experience of cleantech startups. Both startups and investment stakeholders acknowledge the importance of this factor. As Startup 07 explains:

> *"We have been working on this for around 10 years. 10 years to make sure that we can join it together, combine it, and make the constructive and self-insulating product." (Startup 07)*

This extended timeline not only delays commercialisation but also adds to the risk investors perceive. With broad recognition from both startups and stakeholders, long development time is clearly a contributing factor to the Valley of Death, further complicating the journey to commercialisation. Additional supporting quotes can be found in the appendix (App. C.1.2).

Technology
Technological risk emerged as a notable barrier for only one of the interviewees, even though it is often assumed to be a significant challenge for cleantech ventures. Startup 08, which is still in the early stages of its development (TRL5), directly highlighted this issue as a major obstacle in their fundraising efforts:

> *"The technical risk is still too great, we don't know yet whether the product will work at all, that's why they cannot invest yet." (Startup 08)*

This demonstrates that in the earlier stages of development, technological risk can heavily influence investors' willingness to commit. However, it is striking that none of the other startups, nor the investment stakeholders, emphasised technological risk as a primary barrier in their discussions.

Government Dependence
Government dependence emerges as a key characteristic in the development of cleantech startups, driven largely by the nature of their technologies and the barriers they face in achieving market competitiveness. Although the startups interviewed do not explicitly label themselves as government-dependent, their reliance on government support is clear. Nearly every startup mentioned extensive use of national or European grants, underscoring the critical role that governmental bodies play in their survival. As one founder from Startup 06 noted:

> *"We applied for smaller grants, which usually are easier to get, and with those smaller grants, we managed to bridge the gap to get at least the first patent filing, some credibility on the market, and things like that." (Startup 06)*

This reliance on grants and subsidies is essential for early-stage cleantech startups to fund crucial activities such as patent filing, initial product development, and gaining market credibility. Although the startups may not always explicitly discuss this dependency, it is evident that without this government support, many would struggle to progress through the early stages of their development.

In contrast, investment stakeholders focus more on how government policies and regulations influence the competitiveness of cleantech ventures. Investment Stakeholder 03 highlights the importance of adequate government support to the success of cleantech ventures.

> *"You can build such a great company, but if that business case cannot be made because the regulations are not yet in place, for example, so that you always have to use recycled plastic instead of native plastic. Then your idea just can't work." (Investment Stakeholder 03)*

In summary, while startups implicitly demonstrate their dependence on government support through the widespread use of grants, investment stakeholders highlight the critical role of policies and regulations in enabling cleantech startups to compete in the market. Without both financial support and favourable regulations, cleantech ventures face additional barriers to achieving market success. Additional supporting quotes on government dependence can be found in Appendix C.1.2. Moreover, the government support startups have received has significant limitations as well, relevant quotes are presented in the appendix (see App. C.1.2).

Market

Market barriers pose significant challenges for cleantech startups, affecting both their ability to penetrate existing markets and achieve a strong product-market fit. These barriers manifest themselves in different forms, depending on the sector and the nature of the technology. Several startups identified difficulties in entering conservative markets, while others struggled with aligning their technology with customer needs, leading to a lack of product-market fit, which was also highlighted by stakeholders as a critical issue impacting funding and overall business success.

Some startups found it particularly challenging to penetrate conservative industries. Resistance to adopting new disruptive technologies in sectors such as construction and chemicals can hinder market acceptance. As Startup 06 explained:

> *"The chemical industry is very conservative and they know they're big." (Startup 06)*

Similarly, Startup 05 mentioned difficulties in penetrating conservative markets, while Startup 07 highlighted the challenges of entering the construction industry, which tends to resist adopting disruptive, green technologies.

> *"This is how we look at the construction. Give us a roof over our head and don't think about anything else. And if you go to those other things like green technologies, nobody cares." (Startup 07)*

Meanwhile, product-market fit emerged as another key barrier, especially for startups led by teams with strong technical expertise but limited market experience. Investment Stakeholders 02 and 03 identified the lack of product-market fit as a major contributor to the lack of funding and the prolonged Valley of Death. These startups often begin with a solution and later try to find a market, rather than identifying a problem first. Startup 03, for example, struggled with this challenge due to their academic background, which made it difficult to align their technology with market needs:

> *"It's my limitation [lacking product-market fit] because I come from academia. It was tricky for me to get to the market close." (Startup 03)*

As Stakeholder 02 further noted:

> *"I think a lot of companies, if we're all being honest, don't actually really find product-market fit. They don't really have customers. And if they don't really have customers, then I think ultimately everything else becomes kind of a downstream problem of that." (Investment Stakeholder 02)*

This misalignment with the market often results in difficulties securing customers, which then hampers efforts to raise funds and scale. Investment Stakeholder 03 also emphasised that deep tech startups frequently fail to consider customer needs early enough, further complicating their product-market fit:

> *"So very often technology is further developed, but there is very little connection with what the customer wants and what the market wants." (Investment Stakeholder 03)*

In addition to the conservative nature of some markets and product-market fit issues, the complexity of coordinating with a broad range of stakeholders, from supply chain partners to policymakers, further complicates market entry for cleantech ventures. As Investment Stakeholder 01 described:

> *"Bringing the technology to market requires coordination among a large set of stakeholders, corporates who are either customers and off-takers or supply chain partners, investors, but of varying nature, equity, debt, and sort of lots of flavours of all of those, but often also universities, policymakers, and similar entities like that." (Investment Stakeholder 01)*

In summary, market barriers for cleantech startups take various forms, from conservative industry resistance to challenges in achieving a product-market fit. For many, this misalignment with the market hinders their ability to attract funding and scale. The complex ecosystem of stakeholders further complicates the entry of the market, creating additional hurdles for cleantech ventures.

Team

One of the key barriers that emerged from the interviews is the challenge of building and maintaining a well-rounded team in cleantech startups. Both founders and investment stakeholders highlighted difficulties in acquiring and retaining talent, with startups often facing a shortage of skilled individuals, particularly in highly technical roles. Startups repeatedly mentioned that finding the right talent was difficult due to the scarcity of expertise in areas such as technical development and commercial execution which leads to team scaling issues. As Startup 06 noted:

> *"The next big challenge is HR, so finding the right people, finding highly skilled individuals where you're looking at chemists, masters, PhDs, and onwards." (Startup 06)*

Adding to the difficulty of talent acquisition, retention was also identified as a major concern. Startups emphasised the unstable nature of working in early-stage ventures, which often makes it challenging to retain employees, particularly when the future of the startup is uncertain. This instability, combined with the demanding work environment, leads to high turnover rates, as highlighted by Startup 01:

> *"In terms of team and growing the team, there is an issue with the idea that a startup is not stable and not permanent. I'd say that this was one of the key issues for us." (Startup 01)*

On top of these challenges, startups face significant financial constraints, which further exacerbate the problem. Limited resources make it difficult for startups to scale their teams, leaving them unable to hire the necessary people to speed up development and strengthen the business side. This creates a loop where a lack of funding hinders team growth, which in turn delays progress and impacts their ability to attract more investment. As Startup 03 observed:

> *"Without those kinds of freely disposable cash, you can't really grow the team as you'd like. That's why we still don't really have a dedicated business development person." (Startup 03)*

Investment stakeholders also emphasised the scarcity of talent as a critical issue. The combination of a shortage of individuals with the right technical skills and those with strong commercial execution experience was seen as a major hindrance to startup development. According to Investment Stakeholder 01:

> *"There's a scarcity of specific technical skill sets and there's still not quite enough people with real commercial execution backgrounds." (Investment Stakeholder 01)*

Investment Stakeholder 03 even sees the lack of a well-rounded team as a fundamental cause for the barriers cleantech startups face, particularly in achieving product-market fit. Many cleantech startups are often founded by individuals with technical backgrounds, such as engineers, which means that from the start, they lack commercially minded individuals who can focus on business development and customer needs. This weak foundation makes it extremely challenging to scale the team effectively. As the stakeholder pointed out:

> *"There is far too little thinking from the customer's point of view, often if you really have a purely technology founding team." (Investment Stakeholder 03)*

Moreover, even when a startup begins with a well-rounded founding team, it is still very challenging to scale the team according to the barriers. As Investment Stakeholder 03 remarked:

> *"The team does not grow with the challenges the company faces." (Investment Stakeholder 03)*

In summary, team building is a major barrier for cleantech startups, starting with having a well-rounded team from the onset and further scaling the team as the startups grows. Challenges in both talent acquisition and retention emerge, which in turn are exacerbated by financial constraints and the scarcity of skilled individuals. The lack of well-rounded teams does not only delay development but also increase the perception of risk among investors. This further deepens the VoD as cleantech startups struggle to secure the necessary funding to grow and scale. Additional quotes related to team building can be found in Appendix C.1.2.

Investor Reluctance

The various barriers faced by cleantech startups, such as long development time, high capital intensity, dependence on government support, market, and team building barriers all contribute to a high-risk perception among investors. These factors make investors reluctant to commit to cleantech ventures, preferring lower-risk investments, such as software startups, which offer quicker returns. As Startup 06 explained:

> *”The other challenge is that deeptech startups are competing with IT startups or tech startups. The runway or the time for the revenue to get a return is a lot longer, and that’s a big competition you need to overcome.” (Startup 06)*

This high-risk profile creates what many startups perceive as a ”financing gap.” Cleantech startups typically make early progress with the help of grants and subsidies, but as they advance to higher TRLs and seek larger private investments, they face increasing investor hesitance. Investors remain unsure about the progress and the significant capital required to move forward. Startup 08 explains this concept, while additional quotes can be found in Appendix C.1.2.

> *“If the money runs out in that Valley of Death, then we have spent a lot of money, while we have not actually made any progress and so you can say that your company is worth more now. So, that is difficult, is that we are now at a point where we cannot easily attract new money because there is already a certain valuation. Also, we don’t have the proof points yet to say that we’re a step further. It is still too early to start selling and it is still too early to start delivering products. It is also too late to say that we will accept 50,000 euros and with that, we can continue for another year.” (Startup 08)*

Investment stakeholders also acknowledge this issue, pointing out that the stage at which cleantech startups require the most funding is often too risky for typical investor profiles. As a result, investors prefer ventures that are more likely to deliver returns quickly, as explained by Investment Stakeholder 01:

> *”That stage is the hardest to fund, ultimately because investors have financial metrics, they have their own risk-return profiles, and these companies often don’t fit the existing paradigms.” (Investment Stakeholder 01)*

This investor reluctance creates a bottleneck in the commercialisation process, preventing cleantech ventures from scaling their technologies. Without sufficient market traction or revenue, investors perceive these startups as too high-risk. This is especially the case when startups cannot yet generate sales, making it difficult to justify investment. As Investment Stakeholder 03 pointed out:

> *”Where you can’t actually turn over any sales at all yet... that’s a very difficult investment case from the investor’s point of view. So that’s just quite risky.” (Investment Stakeholder 03)*

In summary, the combination of technological uncertainty, high capital requirements, and a lack of market traction results in a high-risk perception for cleantech startups. This risk leads to investor reluctance, creating a financing gap that traps these ventures in the Valley of Death, preventing them from securing the capital needed to advance. Other additional supporting quotes can be found in Appendix C.1.2.

Funding Gap

Cleantech startups consistently identify the lack of sufficient funding as the most significant barrier to their growth. This funding gap stems from the reluctance of investors to commit to these high-risk ventures, leading to serious financial constraints that hinder their development. Many startups see this shortage of capital as the main obstacle to scaling (see App. C.1.2), as highlighted by Startup 01:

> *”The financial part is definitely the main issue.” (Startup 01)*

Startups often make early progress through grants and subsidies, but as they reach higher TRLs, they encounter difficulties in securing larger private investments. Investment stakeholders acknowledge this funding gap, particularly for cleantech startups in the middle stages of development. Stakeholder 01 described the challenge of raising capital as these ventures transition from lab-scale to full commercialisation:

> *"That middle part where you don't yet have a profitable at scale product, but you're also out of the kind of lab scale... That stage is the hardest to fund." (Investment Stakeholder 01)*

The limited availability of capital, especially for cleantech ventures, compounds the challenge. As Stakeholder 02 noted:

> *"You can say that startups have a hard time raising funding. Especially so when it comes to cleantech startups." (Investment Stakeholder 02)*

In summary, the funding gap is the most significant barriers for cleantech startups. Despite their progress, the high capital requirements and reluctance of investors to engage in risky ventures leave many of these startups struggling to secure the necessary investment to scale. Additional quotes are listed in Appendix C.1.2

Europe
Due to the geographical location of the startups, additional barriers emerged from the interviews. The European context led to additional funding scarcity and market fragmentation. However, this issue is primarily raised by investment stakeholders, while only two startup explicitly mentioned the influence of the European environment on their funding difficulties. Startup 07 illustrated this phenomenon:

> *"Even if you go to the European Union, or maybe to the VC funds, my experience tells me that there is simply not enough money on the market." (Startup 07)*

In contrast, investment stakeholders frequently brought up the additional barriers the European ecosystem brings to the already challenging development and scaling of cleantech startups. The limited availability of funding in Europe is highlighted, especially for later-stage cleantech startups. This scarcity of capital makes it harder for these ventures to secure the necessary investment to scale effectively. As Investment Stakeholder 02 emphasised:

> *"Particularly in Europe, there aren't really investors at these later stages in the deeptech space. And that's something that makes it more difficult here." (Investment Stakeholder 02)*

In addition to funding shortages, the fragmented nature of the European market poses another significant challenge. Startups must navigate different legal frameworks, language barriers, and varying market conditions across countries, which increases the complexity and costs of scaling operations. This fragmentation reduces the size of the addressable market and forces startups to adapt their technologies for each new region they enter. As Investment Stakeholder 01 observed:

> *"That also means your addressable market is not as large and it takes a lot of adaptation to take your technology from one country to another. That's definitely an additional layer of challenge." (Investment Stakeholder 01)*

In summary, European-specific barriers such as funding scarcity and market fragmentation were frequently mentioned by investment stakeholders. The startups, however, appear less focused on or

aware of these barriers. Additional quotes can be found in Appendix C.1.2.

Lack of Frameworks

One important note was made by Investment Stakeholder 01, who highlighted that the lack of frameworks and success models makes the path of cleantech startups particularly challenging. Due to the lack, ventures have to figure out the complexities of market entry, funding, and scaling largely on their own. While this is not necessarily a significant barrier on its own, it points to the need for more research and established guidelines to support these ventures. As the stakeholder pointed out:

> *"For most companies there isn't yet a blueprint of how to do this well. We don't have that many success factors, success sort of examples to follow. A lot of companies end up having to kind of figure this out on their own." (Investment Stakeholder 01)*

4.1.3. Summary

This section provides a detailed understanding of when and why cleantech startups face critical barriers during their journey through the VoD. The analysis reveals that the general consensus among startups and investment stakeholders is that the VoD typically begins during the transition from early-stage development to larger-scale commercial operations, around TRL3 to TRL5. Startups often place the onset at TRL4 during the seed stage, where funding needs increase, while stakeholders see it starting slightly later, around TRL5, as companies move beyond lab-scale validation. However, there are variations in the timeline, with some startups, particularly those in conservative industries, experiencing the VoD as early as TRL1 due to market resistance. Others perceive it during the scaling phase, between TRL6 and TRL7. Additionally, some stakeholders identified a "double VoD," occurring in the early stages and then again before achieving product-market fit. Sector-focused investor stakeholders identified a delayed VoD until TRL6-7.

The barriers faced by cleantech startups during the VoD are multifaceted. High capital intensity is a major challenge, as the substantial funding requirements for scaling are difficult to meet. Long development timelines further complicate this, delaying commercialisation and increasing perceived risks for investors. On the other hand, only one startup discussed technological risk. Additionally, startups are heavily reliant on government grants and subsidies, which underscores their dependence on government support, while stakeholders emphasised the critical role of favourable policies and regulations in ensuring market competitiveness. Market barriers also play a significant role, particularly resistance in conservative industries and the struggle to achieve a strong product-market fit. The complexity of coordinating with multiple stakeholders further hinders market entry. Team building emerged as another key barrier, with startups struggling to acquire and retain the right talent, especially given financial constraints. The lack of a well-rounded team not only delays development but also increases investor concerns about the startup's potential. This, coupled with other factors such as long development times and high capital requirements, contributes to a high-risk perception that deters investors, leading to a funding gap during critical stages of development. In the European context, funding scarcity and market fragmentation present additional challenges, making it harder for cleantech startups to scale. Furthermore, the absence of established success models and frameworks forces startups to navigate market entry, funding, and scaling largely on their own, highlighting the need for more structured support in this sector.

4.2. Strategies

Cleantech startups face numerous barriers that make them risky investments, including long development times, high capital requirements, technological risks, and dependence on their ecosystem (see Section 4.1.2). To overcome these challenges, cleantech startups employ strategies to secure funding and reduce risks, making themselves more appealing to investors. The first part of this chapter addresses immediate funding gaps, exploring how startups secure resources through alternative funding sources, bootstrapping, and strategic investor engagement. The second part focuses on de-risking strategies aimed at validating technology, demonstrating market demand, and reducing operational risks. By focusing on effective market engagement, strategic partnerships, technological development, and building strong teams, cleantech startups enhance their chances for sustainable growth and long-term success. Some strategies address multiple barriers simultaneously, but they are discussed in the section where they are most relevant. This chapter highlights how these combined strategies improve investor confidence and create a solid foundation for growth.

4.2.1. Bridging Funding Gaps

Cleantech startups face unique challenges in accessing funding due to the inherent risks associated with their innovations. Given these financial constraints, startups must be creative and strategic in securing resources to sustain operations and growth. This chapter explores the various strategies employed by cleantech startups and highlights the approaches stakeholders recommend for overcoming immediate funding gaps. This section is divided into two parts: the first discusses alternative funding sources, while the second focuses on investor engagement strategies aimed at improving funding applications and increasing the likelihood of securing investment.

Alternatives

Both cleantech startups and stakeholders emphasise the importance of alternative funding sources and creative strategies to overcome immediate funding gaps. They both highlight the use of non-dilutive funding, such as grants, as a crucial resource for mitigating funding challenges. Additionally, generating early revenue through existing activities such as consulting, selling reports, or producing small product batches provides critical cash flow, helping startups reduce their dependence on external investors. Startups also implement bootstrapping techniques to extend their financial runway. Leveraging networks and engaging with investors are key approaches, helping startups attract early-stage capital and increase their chances of securing additional investment down the line. These combined strategies help sustain the business during a difficult period marked by a lack of financial resources.

Non-Dilutive Funding

Leveraging non-dilutive funding, particularly in the form of grants, emerged as a common and effective strategy for cleantech startups, as highlighted in the interviews. Startups often rely on smaller grants during the initial stages of development to obtain critical early support, such as funding patents and completing lab-scale tests. These grants, though limited in size, provide equity-free capital to help startups survive through challenging periods. As Startup 06 noted:

> *"We applied for smaller grants, which usually are easier to get, and with those smaller grants, we managed to bridge the gap to get at least the first patent filing, some credibility on the market, and things like that." (Startup 06)*

As startups progress, larger grants become an essential source of funding, enabling them to sustain development through more advanced stages. While accessing these larger grants might require more

effort and face increased competition, there is considerable availability, especially through European umbrella funding schemes. This provides an opportunity for startups to reduce their dependence on private investors and extend their runway. Startup 01 illustrated this:

> *"Recently, we received a big grant from the European Union, one of the European Union umbrella funding schemes. With this bigger funding, we were able to work through it, and we were not reliant anymore on those VC injections and those smaller grants." (Startup 01)*

Moreover, non-dilutive funding allows startups to secure capital without giving up ownership, which also makes their business a more attractive investment opportunity. By decreasing the amount needed from investors, startups can reduce the perceived risk of investment and facilitate smoother fundraising. Investment Stakeholder 04 elaborated on this benefit:

> *"Reducing the amount required from investors via grants or public funding can make your startup a more attractive investment." (Investment Stakeholder 04)*

In summary, the interviews revealed that strategically leveraging non-dilutive funding is a viable approach for cleantech startups, both in the early and later stages of their development. This strategy helps sustain the business, decreases the risk for investors, and provides a pathway to bridge the funding gap, ultimately supporting startups in navigating the VoD. Additional supporting quotes are presented in Appendix C.2.1, Table C.18.

After employing strategies to leverage grants, startups also acknowledged the limitations associated with them, as discussed in Section 4.1.2. To address these challenges, they have adopted various additional approaches. Startup 03, for instance, selected its geographical location for its favourable grant conditions, making it easier to secure funding. To mitigate the financial impact of unsuccessful grant applications, Startups 01 and 02 applied for multiple overlapping grants, ensuring financial continuity even if some applications were rejected. In addition, startups customised their applications to align with the specific goals and KPIs of grant providers. Startup 02 emphasised adding scientific appendices for clarity, while Startup 01 sought consultancy support for larger umbrella grants, which improved their chances of success. The supporting quotes can be found in the appendix (Table C.19, App. C.2.1).

Alternative Revenue Streams

Another way for cleantech startups to secure necessary funding beyond non-dilutive funding is through alternative revenue streams, as highlighted by Investment Stakeholder 02. These creative approaches, often overlooked by early-stage companies, can generate cash flow even before the main product is market-ready. By monetising existing activities, such as consulting, selling reports, or producing small product batches, startups can achieve positive cash flow without relying solely on external funding sources. While not always a long-term solution, these strategies can offer critical financial support to sustain business operations and development during the VoD. This non-traditional strategy is underlined by the stakeholder:

> *"A non-traditional way is that a lot of deeptech companies might have a way to monetise what they do earlier than their main ideas are ready. I think people can think about how can we make money for things that we're doing anyways. I also think these types of alternative strategies, I think are often overlooked by companies." (Investment Stakeholder 02)*

The stakeholder emphasises the importance of getting positive cash flows as soon as possible to have a sustainable business. Even though, such practices are not necessarily long-term, they can sustain

the business in challenging times.

> *"I'm a bigger proponent of getting to cash flow positivity as soon as you can. And you will have a more sustainable business that way. And even though that's not necessarily like the long term business. It's something that's allowing them to kind of keep the business up and running and develop the product or service." (Investment Stakeholder 02)*

Moreover, examples of such practices include monetising data collected during the development phase, compiling and selling industry reports from customer research, producing and selling small product batches, or offering consulting services based on the startup's in-house expertise. These non-traditional revenue streams help maintain cash flow without relying solely on external funding sources. As Investment Stakeholder 02 highlighted:

> *"In the process of what you're doing, you're able to acquire some interesting data and then you could sell that data, for example." (Investment Stakeholder 02)*

Additional quotes related to the other practices mentioned can be found in Table C.20 in Appendix C.2.1.

Bootstrapping

As seen in the previous parts, strategies to secure funding are leveraging non-dilutive funding such as grants and generating early revenue through alternative streams. In addition to these strategies for raising funds, startups can also focus on cost management to maximise their financial runway. Bootstrapping emerged as a critical strategy to minimise operational expenses and effectively allocate limited resources. By adopting a lean approach, startups can significantly extend their runways. As the CEO of Startup 03 emphasised:

> "We obviously wanted to keep everything lean and everything, that really helped to extend runways." (Startup 03)

Bootstrapping comprises different methods to cut costs, such as limiting personnel expenses, re-using hardware, renting facilities, and adopting do-it-yourself solutions. One of the most common methods was keeping personnel costs low as possible. Startups frequently rely on part-time employees, interns, and external support to manage their burn rates and keep personnel costs low. Startup 06 highlighted how reducing salary expenses, even among founders, is a key aspect of keeping costs down:

> *"We keep the burn rate as low as possible all the time so the founders are always on a very restricted salary." (Startup 06)*

In addition to personnel strategies, startups maximise their use of existing resources through re-using hardware, renting facilities, and fabricating machinery in-house to reduce upfront costs. For instance, Startup 03 shared their approach to renting facilities and using second-hand equipment:

> *"We started by renting a facility rather than having our own or we started with used equipment rather than buying new equipment those kind of like workarounds." (Startup 03)*

In some cases, founders are also willing to invest their personal funds to keep the company operational. Startup 07 illustrated this commitment:

> *"I put like 250,000 euro into this business 13 years ago as there was nothing at the beginning, of course." (Startup 07)*

Bootstrapping strategies are widely used by cleantech startups to extend their financial runway and overcome funding constraints. These strategies encompass minimising operational costs, limiting personnel expenses, reusing hardware, and employing do-it-yourself (DIY) solutions. By leveraging these methods, startups can maximise their resources and maintain progress even when external funding is limited. Additional quotes are found in Table C.21 (App. C.2.1). However, bootstrapping is not without its challenges. Startup 06 highlighted that certain bootstrapping strategies, such as do-it-yourself solutions, require careful decision-making. While they can save significant costs, they may also lead to setbacks if the time and effort invested do not produce efficient results. Knowing when to leverage bootstrapping and when to avoid it is crucial for navigating these challenges effectively. Quotes describing the judgement calls can be found in Appendix C.2.1 in Table C.22.

Leveraging Network
Startups leverage their network and the experience of their founders and employees to secure initial funding. This strategy involves drawing on past connections, trusted relationships, and personal networks to attract early-stage capital. By building on previous startup experiences, these companies gain the trust of key individuals and investors who may provide crucial financial support or insights needed to refine their investment pitches.

For instance, Startup 02 leveraged the founder's personal network to secure initial funding from a wealthy individual, often categorised as "family, friends, and fools." This provided the initial financial resources needed to get the business off the ground:

> *"Very simple, I know someone who has a lot of money. Family, friends, and fools." (Startup 02)*

Additionally, Startup 07 managed to secure an extra €250,000 from a personal connection, offering essential financial support that helped the company advance:

> *"Then I had this first investor, a father of my colleague, he put another 250,000 euro into this business." (Startup 07)*

By strategically leveraging their networks, these startups were able to secure early-stage funding.

Investor Engagement
To increase their chances of securing private investment, cleantech startups engage with value-based investors, gather feedback from potential investors, pursue blended financing strategies that combine grants and venture capital, and focus on clear, concise communication to convey their value propositions effectively. Engaging with value-based investors ensures alignment in mission and vision, increasing commitment during challenging times while engaging broadly helps refine business models and pitches. Blended financing helps reduce risks by decreasing the required capital of each party, and simplifying complex technologies makes startups more accessible and appealing to a broader range of investors.

'Find Your Tribe'
A strategy highlighted by Investment Stakeholder 02 is 'Find Your Tribe.' This approach focuses on seeking out investors who share the startup's values and mission beyond just financial returns. By

aligning with these like-minded investors, startups do not only increase their chances of securing funding but also build a stronger foundation for long-term collaboration and support. As they are more likely to resonate with the vision and have an intrinsic interest in the startup's impact:

> *"In general, what you're way better off doing is finding people who already want what you're trying to sell. Instead of trying to convince the investor, look at who's actually interested in what you're doing. Who's your choir, who's your tribe, and find your choir or your tribe. And if you talk to them, you're probably going to be a lot more successful." (Investment Stakeholder 02)*

The stakeholder highlights that other startups that employed such strategies managed to secure private funding after being unsuccessful with 'regular' private investors.

> "I've seen startups who didn't manage to get funding but still deployed such strategies that made them like it and made it. (Investment Stakeholder 02)"

Moreover, if a startup fails to attract funding from these like-minded investors, it often receives valuable feedback that can help refine its approach:

> "Or on the flip side, if you're not going to be successful with these people, then it's probably a clear indication that you're doing something wrong. And they'll probably give you really good feedback of what you're doing wrong. Because they're the relevant people who you're trying to work with. (Investment Stakeholder 02)"

In summary, engaging with value-based investors significantly enhances the chances of securing funding and provides valuable feedback. Additional supporting quotes are presented in Appendix C.2.1 Table C.23.

Investor Feedback

Building on the idea of leveraging valuable insights from investors, startups actively engage with potential investors to gather valuable feedback on their business models, product development, and investment readiness. This process helps them refine their pitches, clarify value propositions, and adjust their strategies to better align with investor expectations. Engaging with investors for feedback becomes an essential step in improving investment applications.

For example, Startup 06 emphasised the importance of understanding investor feedback, even if it comes in the form of rejection, and using it to make strategic improvements:

> *"We came from another startup before, so we were lucky enough that we had a trust of a number of individuals who also followed on in the first investment. When we tried to get the first investment, they told us no because we were too early, but they told us what they needed and from that, we at least had a bit more clarity of what we need to do to get to an investment." (Startup 06)*

In this way, engaging investors not only helps startups improve their funding prospects but also provides an opportunity to refine their strategies, ultimately making them more attractive to potential investors. Additional quotes are found in Table C.24, Appendix C.2.1.

Blended Financing

In addition to the startups' efforts in engaging with value-based investors and leveraging their feed-

back, Startup 06 is pursuing a blended financing strategy, combining grants with venture capital. This approach aims to balance the capital requirements for each party, increasing the likelihood of being successful in raising funding. Moreover, this strategy is used to maximise the impact of VC money and reduce dependence on grants alone.

> *"We're going to pursue blended financing meaning half or even more than half will be European support and then matched by by VC. Making the VC money go further is something that's welcome nowadays. So we'll try to leverage that." (Startup 06)*

Communication
To further improve their chances of securing funding, effective communication emerged as an essential strategy for cleantech startups. By distilling their narrative to its core, startups ensure that potential investors can quickly understand their value proposition. This approach simplifies complex technological concepts and makes the startup's mission more accessible and appealing to a broader audience. For example, Startup 04 has adopted a strategy of clear and concise communication, refining their message to highlight the essence of their work.

> *"What we have done is strip the story down to what is really the essence of what we do." (Startup 04)*

Furthermore, the CEO highlighted the importance of having clear and concise communication and even stated without being able to, fundraising and general progress are seen as very difficult.

> *"We can explain the story very well simply so that many people can understand it. Often a good check to ask a startup founder what you do and if he can't answer in two sentences then it probably won't work." (Startup 04)*

Another startup faced challenges in making their complex technology relatable to investors. They focused on simplifying their message to convey both the practical benefits and innovative aspects of their technology.

> *"We often struggled to make our complex technology relatable and understandable to investors. We had to simplify our message and ensure that it conveyed the practical benefits and the innovative aspects of our technology." (Startup 01)*

In summary, effective communication is crucial for cleantech startups to secure funding, as simplifying complex concepts and clearly conveying their value proposition makes their mission more accessible and appealing to investors. Startups that refine their messaging to emphasise core benefits and innovation are better positioned to gain investor interest and support.

4.2.2. De-Risking & Sustainable Growth

This section focuses on de-risking strategies employed by cleantech startups to enhance their attractiveness to investors and ensure sustainable growth, helping them overcome the VoD. Unlike strategies that address immediate financial constraints, this chapter explores approaches to reduce overall risks through actions in market engagement, technological development, and team building. Market-oriented strategies include deployment-led innovation to validate technology, customer discovery to align with market needs, and securing demand signals such as letters of intent (LOIs) to demonstrate interest. Forming strategic partnerships and leveraging recognition initiatives further enhance credibility. Tech-

nological development involves forming consortia to facilitate technology refinement. In team building, assembling diverse, experienced teams and implementing effective scaling and retention measures are key. These de-risking strategies collectively reduce perceived risks and build a solid foundation for cleantech startups, making them more attractive to investors and supporting sustainable growth.

Market

This section outlines the de-risking strategies employed by cleantech startups to strengthen their market position to reduce perceived risks and create a more sustainable business. Both startups and stakeholders emphasise strategies such as deployment-led innovation, which demonstrates technological viability through real-world conditions, and customer discovery, which ensures a strong product-market fit through continuous market engagement. Securing market demand signals, including Letters of Intent (LOIs) and off-take agreements, further validates customer interest and reduces investor risk. The importance of forming strategic partnerships, including alliances, joint ventures, and collaborations with research institutes, is highlighted as a means to access resources, validate technologies, and share costs. Additionally, early commercialisation, semi-commercial deployments, and participation in recognition initiatives are leveraged to build traction, visibility, and credibility in the market. These combined approaches ensure a better market position, thereby de-risking the venture and enhancing long-term growth prospects by reducing barriers to investor confidence.

Deployment-Led Innovation

It emerged from both startups and stakeholders that deployment-led innovation is a strategy for cleantech ventures to effectively demonstrate progress, validate their technologies, and ultimately secure funding. By tracking milestones, presenting tangible results, conducting experiments, and testing in challenging real-world environments, startups provide tangible evidence of their progress. This approach not only helps in convincing investors but also enhances market credibility. Deployment-led innovation allows startups to showcase their technology's scalability and real-world effectiveness, thus reducing perceived risks for investors and improving their chances of attracting long-term support. As Investment Stakeholder 04 highlighted:

> *"Demonstration projects are crucial for showing that the technology works at scale, reducing the risk for investors." (Investment Stakeholder 04)*

One example of this approach is Startup 02, which deployed large-scale models and conducted tests in real-world conditions, thereby effectively proving the technology's operational reliability. This tangible evidence helps to reduce uncertainty for investors and stakeholders, making them more inclined to support the project:

> *"I have chosen a strategy where we really built proof points. Not a small model in an excel sheet and a few pieces of hardware on a small scale. No, really building big things. Put it in the sea. And test it for a year." (Startup 02)*

Deployment-led innovation thus serves not only to validate a startup's technology but also to gain investor trust and secure crucial funding. Additional supporting quotes are presented in Appendix C.2.2, Table C.25.

Customer Discovery

Another market-focused strategy is customer discovery. Even though it was not highlighted by all interviewees, it is considered an important strategy. Its relevance lies in ensuring a strong product-market fit through continuous engagement with potential end clients and staying attuned to market

needs. By maintaining consistent communication with customers, startups validate each step of their development process, ensuring that their product aligns with market demands and expectations.

Startup 06, for instance, focuses heavily on customer discovery by engaging with potential end clients to validate every step of their development, ensuring that the product meets the market's requirements. By sending product samples to major manufacturers and partners and leveraging the feedback they receive, the startup strengthens its product's credibility and alignment with market. As the founder explains:

> *"We don't want to produce anything that the market doesn't want. So we're constantly speaking to who the end client is going to be, and every step of that is kind of validated, but it's also one step forward in our success process." (Startup 06)*

Stakeholder 03 also emphasised the importance of actively monitoring market trends and establishing a continuous learning process. By engaging with customers, partners, and other stakeholders, startups can expand their knowledge, adapt to market changes, and refine their product offerings for a better market fit.

> *"The best companies essentially set up a constant learning process. So they're constantly engaged with their customers or partners or other stakeholders within what they're trying to do. And that's basically expanding either their knowledge or the capabilities." (Investment Stakeholder 02)*

Although not all startups highlighted customer discovery as a strategy, it remains highly relevant for cleantech ventures seeking to improve their chances of market success. By leveraging continuous customer dialogue and learning, startups can identify emerging patterns and potential problems, ultimately refining their products to meet market needs effectively. Additional quotes can be found in Appendix C.2.2, Table C.26.

Market Demand Signals

To validate market interest before a product is fully developed, startups are encouraged to secure tangible expressions of customer demand, such as off-take agreements or contracts. These agreements help to standardise customer commitments and confirm that a viable market exists, which in turn reduces the perceived risk for investors. This approach is often utilised by well-known companies such as H2 Green Steel and Northvolt, as noted by a stakeholder:

> *"There's been a lot of talk about that recently with the Vargas Holdings companies like H2 Green Steel and Northvolt, but more of that is going to be happening and really sort of so kind of standardising customer demand to demonstrate that the market exists before you actually have a product." (Investor 01)*

Such contracts provide a comfort level for investors, as they demonstrate a commitment from customers and confirm potential future revenue streams:

> *"Startups should work to secure contracts that specify demand and pricing, as these can provide a comfort level for investors." (Investor 04)*

An example of such an approach is collecting letters of intent (LOIs) from potential customers. This strategy is often employed by startups, such as Startup 08, to demonstrate market interest during early-

stage development. LOIs serve as evidence of demand and validate the relevance of the technology, which strengthens the startup's position to attract additional funding and partnerships, even before achieving actual sales:

> *"We collect letters of intent, to show people's interest, to show market demand." (Startup 08)*

Through strategies such as securing LOIs, off-take agreements, and standardising customer demand contracts, startups can effectively showcase market demand and reduce perceived risk, thus improving their chances of obtaining investment.

Strategic Partnerships

From the interviews, it emerged that strategic partnerships are a crucial strategy for cleantech startups to access resources, validate their technologies, and enhance credibility in the market. These partnerships can be formed in various ways, including strategic alliances, joint ventures, and collaborations with research institutes or universities.

Strategic Alliances

As startups move towards scaling and commercialisation, they can form strategic alliances with different partners to support ongoing projects. By communicating clearly that their technology was still under development and highlighting its green applications alongside regulatory pressures in the construction industry, the startup was able to generate sufficient revenue to further develop the technology, demonstrate market interest, and build credibility. Startup 05 explained:

> *"Strategic partnerships. That party from Belgium and other projects, which have generated money for us, those have also obviously helped us move forward [with the technology development]." (Startup 05)*

Joint Ventures

Another strategy that can be used as further progress is made towards scaling and commercialisation is forming joint ventures (JVs). By partnering with developers and builders in Ireland, Australia, the United States, and other regions, Startup 07 not only gained financial support but also demonstrated the versatility of its technology globally. These joint ventures served as proof of concept, establishing the startup's presence in diverse markets and proving its potential as a viable multinational business. This approach has been instrumental in reducing perceived market risks and positioning the startup as a serious industry player:

> *"Once you spread the technology, you go into certain joint ventures. And we do go into joint ventures nowadays. And we are in pretty serious discussions with some Irish developers, some builders from Australia, and some four groups of the USA. We will be co-financed by our JV partners. This is very good for us because it proves the concept. It proves that this can be a multinational business as well." (Startup 07)*

Partnerships with Research Institutes and Universities

Establishing partnerships with research institutes, universities, and industry partners provides startups with access to innovations, skilled people, and shared facilities, which can reduce the costs and challenges associated with product development. Engaging in joint development programs or pilot projects with established players also helps accelerate technological advancement. These partnerships can help de-risk the startups, Investment Stakeholder 04 elaborated:

> *"Partnerships with corporates or governments can help de-risk your startup by providing both financial and operational support." (Investor 04)*

By leveraging strategic alliances, joint ventures, and partnerships with research institutions, startups can access critical resources, reduce operational costs, and demonstrate their market potential, enhancing their attractiveness to further investment. Additional supporting quotes are provided in Appendix C.2.2 (Table C.27).

Semi-Commercial Deployment

Startup 02 undertook a semi-commercial deployment of its technology to build traction and credibility in the market. This strategy focuses on establishing a commercial track record by deploying their systems at a reduced scale but in real-world conditions. The startup can demonstrate its operational viability and create a track record of generating revenue from innovation. This approach allows them to cover operational expenses (OPEX) while simultaneously showcasing their technology's potential in generating income. Furthermore, this method offers valuable market exposure, enhances credibility, and supports the startup's growth towards full commercialisation. As this strategy generates revenue and covers the OPEX, this strategy certainly relates to securing funding, however, as the CEO mentions, building up a track record is the main aim of this strategy.

> *"We are looking to do a semi-commercial deployment of our technology. We don't have to sell water to recoup the whole machine. That cost tens of millions and that's not relevant because it's all research money. Let's say they pay a euro for the turbine, which is actually quite a reasonable price in many locations, then we can pay our OPEX. Then our people can go to those locations, which is always far away. Plus, what's much more important is we build a track record that we are making money with our innovation." (Startup 02)*

Early Commercialisation

Another startup bypassed the more conservative corporate construction market by directly targeting individual clients. This strategy provided immediate financial resources but, more importantly, it demonstrated the real-world applicability and appeal of their product, allowing the startup to gain early traction and establish a foothold in the market. By focusing on individual consumers who valued their innovative solution, the startup built a foundation for growth and proved that their technology could succeed even without traditional corporate partnerships or investments.

> *"We base our business on those individuals those that like the solution. Because there's basically no money in the deeptech, just no money at all. So, we are financed now by our clients because we are already selling a little bit." (Startup 07)*

By adopting these strategies, the startups not only secured revenue but also gained valuable market insights and built credibility, positioning themselves more effectively for long-term growth. Additional quotes are found in Table C.28 (App. C.2.2).

Leveraging Recognition Initiatives

Startups in the cleantech sector participate in recognition initiatives such as accelerators, awards, and competitions to enhance their market credibility and investor visibility.Engaging in these initiatives not only demonstrates a startup's active involvement and commitment but also builds credibility and traction, both internally and externally. Participating in acceleration programs, community workshops, and competitions provides an opportunity to showcase their efforts, learn, and network, which ultimately

helps in gaining market recognition.

For instance, Startup 06 highlighted how participating in accelerators and applying for awards helped them gain credibility and official traction, which can be crucial for attracting investors and gaining market presence:

> *"We try to put intermediate so joining accelerators, applying for awards. This gives us credibility and some official traction as well." (Startup 06)*

Additional supporting quotes on leveraging recognition initiatives are found in the appendix (App. C.2.2), Table C.29.

Technology

Among strategies to improve the market position and eventually de-risk the venture, one startup employed a strategy to boost technological development. By building consortia, the startup managed to get larger-sized grants and develop the technology further.

Building Consortia

Startup 02 focused on technological development by forming consortia with large corporations, using its experience in securing grants and its network to facilitate pre-commercial testing. This approach allowed the startup to refine its technology in real-world settings, significantly reducing the technological risks associated with its innovation. By demonstrating the technology's progress and viability through practical applications, the startup not only de-risked its business but gained significant traction. The success of the consortia in securing larger grants further supported this development, providing the necessary funding to advance the technology.

> *"We are good at subsidies. So we help them get subsidies. We go out together. We do our thing. They do their thing. And suddenly you have a 12 million euro project where they are actually doing a pre-commercial test. With something they will actually do for a customer six months later. And we bring our technology five steps further." (Startup 02)*

Team

Forming a well-rounded team from the very start emerged as a critical factor for cleantech startups, helping them to gain investor confidence and effectively navigate the complexities of the industry. A diverse and experienced team, combining scientific, commercial, and financial expertise, ensures that startups can address the challenges of both technology development and market positioning. Startup 04 underscored the importance of building such a well-rounded team early on, including co-founders with academic credentials and members with decades of industry experience, which helped them avoid common pitfalls, such as reinventing the wheel or struggling with stakeholder communication:

> *"We have a team that is very experienced and thus inspires confidence with a co-founder who is a professor in this field. People with 30, 20 years of experience in the team who don't have to reinvent the wheel." (Startup 04)*

Similarly, Investment Stakeholder 01 highlighted the value of building a strong team from the early stages to effectively navigate the cleantech sector:

> *"Building a strong team early on that has a commercial financial capability is vital." (Investment Stakeholder 01)*

Apart from forming an experienced team, it is equally important to explore cost-effective strategies to scale the team properly and efficiently. One approach, as illustrated by Startup 03, is to retain only the founding team as paid employees during the early stages, which helps in keeping operational costs low while maintaining core expertise:

> *"These paid employees in the company are the founders at the moment. It's been like that for four years now." (Startup 03)*

Additionally, leveraging incubator support provides startups with access to part-time engineering staff and facilities at reduced costs. This diversifies the skill set within the team and mitigates the financial burden of full-time hires, as noted by Startup 06:

> *"The incubator is a big support because from there we can get like engineering staff part-time and some facilities that otherwise, you know, would be very expensive." (Startup 06)*

Retaining talent, especially those driven by passion and not solely by monetary rewards, is essential for fostering a motivated and aligned team. Strategies such as offering shares or share options help keep key employees captivated and committed to the company's long-term success, as emphasised by Investment Stakeholder 03:

> *"That your employees can grow well also with your company and that they also ultimately benefit from any success of your company. So that is also, for example, giving more shares or share options or SARS or things like that." (Investment Stakeholder 03)*

Building a team with diverse expertise, leveraging strategic partnerships to scale cost-effectively, and implementing measures to retain passionate talent all contribute to creating a strong foundation for navigating challenges and achieving sustainable growth. Additional quotes are found in Appendix C.2.2 in Table C.30.

4.2.3. Summary

Cleantech startups face significant challenges, including high capital requirements, long development times, technological risks, and dependence on their ecosystem. To overcome these challenges and make themselves more appealing to investors, startups implement a combination of funding strategies and de-risking approaches. These strategies are designed to bridge immediate funding gaps, validate their technology, demonstrate market demand, and establish credibility.

To bridge funding gaps, startups leverage non-dilutive funding sources like grants, generate revenue through alternative streams, employ bootstrapping techniques to minimise expenses, and strategically leverage their networks. Engaging with value-based investors, seeking investor feedback, and pursuing blended financing approaches further enhance their chances of securing investment. Clear and concise communication helps convey their value proposition effectively to investors.

To de-risk and ensure sustainable growth, startups adopt market-focused strategies such as deployment-led innovation, customer discovery, and securing market demand signals through Letters of Intent (LOIs) and off-take agreements. They form strategic partnerships, including alliances, joint ventures, and collaborations with research institutes, to access resources and validate their technologies. Early commercialisation and semi-commercial deployments help demonstrate technological viability and build credibility.

Building a well-rounded team from the start is crucial, as it combines scientific, commercial, and financial

expertise, which strengthens the startup's position and helps navigate challenges. Scaling the team cost-effectively, leveraging incubator support, and retaining passionate talent through incentives like shares are also key strategies for sustainable growth.

These combined approaches not only enhance the credibility of cleantech startups but also reduce risks, making them more attractive to investors and ensuring long-term success.

5

Discussion

This chapter discusses the results presented in Chapter 4. As previously stated, the timeline and barriers of the VoD provide essential context for understanding the strategies employed by cleantech startups. These elements are examined to highlight how they shape the barriers faced and influence strategic responses. The discussion will cover the different perspectives on both the timeline and the barriers. The chapter will conclude with a discussion of the various strategies identified to address these barriers.

5.1. Timeline & Barriers

This section discusses the differing viewpoints on the timeline of the VoD for cleantech startups. The commonalities and differences in these viewpoints will be analysed, considering how they relate to specific barriers and strategic needs during different stages of development.

5.1.1. Timeline

The interviews reveal that cleantech startups generally perceive the onset of the VoD around TRL4, coinciding with the seed stage when funding needs increase significantly, and private investment becomes more challenging to secure. A large share of stakeholders similarly identify the onset of the VoD around this time but see it slightly later, around TRL5, as companies move beyond initial validation and lab-scale efforts without yet reaching a profitable, at-scale product. Among these stakeholders, there seems to be a general consensus that the VoD arises once capital requirements start to grow significantly, and initial funding sources, such as grants, angel investors, and ”family, friends, and fools,” are no longer sufficient. This stage is where venture capital play starts to play a crucial role, but they are hesitant to invest without clear evidence of profitability and scalability.

This view from the interviews differs significantly from the literature, such as the study by Romme et al. (2023), which identifies the onset of the VoD as early as TRL2-3 for deeptech ventures. The literature suggests that many startups face challenges almost immediately after transitioning from lab research to development, even before obtaining significant external funding. The difference in perspectives can be explained by the fact that Romme et al. (2023)’s analysis encompasses deeptech ventures more broadly, while the interviews conducted here focus exclusively on cleantech startups. Cleantech startups often benefit from strong government support, early public funding, and widespread availability

of grants, as highlighted in both the literature (Cumming et al., 2016; Sarzynski et al., 2012; Shakeel, 2021) and the interviews. This support allows cleantech startups to mitigate early financial constraints more effectively than other deeptech sectors, which might lack similar support mechanisms. As a result, cleantech startups appear to survive the early stages better, only experiencing the VoD later when capital needs grow substantially, and grants become limiting or harder to obtain.

The interviews also presented viewpoints that significantly diverged on the onset or entire duration of the VoD, likely due to the differing sectoral focus of the participants. For instance, one cleantech startup experienced barriers from the very beginning, as early as TRL1, due to the highly conservative nature of the construction industry and the disruptive impact of their technology. In contrast, another startup operating in the same conservative market but offering a complementary technology could leverage green regulatory pressure on construction companies, which allowed them to overcome many barriers and delay the onset of the VoD until TRL6-7. This divergence underscores the importance of the market context and the nature of the innovation, with disruptive technologies facing much earlier challenges compared to complementary innovations that benefit from existing regulatory drivers.

Similarly, an investment stakeholder reported observing a delayed onset of the VoD for cleantech startups involved in first-of-a-kind (FOAK) plants. This delay was attributed to strong support mechanisms available for FOAK projects, which help bridge the early-stage funding gap until the scaling phase. This aligns with the idea that targeted government support can significantly influence the timeline of the VoD, particularly for complex, capital-intensive projects that serve as pilot demonstrations.

Interestingly, one stakeholder's perspective closely mirrored the analysis of Romme et al. (2023), describing a "double VoD," with one phase occurring early between TRLs 2-4, as startups struggle to secure their first round of funding, and a second phase just before achieving product-market fit (TRL6-7). This view aligns closely with the findings of Romme et al. (2023) for deeptech sectors, indicating a recurring funding gap during critical developmental transitions, regardless of government support. The stakeholder's focus was also primarily on deeptech, which further supports this alignment with the perspective of Romme et al. (2023) on the challenges faced by deeptech ventures.

Determining the endpoint of the VoD is challenging, as it largely depends on overcoming significant barriers related to funding, technology, and market fit. However, there is a general consensus that the VoD ends around TRL8, regardless of the sector or type of technology involved. This is because the main barriers of the VoD, such as funding shortages, high innovation risks, and a weak market position, gradually diminish as startups progress. As they begin commercialising, startups generate revenue and move toward financial independence, which significantly reduces perceived risks. This progress attracts investors, and the financial barriers that define the VoD start to disappear (Romme et al., 2023). By addressing these key barriers, startups eventually reach a stage where they can sustain operations independently, signaling the end of the VoD (Mankins, 1995).

5.1.2. Barriers

This section discusses the barriers faced by cleantech startups by comparing insights from interviews with existing literature. It highlights both alignments and differences, providing a deeper understanding of key challenges such as financial risks, technological risks, government dependence, market dynamics, team challenges, investor reluctance, the funding gap, and European-specific obstacles.

Financial Risk

Financial risks, including high capital requirements and long development times, are consistently identified by both interview participants and the literature as significant barriers for cleantech startups. These

challenges increase uncertainty and make it difficult for startups to secure necessary funding, particularly during the scaling phase (Gaddy et al., 2017; Polzin, 2017; Romme et al., 2023). High capital requirements are a substantial burden as the startups progress through the stages of development, while the extended timeline of technological maturation further compounds investor hesitation, contributing to the VoD (Bianchini & Croce, 2022; Cumming et al., 2016).

Technological Risk

The technological risk, which is considered another significant barrier to the unique VoD of cleantech ventures (de la Tour et al., 2017; Romme et al., 2023), was only brought up a single time during the interviews. The lack of emphasis on technological risk in the interviews, despite its assumed significance, could be attributed to several factors. First, many of the startups interviewed are at more advanced stages of development, typically beyond TRL5 (see Table 3.1 in Chapter 3), where technological uncertainties have been more addressed. At this stage, major technical hurdles have probably been resolved through testing and validation, shifting the focus toward scaling and commercialisation. As a result, technological risk may no longer be seen as a dominant concern. In addition, for both startups and investment stakeholders, the emphasis naturally shifts from technical viability to market readiness as ventures progress. Once the technology has been proven, the primary barriers tend to revolve around securing larger rounds of funding, building production capacity, and navigating market entry. These commercialisation barriers often overshadow any lingering concerns about technological risk.

Furthermore, investment stakeholders tend to focus on later-stage startups, which have already proven their technology. Their attention is usually on scaling and commercialising these ventures, further explaining why technological risk may not be highlighted as a major concern in their interviews. For many of these stakeholders, the risks associated with scaling and market entry far outweigh any lingering technological uncertainty. Moreover, startups may view technological risk as an inherent part of early-stage development. Once these risks have been managed, they may no longer be perceived as a distinct barrier, with attention shifting to more immediate concerns such as financing and commercialisation. Consequently, even if technological risk played a significant role early on, it may not be seen as the primary barrier beyond the initial stages.

Government Dependence

The discussion in the interviews and the literature both agree on the significant role of government support in the development of cleantech startups, but they present slightly different perspectives on the nature and reasons for this dependence. From the interviews, it is evident that cleantech startups heavily rely on direct government support, such as grants and subsidies, especially during the early stages of their development. This direct financial support is portrayed as essential for helping startups bridge early funding gaps before they can attract private investment, however, many startups leverage grant provision until late development stages. The investment stakeholders highlight a different aspect, specifically, the influence of government policies and regulations on market competitiveness. Stakeholders emphasise that favourable regulations are essential for cleantech startups to build viable business cases, which can significantly impact their ability to attract further investment and succeed in the market. This regulatory aspect, as discussed by stakeholders, contrasts with the startups' more immediate focus on securing direct financial assistance to overcome early-stage challenges.

The literature echoes the importance of government support but highlights both direct and indirect forms of dependence. Direct dependence is described in a similar way, emphasising how government subsidies are needed to make cleantech technologies competitive due to their non-competitive pricing and market resistance (Christensen et al., 2016; Woschke et al., 2017). This aligns with what stakeholders discussed in the interviews regarding the need for subsidies and regulations to enable competitiveness.

However, the literature also points out an indirect dependence, which is driven by investor reluctance. This reluctance to fund cleantech startups due to high perceived risks results in a funding gap, forcing startups to rely even more on government support as an alternative funding source (Harrer & Owen, 2022). This aspect of indirect dependence, stemming from investor behaviour, is less explicitly discussed by the interview participants, nevertheless, it is evident from the wide use of grants by the startups.

A key insight from the interviews was the limitations associated with grants, adding nuance to the barriers already discussed in the literature. Startups noted that while smaller grants are accessible, they are insufficient for scaling, whereas larger grants are highly competitive and difficult to secure, particularly at early stages. This highlights the restrictive nature of grants, which limits adaptability due to predefined KPIs and project requirements. Furthermore, the interviews revealed communication challenges and biases from grant providers, making it more difficult for startups to align their innovations with grant criteria (Harrer & Owen, 2022; Hartley & Medlock, 2017). These practical challenges suggest that while government grants are essential, they also impose constraints that add to the risk perception of cleantech ventures.

Market

The participants and the literature align in recognising the significant barriers cleantech ventures face in penetrating existing markets due to their disruptive nature. The literature highlights that introducing cleantech solutions into established industries often leads to difficulty in market entrance, which makes revenue generation uncertain and positions such ventures as high-risk investments for potential backers (Christensen et al., 2016; Frank et al., 1996; Hartley & Medlock, 2017; Shakeel, 2021; Woschke et al., 2017).

The interviews add further nuance to this understanding. Two stakeholders placed a strong emphasis on product-market fit as a crucial barrier, identifying it as a significant issue that hinders funding and business progress. The lack of a well-defined product-market fit often results in startups developing a solution first and seeking a market later, which complicates efforts to secure customers and attract investment. This perspective underscores the importance of aligning technological developments with market needs early in the process—something that is not as explicitly emphasised in the literature. Another stakeholder aligns with the literature to recognise the challenges posed by market resistance to disruptive technologies (Brown et al., 2007; Shakeel, 2021). Furthermore, the stakeholder points out the complexity of coordinating among a large set of stakeholders, as also discussed in the literature (Giudici et al., 2019).

In addition, startups often encounter markets unwilling to adapt to innovative technologies, a challenge echoed by several startups interviewed. For instance, three startups highlighted the conservative nature of certain industries, such as chemicals and construction, which creates additional resistance to market acceptance and entry beyond what is generally discussed in the literature. This sector-specific conservatism makes it even more challenging for cleantech ventures to gain market entry, suggesting that sector-specific dynamics play a critical role in shaping market barriers. Furthermore, biases in grant applications, as noted by two startups, add another layer of difficulty, reflecting broader systemic challenges in accessing early support for market entry.

Moreover, while one startup admitted to struggling with product-market fit, it is notable that only a few startups explicitly mentioned this as a barrier. A possible explanation for this limited mention could be that some startups, particularly those led by teams with strong technical backgrounds, may not fully recognise the significance of market fit issues until they face direct challenges in attracting customers and funding. This highlights an important gap in the understanding of early-stage market challenges

among technical founders, who may focus more on technological development than on aligning their product with customer needs. Additionally, it could also be reflective of a good batch of startups in the sample, as multiple startups indicated that they actively seek market alignment. This effective batch could also be observed in their strategies, which include customer discovery, engaging with investors to refine their approaches, and other strategic efforts to improve product-market alignment. Some have even advanced to TRL8, where product-market fit ought to be established or at least significantly validated.

Team

The significance of team building as a critical barrier for cleantech startups is underlined by both the participants and the literature (Romme et al., 2023). Both emphasise that forming a well-rounded team is crucial for securing investment and managing the unique complexities of cleantech ventures. The need for a diverse set of skills, including technical, commercial, and legal expertise, is echoed in both the literature and the interviews. The difficulty cleantech startups face in assembling teams capable of tackling the sector's inherent challenges is highlighted by Paola Garrone and Mrkajic (2017), Singh and Subrahmanya (2023), and Ye and Zheng (2023).

The interviews reveal a major consensus regarding the scarcity of skilled individuals, particularly in technical and commercial roles, as a significant additional barrier to startup growth. On the other hand, the literature further explains that forming a complementary team often necessitates looking beyond existing social networks, which may limit the ability to quickly bring in needed talent (Ruef et al., 2003).

Another divergence between the interviews and the literature is the focus on scaling the team according to the growing needs of the startup. While both underscore the importance of starting with a well-rounded team (Paola Garrone & Mrkajic, 2017), the interviews indicate that even after assembling a strong initial team, scaling it appropriately as the startup grows remains challenging. Stakeholders in the interviews pointed out that the ability to scale the team to meet evolving barriers is critical, suggesting that the team should grow in response to the company's development, which the literature does not extensively address.

The literature stresses that the quality of the team often outweighs other factors, such as technology, for venture capitalists (Zacharakis & Meyer, 2000). The interviews reflect this sentiment to an extent, with stakeholders emphasising the importance of having commercial expertise within a founding team. However, the notion that team quality outweighs all other factors is explicitly stated by only one stakeholder and one startup. The stakeholder identified the lack of a well-rounded team as the root cause of poor product-market fit, which ultimately hinders the ability to attract investment. The startup highlighted that having a strong team reduces risk, provides valuable networks, and brings experience, thereby facilitating smoother development and growth. Thus, the importance of team quality is acknowledged throughout the interviews, however, it is not consistently presented as outweighing other critical elements like technological readiness or market alignment. Where the literature and interviews do agree is how a well-rounded team mitigates investor risk perceptions (Singh & Subrahmanya, 2023; Ye & Zheng, 2023). This connection between team quality and risk perception is a consistent theme in both sources.

Continuing from that point, the literature highlights that due to the inherent complexity of the sector and the high risks, investors are more hesitant to engage with cleantech ventures, especially in the absence of a well-rounded team (Cumming et al., 2016). The interviews reinforce this and an extra nuance to this issue, noting that financial constraints combined with a shortage of skilled talent make it even more difficult for startups to address team building challenges. This creates a loop where a lack of funding

limits team growth, which in turn impedes progress and hinders the startup's ability to attract additional investment, further highlighting the interdependence between team building and financial barriers.

Investor Reluctance

Investor reluctance is seen as a significant barrier for cleantech startups by both the literature and the interviews, largely due to their high-risk nature. While the literature categorises these risks broadly, the interviews provide practical insights into how these perceptions impact funding. Both sources agree that investors are more inclined to choose ventures with quicker returns, such as IT startups, which offer lower-risk opportunities (Cumming et al., 2016; Gaddy et al., 2017). For instance, Startup 06 specifically mentioned the challenge of competing with faster-moving industries, emphasising how this competition adds to their funding difficulties.

Investment stakeholders in the interviews elaborated on the misalignment between the risk profiles of cleantech startups and the expectations of typical investors, driving them to prefer more established or less risky ventures (Cumming et al., 2016). This perspective supports the literature's view that investor reluctance stems from the significant uncertainty associated with cleantech ventures, especially during scaling phases. Stakeholder 04 further noted that this reluctance is particularly pronounced during critical stages of capital-intensive growth, creating a bottleneck that hinders commercialisation.

The interviews also add nuance to the literature by emphasising specific challenges faced by cleantech startups as they move beyond the early funding stages. Startup 08 expressed difficulty in securing new investments when proof points are lacking, even if they have progressed through significant development stages. This aligns with the literature's assertion that cleantech ventures face a financing gap due to the delayed returns they offer, leading to reduced investor confidence and prolonged time spent in the VoD (Harrer & Owen, 2022; Hartley & Medlock, 2017).

Funding Gap

The funding gap is the most significant barrier for cleantech startups, more pronounced than in other sectors due to the unique characteristics of cleantech ventures according to both the literature and the participants. Both sources identify investor reluctance and the high risks as a core reason for this funding gap, which restricts the growth of these startups and hinders their progression to full commercialisation (Cumming et al., 2016; Romme et al., 2023). The interviews highlight that this challenge becomes particularly acute as startups progress beyond early TRLs, when grants and subsidies are no longer sufficient, and larger private investments are required. Stakeholders noted the difficulty of securing funding in the transition phase from lab-scale to scalable operations, reflecting the deeper and prolonged VoD unique to cleantech startups (Frank et al., 1996; Muscio et al., 2023).

The literature explains that cleantech ventures face heightened risk perceptions among investors due to their unique risk profile making them more vulnerable to the VoD (Harrer & Owen, 2022; Shakeel & Juszczyk, 2019). This aligns with the sentiments expressed in the interviews, where both startups and stakeholders pointed out the particular challenges of securing capital for scaling, largely due to the high-risk nature of these ventures and the reluctance of traditional private investors to engage.

Europe

The interviews with stakeholders align closely with the literature regarding the European-specific barriers faced by cleantech startups, particularly funding scarcity and market fragmentation. Both sources emphasise the limited availability of later-stage venture capital in Europe compared to the United States, creating a significant hurdle for scaling (Duriaux et al., 2021; European Innovation Council, 2021; Kurowski, 2024; Romme et al., 2023). Similarly, the fragmented European market—with its diverse

regulations and complexities—aggravates the challenge of scaling across the continent, as highlighted in both the interviews and literature (Aernoudt, 2017; Botsari et al., 2019).

However, a notable difference between the interviews and the literature is the extent to which these barriers were recognised by the startups themselves. Only two startups explicitly mentioned the influence of the European environment on their funding difficulties. A potential reason for this disparity could be that the startups might not have an external benchmark to recognise these limitations, as they are deeply embedded in the European ecosystem. Since funding is often sourced locally, these startups may not be fully aware of how European funding compares internationally, resulting in limited recognition of regional funding scarcity. This leads them to perceive the current environment as standard.

Another explanation could be that there appears to be a wide availability of grants in Europe, which partially mitigates the challenges of private funding scarcity. For some startups, the grant provision has been sufficient to sustain their development journey until TRL7 or 8. As such, while Europe may have less private funding available, the relatively abundant grant support may create an impression that funding challenges are less severe than they are in reality.

5.2. Strategies

Cleantech startups and investment stakeholders collectively recognise a range of strategies employed by startups to navigate the VoD. This unified approach adopts a double-sided strategy, focusing on both meeting immediate financial needs and addressing the inherent high risks of cleantech ventures. In essence, these strategies are designed not only to ensure the survival of the ventures in the short term but also to establish sustainability and viability in the long term.

5.2.1. Bridging Funding Gap

The ability to effectively bridge funding gaps is crucial for cleantech startups to bridge the VoD. This section discusses several strategies that startups use to address these funding challenges, focusing on non-dilutive funding, alternative revenue streams, bootstrapping, and investor engagement. Each of these approaches offers distinct advantages for addressing immediate financial needs while also contributing to the long-term viability and scalability of the venture.

Non-Dilutive Funding

Non-dilutive funding, such as grants, serves as a cornerstone strategy for cleantech startups, particularly during the early and intermediate stages of development. In the initial phases, this type of funding is most applicable because smaller grants are relatively easy to obtain and sufficient to cover capital requirements for early R&D, intellectual property protection, and prototyping. By providing essential financial support without requiring equity, non-dilutive funding allows startups to retain full ownership and control during these critical early phases, creating a solid foundation for the rest of the development journey. This ensures that startups are better positioned for future negotiations with private investors while maintaining high investability, as they do not need to dilute ownership early on.

As startups progress to TRL4 and 5, their capital requirements increase significantly, making it more challenging to secure funding solely through non-dilutive means. At this stage, obtaining larger grants becomes more difficult due to increased competition and more stringent requirements. Consequently, startups need to diversify their approach by also seeking venture capital to meet their growing financial needs while maintaining momentum in scaling their technology. However, for multiple startups, non-dilutive funding continues to suffice beyond the initial stages, as demonstrated by half of the sample

(Startups 01, 02, 03, and 04). These startups successfully leveraged larger grants to support their development journey through more advanced TRLs. This enabled them to sustain their progress without immediate recourse to private financing. This suggests that in certain circumstances, grant funding alone can be a viable source of capital even as the startup moves towards commercialisation, reducing dependency on private investors during these critical growth stages.

Beyond its immediate impact on bridging funding gaps, non-dilutive funding offers additional benefits that contribute to the long-term sustainability of cleantech startups. One significant advantage is that it allows founders to retain equity, which is particularly important in the early stages when equity is most valuable. This retention ensures that founders maintain control over strategic decisions, allowing for greater flexibility and stronger positioning when seeking future funding rounds. Additionally, securing government grants or subsidies serves as a form of validation, signalling credibility to potential customers, partners, and investors, which is particularly valuable in sectors where regulatory compliance and credibility are crucial. Moreover, grant provisions can reduce the amount of capital required from venture capital, thereby lowering the risk of the investment and reducing investor reluctance, which in turn makes it easier for startups to attract private funding.

Moreover, reliance on government support for grants and subsidies forms a critical element of non-dilutive funding, especially in regions like Europe, where public support for cleantech is relatively strong. While this reliance provides critical resources during early development, it also poses challenges due to the competitive nature and restrictive conditions associated with securing larger grants as the startup grows. Grants can be restrictive, often accompanied by predefined conditions such as specific KPIs and timelines, which may limit the startup's flexibility to pivot or adjust its strategy in response to changing market dynamics. Additionally, biases in grant allocation and communication issues with grant providers further complicate the process.

However, the startups interviewed demonstrated strategies to effectively address these challenges. They tailored their grant applications to align closely with the objectives of the funding organisations, thereby improving their chances of success. To mitigate the financial impact of unsuccessful applications, they often submitted overlapping applications, ensuring that there was always funding pending and reducing the risk of a funding gap. They also worked on enhancing the clarity and specificity of their communication, sometimes with the help of consultancy companies, to ensure their applications met the requirements set by the grant providers.

Furthermore, leveraging blended financing emerged as a practical strategy. By combining grants with venture capital, startups such as Startup 06 maximised the benefits of both funding types, by using grants to lower capital requirements and venture capital to supplement necessary funding. This approach not only made the venture more attractive to private investors by reducing investment risk but also ensured that the startups were not overly dependent on either source alone. Thereby, they maintain a balanced and sustainable financing structure. This strategy allowed startups to make the most of available grants while also benefiting from private investment.

Alternative Revenue Streams

The use of alternative revenue streams represents a creative and pragmatic approach for cleantech startups to overcome funding constraints. This strategy is particularly applicable during early stages or periods of cash flow shortfall. By monetising existing activities, such as consulting, selling industry reports, or producing small product batches, startups can achieve a degree of financial independence during their development. This approach addresses the immediate need for operational funding without the complexities or conditions associated with traditional financing or grants. As such, it offers a practical mechanism to bridge funding gaps characteristic to the VoD.

The applicability of alternative revenue streams is particularly evident during the pre-commercialisation stages, roughly between TRL4 and 6. During these stages, product development may still be underway, and the main technology might not yet be scalable. However, the expertise and capabilities developed along the way such as technical knowledge or accumulated industry data provide opportunities for generating revenue.

The strategic value of alternative revenue streams also lies in their role in reducing perceived investment risk. By generating positive cash flow early, startups can signal their viability and operational efficiency. This in turn demonstrates a capacity for sustaining the business without the use of external funding. This capability can enhance the confidence of potential investors, making it easier to attract venture capital when needed. While these alternative revenue activities may not necessarily represent long-term solutions, they can fulfil an essential role by providing the startup with the financial breathing space needed through critical stages.

However, there are limitations to the scalability and sustainability of alternative revenue streams. These activities are often supplementary and might not contribute significantly to long-term growth or profitability. For instance, consulting or producing small product batches may help generate cash flow, but they could also divert attention and resources away from the core business. Thus, employing such strategies could delay commercialisation. The balance between sustaining the business in the short term and focusing on long-term product development is a nuanced challenge, which requires careful assessment.

Furthermore, the success of leveraging alternative revenue streams depends largely on the nature of the startup's innovation. Not all startups may possess products or services that can be monetised easily before full development. There may be significant variation depending on the specific sector or technology within cleantech. Nevertheless, as highlighted by the stakeholder in the study, alternative revenue streams could help navigate financial constraints, potentially reducing their dependence on other, often more restrictive, forms of funding.

Bootstrapping

Bootstrapping emerged as a critical approach for cleantech ventures to extend their financial runway and manage limited resources effectively. It is an accessible strategy applicable to almost all startups. By minimising operational costs, startups extend financial runways and maximise the use of the available financial resources. Key bootstrapping methods include limiting personnel expenses by relying on part-time employees, interns, and founders taking reduced salaries; re-using hardware; renting facilities instead of buying; and fabricating machinery in-house. These actions significantly help reduce operational expenses, as demonstrated by several startups in the study.

Bootstrapping is highly accessible, making it an attractive option for startups, regardless of their development stage or sector. This broad applicability enhances its value as a low-threshold strategy that can be adopted without requiring external funding, similar to alternative revenue streams. However, bootstrapping is not without limitations. Founders investing personal funds may face financial risks and may not have the financial resources to do so. Furthermore, relying on in-house solutions, as highlighted by Startup 06, requires careful judgment to ensure that the cost-saving measures do not hinder progress or result in inefficient use of time and resources. Moreover, while bootstrapping can effectively cut down costs, it is not a substitute for significant external funding. The savings achieved through bootstrapping are often limited in scale and cannot replace the larger sums typically needed for scaling and commercial growth.

Nevertheless, bootstrapping complements other financial strategies such as alternative revenue streams

and non-dilutive funding. By implementing accessible cost-management strategies, cleantech startups can extend their runway while seeking more substantial funding.

Investor Engagement

Investor engagement is an essential domain for cleantech startups to address to increase their chances of securing private investment. Engaging with investors involves several approaches, including targeting value-based investors, gathering feedback from investors, and focusing on effective communication. Each of these strategies contributes to enhancing the funding application of cleantech ventures.

One key approach within investor engagement is to ”Find Your Tribe,” which refers to seeking value-based investors whose interests align with the startup’s mission beyond financial returns. This strategy is essential for cleantech startups because investments in cleantech solutions often do not offer a quick and easy return. Unlike other sectors such as IT which can provide less risky and faster returns, cleantech ventures typically require longer development times and have higher capital needs, making them riskier. Unlike traditional investors, who are primarily driven by financial returns, value-based investors are more likely to prioritise the environmental and societal impact of their investments. By targeting these like-minded investors, startups can create more long-term partnerships that enhance commitment during difficult times. This alignment with the values and goals of potential investors leads to greater agreement on the startup’s mission, which in turn increases the likelihood of securing their financial support. Moreover, when startups approach these investors but fail to secure funding, they often receive valuable feedback. Moreover, in general by actively seeking and applying investor feedback, startups can refine their value proposition, product development, and business model. In this manner, startups can improve their overall alignment with market and investor expectations. As illustrated by Startup 06, even when facing initial rejections, understanding what investors require allows startups to make strategic adjustments to improve their chances of securing investment later. Getting regular feedback from investors helps startups to continuously adjust and align with market demands. Ultimately, this strategy reduces perceived risks and makes their ventures more attractive to investors. The engagement with investors is therefore not just about acquiring funding but also about enhancing the overall business proposition through external validation and insights.

5.2.2. De-Risking & Sustainable Growth

This section focuses on the strategies employed by cleantech startups to ensure sustainable growth and mitigate the various risks inherent to their ventures. These strategies go beyond bridging immediate funding gaps and are designed to strengthen the startups’ market position, validate their technology, and establish credibility in order to attract long-term investment and successfully commercialise their innovations. The following subsections explore different approaches used by startups to achieve these goals.

Market

The market-focused strategies discussed in this section highlight strategies adopted by cleantech startups to strengthen their market position and mitigate related risks. These strategies are not only vital for demonstrating the technology’s potential but also play a crucial role in enhancing investor confidence by validating market demand and showcasing tangible progress. The combined use of deployment-led innovation, customer discovery, market demand signals, strategic partnerships, semi-commercial deployment, early commercialisation, and recognition initiatives provides a multi-faceted approach to reducing market risks.

Deployment-Led Innovation

Deployment-led innovation is instrumental in demonstrating technological scalability and operational reliability throughout the entire development. This approach involves building in proof points where the technology is validated at different scales and environments. This staged progression allows startups to demonstrate tangible progress at each level, thereby addressing investor concerns about the viability of the technologies. By showcasing that the technology works in progressively challenging conditions, startups such as Startup 02 can provide concrete evidence of their progress, ultimately reducing perceived risks. By validating the technology in increasingly realistic environments, startups can gradually establish credibility in the market, which supports both investor engagement and customer interest.

However, this strategy comes with different resource requirements and benefits at each stage. Early lab-scale validation typically requires fewer resources and is useful for initial proof of concept, but it may not be sufficient to convince investors about scalability. Controlled external environments require more resources but offer greater validation, as they simulate real-world conditions without the full complexity. Finally, large-scale deployments require substantial resources but provide the most convincing evidence of scalability and market readiness. The challenge, therefore, lies in balancing the costs and efforts associated with each stage with the benefits of reducing risk, building credibility, and setting a solid foundation for future growth.

Customer Discovery
Customer discovery focuses on achieving a strong product-market fit by engaging consistently with potential customers and key stakeholders. By continuously interacting with the market, startups ensure that their product development is closely aligned with actual customer needs. This helps to avoid the risk of building solutions that lack real demand. This iterative feedback process enables startups to adapt and refine their product-market fit, which makes them more attractive to customers.

When investors see that a startup is actively validating its product with end clients and responding to feedback, it signals a proactive approach to understanding market needs and mitigating risks. This market responsiveness provides a solid foundation for commercialisation, ensuring that the product is well-positioned to meet the expectations and demands of its target market.

However, the success of customer discovery relies heavily on the startup's ability to effectively identify, engage, and learn from relevant customers. This capability is strongly influenced by the quality and composition of the team. In particular, the presence of individuals with the skills to build relationships, communicate effectively, and understand market needs is vital. A well-rounded team that combines technical and commercial expertise is crucial for good customer engagement.

Market Demand Signals
Market demand signals, such as LOIs and off-take agreements, add to validating market interest and reducing investor risks. These commitments provide evidence of customer demand, reassuring investors of future revenue potential even before full commercialisation. By demonstrating interest, startups reduce doubt concerning market demand.

The effectiveness of market demand signals lies in their ability to validate the business model. For instance, LOIs and off-take agreements provide a promise of future sales, which serves as evidence of customer commitment and interest. By demonstrating that customers are willing to commit, startups show that their technology is not only viable but also demanded in the market. This is particularly valuable in the cleantech space, where uncertainty around market adoption can pose significant risks. The use of such strategies by prominent companies such as H2 Green Steel and Northvolt underscores the potential of these strategies.

However, it is important to consider that securing these types of agreements is often more feasible for startups that have already achieved some degree of technology validation. For early-stage startups without an established track record, it can be difficult to convince customers to commit to such agreements. Therefore, this strategy tends to be more applicable once a startup has demonstrated tangible progress, such as through successful pilot projects or deployment-led innovation.

Strategic Partnerships

Strategic partnerships play a crucial role in the development and scaling of cleantech startups. These partnerships can take several forms, such as strategic alliances, joint ventures, or collaborations with research institutes and universities. The applicability of these partnerships generally becomes more pronounced in the later stages of product development when startups are nearing commercialisation. However, these partnerships can apply to earlier phases as well under the right circumstances.

Strategic alliances, for example, can offer significant advantages to startups still in the development stage. By communicating clearly that their technology is under development and by aligning their offering with market needs startups can demonstrate market interest and generate revenue even before their product is fully completed. Startup 05 effectively leveraged a strategic alliance by focusing on its green applications within the construction industry, gaining early credibility and support to further develop their technology. This approach highlights that strategic alliances can bridge the gap between development and market readiness. This allows the startups to begin commercialisation earlier than would typically be possible.

Joint ventures, on the other hand, are more suitable when startups are advancing towards scaling and commercialisation. These partnerships enable cleantech startups to enter diverse markets, gain financial backing, and validate their technology in different environments. Startup 07, for example, used joint ventures to demonstrate the potential of their technology in various international markets, thus establishing themselves as a serious industry player. This global proof of concept significantly mitigated market risk, enhancing the startup's appeal to both investors and future customers.

Partnerships with research institutions and universities offer further benefits, particularly in terms of accessing innovation, skilled talent, and shared facilities. Such collaborations have high applicability across most stages from early-stage research and pilot projects to scaling and commercialisation. These partnerships accelerate technology development while reducing associated costs. Financial and operational support is offered that de-risks the startup and positions it more favourably for future investment.

Semi-Commercial Deployment

Semi-commercial deployment is a strategy aimed at bridging the gap between technology validation and full-scale commercialisation. By deploying the technology at a reduced scale but under real-world conditions, Startup 02 established a track record of operational viability and revenue generation. This strategy allows startups to demonstrate their ability to generate income while covering operational expenses (OPEX). Such an approach is particularly advantageous for securing investor confidence, as it offers concrete evidence of the product's ability to perform under actual market conditions, thereby reducing perceived risks.

This strategy is most applicable in the later stages of development, when the technology can be tested in real-world conditions. However, while the primary aim of semi-commercial deployment is to build a track record and demonstrate technology viability, the revenue generated also contributes to maintaining operations and decreases investors' reluctance. So, this strategy contributes both to de-risking and securing funding.

However, semi-commercial deployment also has its downsides. It requires significant resources and investment to establish the infrastructure needed for even a reduced-scale deployment. This can be a financial burden for startups that are already resource-constrained. Moreover, the outcome of the deployment can also be negative resulting in further financial constraints.

Early Commercialisation
Early commercialisation, as demonstrated by Startup 07, involves bypassing traditional corporate customers to directly target individual consumers. This allows the startup to begin generating revenue and demonstrate market demand sooner. By selling directly to early adopters, the startup can create a strong customer base and validate market demand without having to secure partnerships with corporate entities. As these entities may be conservative and therefore hesitant to adopt new technologies. This approach helps startups to enter the market and provide valuable cash flow to further scale the technology.

Similar to semi-commercial deployment, early commercialisation is most suitable for startups in their later stages of development when the product is market-ready and capable of delivering immediate value to users. This strategy not only helps to secure financial resources in the short term but also builds essential market traction and validates the startup's value proposition. Although these strategies are only applicable when most significant technological risks are mitigated, they are useful for establishing credibility, generating income, and establishing a market presence.

Leveraging Recognition Initiatives
Leveraging recognition initiatives, such as accelerators, awards, and competitions, serves as a low-budget and highly accessible strategy for cleantech startups to enhance their credibility and visibility in the market. By participating in these initiatives, startups demonstrate their active involvement in the innovation ecosystem, which can lead to being noticed by relevant parties such as investors. This engagement also provides valuable opportunities for networking, learning, and refining business models. All benefits contribute to a better market and investment position.

This strategy's strength lies in its broad applicability across all stages of a startup's journey. Whether in the early stages of idea development or during the more advanced phases of scaling, startups can use recognition initiatives to showcase their potential to stakeholders. For example, as highlighted by Startup 06, participating in accelerators and applying for awards helped them gain "official traction," which contributed to attracting investors and enhancing their market presence.

However, while leveraging recognition initiatives is an accessible and cost-effective strategy, the extent to which actual credibility and investors' attraction is established remains a question. While awards and accelerator participation can provide external validation, these forms of recognition alone might not be sufficient to overcome the significant risks perceived by investors, especially in the cleantech space where long development cycles and high capital requirements are involved. While these initiatives may draw interest from various stakeholders, the key aspects of the startup remain unchanged. Therefore, while such initiatives can enhance visibility, they are often most effective when used in combination with other more substantive de-risking strategies.

Technology
Building consortia to boost technological development represents a strategic approach focused primarily on reducing technological risks. However, even though such risks were not a dominant concern among startups at the stages observed in the interviews, Startup 02 made use of consortia. These consortia, particularly with large corporations, enabled it to secure larger-sized grants and facilitate further technological development. This approach helped to refine the startup's technology in a real-world setting by reducing uncertainties and ultimately de-risking the venture. By advancing its technology significantly through these consortia, the startup was able to validate its progress, thus increasing investor confidence and market viability.

Beyond addressing technological risk, building consortia brings other significant benefits to the startup.

This strategy enhances its market position by enhancing the startup's credibility through collaboration with well-established corporations. The involvement of large partners not only ensures financial support in the form of larger-sized grants but also provides access to resources, expertise, and testing environments that would otherwise be inaccessible. As a result, this strategy contributes to broader business goals, such as securing further funding, improving market readiness, and demonstrating commercial viability.

However, the success of this strategy heavily relies on the startup's existing network resulting from the team. This highlights the importance of having a well-rounded team capable of establishing industry connections. In this way, this strategy demonstrates how technological development is deeply linked to financial and market considerations, and the team's strength and capabilities. This reinforces the notion that a well-rounded team plays a crucial role in the successful implementation of such strategies.

Team

The formation of a well-rounded and experienced team from the early stages is a critical strategy for cleantech startups. Instead of trying to build a capable team over time, having a strong foundation at the start mitigates many risks related to technological development and market fit. A well-rounded team, with both technical and commercial expertise, helps align innovation with market needs and improve investment applications. However, assembling such a team early on can be challenging due to limited resources and competition for skilled talent, making it difficult for startups to attract experienced professionals without offering significant incentives, especially very early on.

In addition to starting with a solid core team, startups must also expand their workforce as they grow. Strategies such as hiring part-time staff, interns, and leveraging incubator support are instrumental in keeping operational costs low while attracting the necessary talent. However, relying on part-time staff or interns may lead to a lack of continuity and commitment, and the limited experience of interns might slow down progress in critical areas.

A well-rounded team can also provide significant benefits beyond internal capabilities. A diverse and experienced team often has an extensive network, which can open up additional investment opportunities, such as attracting angel investors or wealthy individuals. Furthermore, these connections can facilitate the establishment of consortia and strategic partnerships, which are crucial for accessing resources, securing grants, and advancing technological development.

Adding diverse talent to the team also enhances the startup's ability to communicate and engage effectively with customers and investors. Team members with different skills and backgrounds can better address the various needs and concerns of stakeholders, making it easier to align the product with market demands and articulate the value proposition clearly to potential investors, thereby improving the startup's chances of securing funding.

Retention is another critical element, especially given the long development timelines and delayed profitability typical of cleantech ventures. Startups often offer ownership options or shares to align the success of the employees with the company. This sense of ownership helps retain key talent, despite the inherent risks and uncertainties in the cleantech sector. Nonetheless, offering equity as a retention strategy can dilute the founders' ownership over time, and the delayed realisation of value from stock options may not always be enough to keep key employees motivated through extended periods of uncertainty.

By prioritising building a strong team early, using cost-effective hiring practices, and aligning incentives with long-term company goals, cleantech startups are better positioned to navigate challenges,

attract investment, and achieve sustainable growth. However, forming and growing a well-rounded team remains very challenging, especially due to the scarcity of skilled people.

5.3. Limitations

This study has several limitations that must be considered when interpreting the findings. First, the sample size is relatively small, comprising eight cleantech startups and four investment stakeholders. This limited sample size restricts the generalisability of the findings, particularly across different sectors or developmental stages within the cleantech ecosystem. The study's focus on a specific group of European cleantech startups further narrows its applicability, potentially overlooking diverse experiences and practices in other regions and markets.

Second, the research relies on a qualitative methodology, which provides in-depth insights but may introduce potential biases in data collection and interpretation. The interview-based approach may be subject to social desirability bias, where respondents present themselves or their startups in a more favourable light, especially when asked about barriers such as fundraising and risk-mitigating challenges. Moreover, the qualitative approach might reflect the researcher's biases during data coding and interpretation. While efforts were made to mitigate these biases through data triangulation and iterative coding, the qualitative nature inherently limits the objectivity and reproducibility of the findings.

Third, the study provides a snapshot of strategies employed by cleantech startups at a specific point in time, without considering how these strategies may evolve as market conditions, regulatory frameworks, and funding environments change. This temporal limitation restricts the findings' relevance for understanding longer-term trends and the dynamic nature of the cleantech sector. Moreover, it can be seen that the identification of certain barriers and strategies is strongly related to the current stage startups find themselves in. Other barriers and therefore, strategies are less or more relevant in the different stages of technology development.

Fourth, the study primarily captures the perspectives of startups and investment stakeholders, with limited input from other key stakeholders such as government agencies, regulatory bodies, or customers. This narrow focus may overlook important factors that influence strategy formulation, including policy changes, customer behaviour, and broader ecosystem dynamics. To mitigate this limitation, an green tech initiative stakeholder is added to the investment stakeholders to provide additional insights from a different perspective.

Lastly, the research does not account for external factors such as economic conditions, geopolitical dynamics, or technological advancements that could significantly impact the strategies employed by cleantech startups. These factors could serve as important moderators that influence the effectiveness of various strategies but were not specifically addressed within the scope of this study. For example, the recent COVID crisis has had a significant impact on the startup ecosystem in general, more specifically on the cleantech ecosystem.

5.4. Recommendations

To build on the findings of this study, future research should aim to address its limitations and provide targeted insights for different stakeholder groups, specifically cleantech startups, investors, policymakers, and other relevant stakeholders.

Future research should expand the sample size to include a more diverse range of cleantech startups across different European countries and stages of development. This would enhance the generalisability of the findings, allowing startups to understand various strategies that can be employed under

different conditions. For investors, a larger sample could provide insights into the variability in risk profiles and the investment opportunities present across the cleantech sector, helping them make more informed decisions about supporting startups.

Conducting longitudinal studies is recommended to examine how startup strategies evolve over time in response to changes in market dynamics, regulatory frameworks, and funding environments. This would help startups understand the adaptability and long-term effectiveness of their strategies. Investors would benefit from insights into how startups can adapt to long-term challenges, which could influence their decisions on which ventures to support. Additionally, this type of research would help policymakers understand the impact of their regulations on startups, allowing for the development of more effective support measures. The importance of a possible longitudinal study is underlined by the differing focuses of the startups at different stages.

Future research should include a wider range of stakeholders, such as policymakers, regulatory bodies, and customers, to develop a holistic understanding of the cleantech ecosystem. For startups, understanding the perspectives of these stakeholders will provide insights into how their strategies need to align with regulatory and market needs. For policymakers, this research would highlight the specific challenges startups face and inform more effective regulatory support, such as targeted incentives and funding mechanisms to help startups navigate barriers such as the VoD. Thus, by including more stakeholders, a better understanding can be created from both sides. In that manner, strategic approaches can be tailored better according other stakeholders in the ecosystem.

Given that this study lays the groundwork for understanding strategic responses by cleantech startups, the next step should involve conducting a study that quantifies the success of various strategies. Such a study could provide startups with clear, data-driven guidance on which strategies are most effective for overcoming barriers in the VoD. For investors, a structured framework would help evaluate the potential of cleantech startups and make informed decisions when considering funding opportunities. This practical, evidence-based guidance would aim to contribute to academic literature as well as provide actionable insights for the cleantech community.

By addressing these targeted recommendations, future research can provide valuable, stakeholder-specific insights into how cleantech startups can overcome barriers and achieve sustainable growth.

6

Conclusion

This chapter draws a final conclusion from the research presented in this paper. It defines the timeline of the Valley of Death as identified by the cleantech startups. Furthermore, the nuances and differences between the barriers as perceived by the startups and described by the literature are concluded. Lastly, it identifies key strategies discussed by cleantech startups and investment stakeholders. All three conclusions are used to answer the sub-questions and eventually the main research question.

6.1. Timeline & Barriers

To address the sub-question, this section integrates insights from both cleantech startups and investment stakeholders to identify the critical stage at which barriers characteristic to the Valley of Death occur. Consequently, the relevant nuances and differences concerning the barriers are presented. The relevant sub-question is presented below:

Sub-Question 1

At what stages does the Valley of Death occur for European cleantech startups, and what barriers do they encounter?

6.1.1. Timeline

Based on the analysis presented, it can be concluded that the timeline of the Valley of Death for cleantech startups differs from what is typically described in the literature, with the onset occurring later. This delay can be attributed to the wider availability of grants and strong government support, which are unique to the cleantech sector. This sets cleantech ventures apart from deeptech as a whole, where challenges often arise earlier (around TRL2-3) due to limited funding availability (Romme et al., 2023).

Moreover, the timeline of the Valley of Death is highly specific to the sector, field, and even the type of technology being developed. However, for the cleantech sector specifically, there is a general trend that the Valley of Death starts around TRL4-5 and ends around TRL8, as startups move towards commercialisation, generate revenue, and gain financial independence, thereby overcoming the significant barriers that initially defined the Valley of Death.

6.1.2. Barriers

Based on the analysis in this section, it can be concluded that there is a general consensus between the interviewees and the literature regarding the key barriers faced by cleantech startups during the Valley of Death. Barriers such as high capital intensity, long development times, government dependence, market resistance, team building challenges, investor reluctance, and funding gap are consistently identified as critical challenges by both the literature and the interviewees. These barriers collectively create a high-risk environment for cleantech ventures, hindering their ability to secure the necessary funding for scaling and commercialisation.

However, a notable difference from the literature is the reduced emphasis on technological risk by most of the interviewees. While the literature often highlights technological risk as a major challenge in the early stages of cleantech development, the interviewed startups, most of which have reached stages beyond TRL5, did not consider it a significant barrier. This suggests that once cleantech startups have progressed past initial technical validations, the emphasis shifts towards overcoming market, financial, and team-related challenges.

Another key difference is the greater emphasis on product-market fit as a significant barrier. Both startups and investment stakeholders highlighted difficulties in aligning technologies with market needs, which often resulted in severe challenges in securing customers and investment. This focus on product-market fit contrasts with the literature, which tends to emphasise technological, financial, and market barriers without explicitly considering the challenge of aligning innovation with customer needs.

Additionally, the importance of team-related barriers was emphasised in a more nuanced way compared to the literature. The interviews assigned a more equal importance to the team compared to other barriers. Moreover, they not only illustrated the difficulty in assembling a well-rounded team from the start but also the challenges of scaling the team in line with the startup's growth. This included both talent acquisition and retention issues. Moreover, the interviews highlighted the impact of the scarcity of skilled people on growing their teams properly, which is not explicitly discussed in the literature.

The dependence on government support emerged as another nuanced insight. While the literature acknowledges this dependency, the interviews revealed more practical challenges, such as the limitations and constraints of grant funding and biases in grant allocation. This reflects a more complex relationship between startups and government support than what is typically discussed in the literature.

Overall, while there is broad alignment between the literature and the interview findings regarding the types of barriers faced by cleantech startups, the differences lie in the emphasis on product-market fit, the reduced concern for technological risk in later stages, and the nuanced understanding of team building and government dependence challenges. However, it must be noted that the literature creates a well-informed overview of the barriers cleantech startups encounter.

6.2. Strategies

To conclude, the strategies employed by European cleantech startups to overcome the barriers of the Valley of Death can be understood through the two sub-questions which address strategies concerning the immediate financial constraints and de-risking the ventures.

6.2.1. Bridging Funding Gap

To overcome the barriers of the Valley of Death, European cleantech startups must address the immediate financial constraints that hinder their progress. This section explores the various strategies these startups employ to secure the funding needed during critical phases of development. The relevant

sub-question is presented below:

Sub-Question 2

What strategies do European cleantech startups employ to address immediate financial constraints during the Valley of Death?

In terms of addressing immediate financial constraints, cleantech startups employ several approaches to bridge the funding gap that emerges during the Valley of Death. Non-dilutive funding, such as grants, serves as a critical source of early and intermediate-stage capital, allowing startups to retain ownership while advancing through the stages of development. However, as startups progress, these funding sources become increasingly competitive, necessitating the use of blended financing. The combination of grants and private venture capital are employed to meet growing financial needs and maximise the use of each funding source. Additionally, alternative revenue streams are leveraged to achieve some degree of financial independence during development. By monetising existing expertise and practices, startups can generate revenue to cover operational expenses. Bootstrapping is also a key method for reducing operational costs, through actions such as relying on part-time employees, using in-house fabrication, or renting facilities. This helps startups extend their financial runway without the immediate need for external capital. Lastly, investor engagement by targeting value-based investors, gathering feedback, and refining communication strategies plays an essential role in improving funding applications and reducing perceived risks.

6.2.2. Bridging Funding Gap

Managing the inherent risks of cleantech ventures is essential for startups to overcome the challenges of the Valley of Death. This section highlights the various strategies European cleantech startups employ to mitigate risks and establish a solid foundation for growth.

Sub-Question 3

What strategies do European cleantech startups use to manage the inherent risks of their ventures?

To manage the inherent risks of their ventures, cleantech startups adopt strategies that demonstrate the viability of their technology, strengthen their market position, and build credibility. Deployment-led innovation is utilised to validate the technology at various scales and environments, which helps establish proof points and build investor confidence. Customer discovery and engaging with potential customers ensure that the technology is closely aligned with market needs, reducing the risk of poor product-market fit. Market demand signals, such as letters of intent and off-take agreements, provide evidence of customer demand, reassuring investors of future revenue potential. Strategic partnerships and consortia-building with established companies or research institutions are used to access financial support, resources, and expertise that facilitate technological development and increase credibility. In later stages, semi-commercial deployment and early commercialisation are used to validate the technology under real-world conditions and generate revenue, further reducing perceived risks. Recognition initiatives, such as accelerators and awards, are also used to build credibility and visibility, which helps attract investor interest.

6.3. Final Conclusion

To conclude the research, the main research question is answered and presented below:

Research Question

What strategies do European cleantech startups implement to overcome the barriers encountered in the Valley of Death?

To overcome the barriers encountered in the Valley of Death, European cleantech startups implement a combination of strategies that address both immediate financial constraints and the inherent risks associated with their ventures. These strategies are most effective when integrated, as they provide both short-term solutions and long-term stability.

The key strategies identified include non-dilutive funding, blended financing, alternative revenue streams, bootstrapping, investor engagement, deployment-led innovation, customer discovery, market demand signals, strategic partnerships, consortia-building, semi-commercial deployment, and early commercialisation. Non-dilutive funding, blended financing, alternative revenue streams, and bootstrapping help bridge funding gaps while retaining ownership and extending the financial runway. Investor engagement improves funding applications and reduces perceived risks. To manage inherent risks, strategies such as deployment-led innovation, customer discovery, market demand signals, and strategic partnerships establish credibility, validate technology, and demonstrate market fit, ultimately enhancing investor confidence. By combining these approaches, cleantech startups can effectively navigate financial, technological, and market challenges, positioning themselves for sustainable growth and successful commercialisation.

Upon reflection, the conclusion that the strategy for cleantech startups to overcome the Valley of Death revolves around attracting more capital and generating early revenue streams is not a new or surprising result. This approach has been well-documented in existing literature across various industries, indicating that the strategies employed by cleantech startups align with broader entrepreneurial practices for bridging funding gaps and managing development risks (Casson & Nisar, 2007; Gbadegeshin et al., 2022; Perry et al., 2011; Rudolf, 2019).

While the focus of this study was on cleantech startups, the findings suggest that there may be no significant difference between cleantech startups and those in other industries in terms of bridging the Valley of Death for the majority of the strategies. Many of the strategies identified, such as bootstrapping, engaging with investors, and strategic partnerships, are commonly recommended across sectors (Casson & Nisar, 2007; Gbadegeshin et al., 2022; Perry et al., 2011; Rudolf, 2019). Studies such as those by Gaddy et al. (2017) and Polzin (2017) also emphasise the importance of early revenue generation and strategic financial management to navigate critical developmental stages, which resonates with the findings here.

However, it is important to consider whether there may still be unique aspects to cleantech startups. Factors such as the specific role of government support could set these ventures apart from other sectors. The heavy reliance on government grants and the specific market and regulatory dynamics of cleantech suggest there might be more nuanced differences that influence how these startups navigate the Valley of Death compared to startups in other industries. One unique aspect of cleantech startups is the extent to which they widely leverage non-dilutive funding in the form of grants, often until very late stages or even throughout the entire development phases. While other sectors also leverage grants, cleantech ventures seem to enjoy a wider availability of grants due to their nature of addressing

alarming problems such as the climate crisis and sustainability.

In conclusion, while the strategies employed by cleantech startups to overcome the Valley of Death broadly align with general entrepreneurial practices, the specific context of cleantech does present additional nuances. The heavy reliance on government support, often in the form of non-dilutive funding, can be attributed to the fact that these startups address climate change and sustainability, which sets cleantech startups apart from other sectors. Understanding these unique aspects could provide valuable insights for policymakers, investors, and startup founders in effectively supporting cleantech ventures on their path to commercialisation and sustainable growth.

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A

Literature

A.1. Conceptual Framework

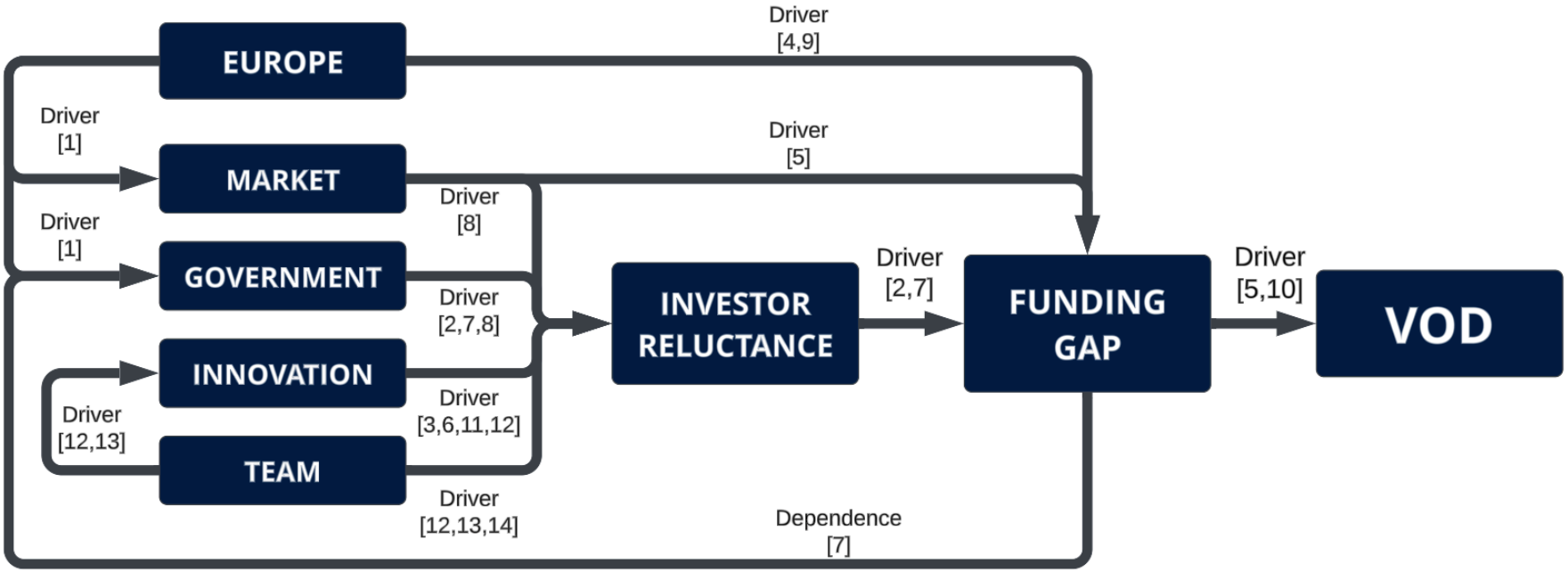

Figure A.1: Conceptual Framework

1. Botsari et al., 2019
2. Cumming et al., 2016
3. de la Tour et al., 2017
4. Duriaux et al., 2021
5. Frank et al., 1996
6. Gaddy et al., 2017
7. Harrer and Owen, 2022
8. Hartley and Medlock, 2017
9. Kurowski, 2024
10. Muscio et al., 2023
11. Polzin, 2017
12. Romme et al., 2023
13. Singh and Subrahmanya, 2023
14. Zacharakis and Meyer, 2000

B

Methodology

B.1. Interview Script

Interview Guide

1. **Introduction**

Thank you for taking the time to speak with me today. We will be discussing the timeline, challenges, and strategies that European cleantech startups employ to navigate the Valley of Death and overcome unique barriers in the cleantech sector. The goal of this research is to better understand the specific challenges and strategies cleantech startups are using to achieve market viability.
Before we begin the recording: I have sent you the consent form. Do you have any questions about it? Did you have the opportunity to sign the form?
I am now starting the recording. **[START]** The recording has started. Could you please confirm once more that you agree to the informed consent form and to being recorded?
If yes:
To Startups: Can you please introduce your role and responsibilities at [Company Name], and provide an overview of your company's technology and in which development stage you currently are?
To Investment Stakeholders: Can you please introduce your role and responsibilities at [Company Name], and provide an overview of your company's investment focus in terms of the industry sector, investment stage, and geographical location?

2. **Timeline**

To Startups: From your perspective as a startup, at what stage in your development process do you encounter the Valley of Death?
To Investment Stakeholders: From your perspective as an investor, at what stage do you see Cleantech startups typically encountering the Valley of Death?

3. **Barriers**

To Startups: Could you please explain the barriers you faced as an entrepreneur while traversing the Valley of Death?
To Investment Stakeholders: Could you please explain the barriers you have observed Cleantech startups facing while traversing the Valley of Death from an investment perspective?

4. **Strategies**

To Startups: Could you describe the strategies your company has implemented to overcome the barriers encountered in the Valley of Death?
To Investment Stakeholders: What strategies have you observed Cleantech startups using to overcome the barriers in the Valley of Death?

5. **Conclusion**

Thank you for sharing your insights and experiences about the Valley of Death. Last question: Is there anything else you would like to share about your experience in or with the Valley of Death?
[RECORDING STOP] Thank you again and have a great day.

B.2. Consent Form

Dear Participant,

You are being invited to participate in a research study titled **"Navigating the Valley of Death: Strategies and Barriers for European Cleantech Startups".** This study is being conducted by Rex Vroon as part of the Master Thesis project in the TPM faculty of TU Delft.

Purpose
The purpose of this research study is to understand the barriers faced by European cleantech startups as they traverse the Valley of Death, and to explore the strategies they employ to overcome these challenges. By participating in this study, you will contribute valuable insights into the financial, regulatory, and market obstacles that hinder the progress of cleantech startups, and the innovative approaches used to navigate these barriers.

Procedure
Your participation will involve an interview lasting approximately 30-45 minutes. During the interview, we will discuss topics related to the specific financial, regulatory, and market challenges your startup has encountered, and the strategies you have used to address these issues. This will help to identify effective methods for overcoming the Valley of Death in the cleantech sector.

Your input will be aggregated with the input of other members of the cleantech startup and be presented anonymously in the resulting MSc thesis. The thesis will be made publicly available upon completion of the project. The name of the company shall not be associated with or named within the study.

Confidentiality & Data Handling
We recognise the importance of safeguarding your privacy and confidentiality. Any information you provide during the interview will be treated with strict confidentiality. Your personal information will not be disclosed, and all data collected will be used solely for this research study.

The data collected will be securely stored on TU Delft's servers and will only be accessible to the TU Delft researcher(s) involved in this study. Your data will be stored for a maximum of a month after the end of the study (October 2024), after which it will be securely deleted.

Participants will be provided with a transcript of their interview for review before any information is included in the final thesis. This allows participants to identify and request the removal of any commercially sensitive or personal information they do not wish to be included.

Voluntary Participation and Withdrawal
Your participation in this study is entirely voluntary, and you have the right to withdraw at any time without providing a reason. Your decision to participate or withdraw will not result in any negative consequences.

Informed Consent

Please tick the appropriate boxes	Yes	No
I have read and understood the information above, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.		
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.		
I understand that I will receive transcript of the interview for review and after review that it will be made public in the Thesis.		
I understand that taking part in the study involves audio-recording and transcription of the interview for academic analysis purposes. The data will not be shared with third parties to minimize the risk of data breach.		

If you have any questions or concerns about the research study or your participation in it, please feel free to contact me.

By participating in this study, you indicate your consent to the terms outlined above. If you agree to participate, please sign and date this form below.

[Participant's Signature] [Date]

C

Results

C.1. Timeline & Challenges

C.1.1. Timeline

The following table presents supporting quotes from startups and investment stakeholders, reinforcing the general consensus of both groups of interviewees.

Table C.1: Quotes Timeline

Source	Quote
Startup 03	”Getting that first early-stage investment is definitely something that slowed us down, essentially.”
Startup 06	”Grants will limit probably around the seed stage latest because then you need much more money, and that only comes from private investors.”
Startup 06	”So finance is getting someone to believe in you, the earlier you are, the harder it is. That’s if you’re looking at private investment.”
Startup 08	”The problem with that money slowly running out is that now we have raised quite a bit of money to develop that product. Then we have spent a lot of money, while we have not actually made any progress. So, we are now at a point where we cannot easily attract new money because there is already a certain valuation.”
Stakeholder 02	”Generally speaking of the VoD, and in most markets, besides maybe the US, there’s especially in the deeptech side, there is a huge lack of funding. It’s just a challenge and especially if you look at Europe, especially kind of as you get later and later, becomes more and more difficult to get funding.”
Stakeholder 04	”So that’s where personally I see the bigger VoD or where companies struggle to attract funding in those 10 to 60 million equity rounds [around moving from demo plant to commercial plant].”

This table provides quotes that illustrate alternative perspectives, where some startups and stakeholders experience an earlier or later VoD onset due to sector-specific challenges.

Table C.2: Quotes Timeline Different Views

Source	Quote
Startup 05	”Yes right, that’s true.” [As a response to the question if the construction market is conservative]
Startup 07	”If you invent something new in the construction, the chance that you will succeed is close to 0%. One of the reasons is that the current technologies, deliver what seems to be expected from the construction.”
Startup 07	”This is how we look at the construction. Give us a roof over our head and don’t think about anything else. And if you go to those other things such as green technologies, nobody cares.”
Stakeholder 04	”If it comes from a university, you usually have a good amount of research on that done prior within the university. So then you have usually at least a bench scale. Sometimes if they do it via grants, public-private partnerships or bigger calls, they might even have a small demo plant. Then the next step is the demo plant where they have a big vessel that shows that it works at scale. However, scale is still in air quotes because that’s not a commercial plant.”

C.1.2. Barriers

Additional supporting quotes on the barriers cleantech startups face are presented here. The quotes are presented per barrier identified from the literature.

Capital Intensity

Below additional supporting quotes regarding the high capital intensity of cleantech ventures can be found.

Table C.3: Quotes Capital Intensity

Source	Quote
Startup 01	”As a hardware business, you need more capital, more often.”
Startup 03	”Especially when it’s hardware then it can get very expensive.”
Startup 04	”The challenge is to start financing that... where you relatively need a lot of money to get through those different stages.”
Startup 05	”You can already hit the numbers pretty quickly if you want to set up whole cultivation.”
Startup 06	”Around the seed stage you need much more money.”
Startup 07	”In deep tech, you will never know how much money you will need. It’s almost impossible to figure out how much money you would really need, it’s always much more than you think. If you think you need 5 million, you will end up with 25. That’s a huge difference.”
Startup 08	”The development takes a very long time and is very capital intensive.”
Stakeholder 01	”I saw how painful and inefficient the fundraising process still was for, in particular, the capital-intensive industries.”
Stakeholder 03	”You really need sufficient capital and that is also something that is not always available on the market.”
Stakeholder 04	”The problem is that you’re not just looking at a few million; you might need tens of millions to build a commercial facility.”

Development Time

The supporting quotes regarding the long development time of cleantech ventures can be found below.

Table C.4: Quotes Development Time

Source	Quote
Startup 01	”We spent a lot of time developing the technology, because we have hardware, we spent a lot of time developing the technology.”
Startup 02	”Developing our technology takes time, especially as we need to ensure everything works seamlessly before scaling up.”
Startup 05	”You have to imagine the moment I put a sample in or put it outside and I put some water on it and I see if it grows then I am three weeks down the line before I know if I have done something good or not.”
Startup 06	”Success takes so long in the material sector, even just to install a machine, it can take a year, so your progress looks really slow at certain points.”
Startup 08	”The development takes a very long time and is very capital intensive.”
Stakeholder 03	”Especially so when it comes to cleantech startups,… that you’re developing hardware, which takes way longer before that makes money and requires quite some high, capital-intensive investment upfront.”
Stakeholder 04	”Even though the technology works, it takes time for a commercial-scale operation to become profitable.”

Government Dependence

The following quotes provide additional supporting evidence of government dependence, showcasing the reliance on grants and the impact of government policies on cleantech startups.

Table C.5: Quotes Government Support

Source	Quote
Startup 01	”Recently, we received a big grant from the European Union, one of the European Union umbrella funding schemes.”
Startup 02	”We are looking for an investment of 12 or 15 million. Half of that we still manage to get from public funds with subsidies.”
Startup 03	”So now, since we have those two national grants, essentially giving us a runway of two years, which is very nice for a change.”
Startup 04	”Subsidies worked well for us... We just secured a subsidy of 25 million euros.”
Startup 08	”We did that [raising funding] through subsidies.”
Stakeholder 01	”They are often dependent on regulation, policy, et cetera, for their pricing. So, they are going to be more expensive in the near term. How much more expensive depends on timing and magnitude of certain supportive policies.”
Stakeholder 03	”I think you see that a lot with impact entrepreneurs that they actually have some kind of additional barrier to success [dependence on government policies and subsidies].”

Uncertainty Government Support

The limitations of government support for cleantech startups are presented here, there are divided per category of the limitations.

An emerging limitation was the small grant size, which was insufficient as startups scaled and required larger funding to continue their development.

Table C.6: Quotes Grant Size

Source	Quote
Startup 01	”We received small grants from 10 to 50k. It was the smaller super teeny-tiny injections in our capital because as a hardware business, you need more capital, more often.”
Startup 06	”Grants will limit probably around the seed stage latest because then you need much bigger money, and that only comes from private investors.”
Startup 08	”We have now run out of subsidies so now it is difficult to find a new bigger one.”

Despite the availability of larger grants, they were significantly harder to secure due to intense competition, making it more difficult for startups to obtain significant funding.

Table C.7: Quotes Competition Grants

Source	Quote
Startup 08	The larger the subsidy, the less likely you are to get it, usually. That is not entirely true, but for the substantial large subsidies, there is often only a small chance that you will receive it, so that is more difficult, especially if we find a larger amount."
Startup 08	You have some major European subsidies. It is not necessarily inherent to the subsidy, but it is more simply a consequence of, if there is a lot of money, many people will apply for such a subsidy. So especially for European subsidies, they are very competitive, because a lot of people apply for them, within the Netherlands it is a bit more manageable."

Furthermore, a lack of sustained support was noted, where initial grants did not extend to later stages, leading to development delays.

Table C.8: Quotes Sustained Grants

Source	Quote
Startup 02	"We often saw was: Yes but we have already funded that? No, you funded step 1 or you funded step 2. I always explain this is our development trajectory. This is the timeline we expect that comes with it. These are the steps we take and we are now talking about step 1. Well, then you go for a while. Yes, step 1 was successful and this is step 2."
Startup 02	"There should be a 'memory' between the subsidies; having previously received a grant and moving to the next step should be a plus."

The restrictive nature of grants prevented startups from pursuing commercial opportunities or adjusting their projects as they evolved.

Table C.9: Quotes Restrictive Nature Grants

Source	Quote
Startup 03	"The issue there is that it's not as, what should I say, fluid, right? It's restrictive funding. So you have to do certain specific things, and you can't do commercial things."
Startup 06	"And when you write, when you apply for a grant, sometimes you're made to stick to it."

Startups encountered information asymmetry and biases among evaluators, particularly when dealing with non-traditional or complex technologies.

Table C.10: Quotes Information Asymmetry & Biases Grants

Source	Quote
Startup 01	”The evaluators are very biased, they are putting in a lot of their personal views on the technologies. Sometimes they don’t even have the scientific background enough to understand what is going on and what is being proposed. So, they are perceiving it as a regular, as a bystander on the street, while I am explaining it to someone who I expect to understand the science, so that was probably also a mismatch the first time around.”
Startup 02	”Where a major bottleneck lies in grant provision is that both the officials who have to form an opinion about it and the experts they hire... usually your dominant way of doing things now... if you come from a round cookie factory and someone proposes square cookies you can probably find twenty reasons why square cookies are really stupid.”

Communication with grant providers was often a challenge, as startups struggled to explain their technologies in ways that aligned with grant expectations and KPIs.

Table C.11: Quotes Communication Grants

Source	Quote
Startup 01	”We often struggled to make our complex technology relatable and understandable to investors. We had to simplify our message and ensure that it conveyed the practical benefits and the innovative aspects of our technology.”
Startup 01	”Each grant body has different KPIs in mind, some are looking for the impact goals, another is looking at the revenue generation, traction, technology aspects, or energy efficiency of the technology, and so on.”
Startup 02	”The biggest delaying factor has been that we had a lot of trouble explaining to the grant provider... We have had to submit a lot of applications two three four five times. Each time with improvements to actually explain what we were already explaining.”

Market

The following quotes highlight the market barriers cleantech startups face.

Table C.12: Quotes Market

Source	Quote
Startup 04	”The problem is that many startups are run by scientists who often have a lot of details and nuances, making it difficult for the layperson to follow.”
Startup 05	”The market is very conservative.”
Stakeholder 02	”It’s actually a lot harder to find something that actually creates value for people than people think. It’s not just sort of like, oh, we found something that’s technically cool. No, it actually has to do more than that.”
Stakeholder 02	”Particularly with deep tech... they often start with the solutions and then try to figure out what problem is connected to that solution.”
Stakeholder 03	”There is far too little thinking from the customer’s point of view, often if you really have a purely technology founding team.”
Stakeholder 03	”You often see that this is checked far too late what does the market want and is this still competitive, does this still meet the requirements that customers actually want, who are my customers anyway, how do they develop.”

Team Building

The following quotes highlight the team building challenges faced by the startups.

Table C.13: Quotes Team Building

Source	Quote
Startup 01	”We struggled to hire technical talent.”
Startup 05	”The real challenge is the enormous shortage of manpower, and trying to keep up with so many tasks simultaneously.”
Startup 06	”Once you’re getting them in, you’re also working with limited resources, so once people study or spend five, ten years in the industry, you want a certain level of comfort at some point, so you’re also taking away that comfort, so you’re really narrowing down.”
Startup 06	”When you’re looking, getting them to come to a situation where you’re living month by month because it is a startup, you don’t know if this will actually get to the end is [gets even harder]. It takes a very, very specific type of individual.”
Startup 06	”Finding the right person is extremely difficult, and then managing to retain that person [is even more difficult]. So if it’s the right person, they usually stay, but you can’t think it’s the right person, so okay, on paper it looks good, in the first month it looks good, but by the sixth month, they actually realise, ‘Hey, this is going to be tough’, and that personality, that’s when it kicks in, and I think that’s really hard.”
Startup 08	”Finding good people is always difficult. That’s for everyone and that is also difficult at every stage.”
Startup 08	”You need more people to speed up your development. But development takes longer so you have less money to hire people.”
Stakeholder 01	”The other point to make is also talent availability, a lot of people want to go into climate, but I think there’s a scarcity of specific technical skill sets.”

The following table presents additional supporting quotes for the view of Investment Stakeholder 03 that the lack of a well-rounded team leads to the VoD.

Table C.14: Quotes Team Building as Main Cause

Source	Quote
Stakeholder 01	”There’s still not quite enough people with real commercial execution background that are going into these companies who have the level of ambition, but also the execution capabilities.”
Stakeholder 03	”There is far too little thinking from the customer’s point of view, often if you really have a purely technology founding team.”
Stakeholder 03	”In management teams of start-ups, it is just far too little diverse often.”
Stakeholder 03	”It’s all the same kind of people who just really like developing technology or who really like doing marketing, for example, because they’re good at that or certain things, but because of that they really have a big blind spot.”
Stakeholder 03	”A company goes through different phases... after that when you have to scale up, for example, you have to do some more repetitive things, then you have to have some more operational people, some more structured people who, for example, make sure it’s all well organised.”
Stakeholder 03	”So again that has to do with diversity. I think if you come from a family where people are just, or not just, also entrepreneurial and have field. Then it’s much easier to raise that first pre-seed funding, as it’s called.”
Stakeholder 03	”I think funding, picking up the field, is just I think also difficult if you don’t have the right network.”

Investor Reluctance

The following table provides additional quotes illustrating the high risk perception leading to investor reluctance.

Table C.15: Quotes Investor Reluctance

Source	Quote
Startup 02	”In Europe, we are completely uncomfortable when a startup comes along and says, I’ve already burned 50 million, this is my plan, I want to raise 15 million, do you have 3 million for me. Then you notice that that question is either bigger than the wallet or too complex. Then they find that the amount of money you’re asking for doesn’t match the stage of the technology.”
Startup 03	”You need money to get traction and you need traction to get money.”
Startup 04	”It is primarily the seed round that is difficult, especially in the Netherlands, but also more broadly in Europe, where they want you to have shown a lot already. And as I just mentioned, it is relatively capital-intensive. So you have to be very careful about what you do and don’t do.”
Stakeholder 01	”More and more investors now are looking at kind of easier later stage more cash flow profitable deals.”
Stakeholder 04	”Investors are typically hesitant to commit to these large-scale projects, leading to a significant bottleneck in the commercialisation process.”
Stakeholder 04	”The challenge is proving that the facility can generate consistent revenue before running out of capital.”

Funding Gap

The following quotes serve as additional support to the funding gap experienced by cleantech startups.

Table C.16: Quotes Funding Gap

Source	Quote
Startup 02	”We’ve already invested a substantial amount, and we still need more to continue. Investors are hesitant because they want to see clear evidence of potential returns, and we haven’t been able to show significant profitability yet.”
Startup 03	”Fundraising is definitely the most tricky part.”
Startup 04	”It is primarily the seed round that is difficult, especially in the Netherlands, but also more broadly in Europe, where they want you to have shown a lot already and it is relatively capital-intensive. So, you have to be very careful about what you do and don’t do.”
Startup 05	”There is a lot to do and with little money, you are forced to do a lot yourself.”
Startup 06	”The biggest challenges are financing.”
Startup 07	”There’s basically no money in deep tech, just no money at all.”
Stakeholder 01	”The fundraising process is still painful and inefficient for, in particular, the capital-intensive industries.”
Stakeholder 03	”You really need sufficient capital and that is also something that is not always available on the market.”

Europe

The following additional quotes highlight the challenges of funding scarcity and market fragmentation specific to the European cleantech ecosystem.

Table C.17: Quotes Europe

Source	Quote
Stakeholder 01	”The fragmentation of the European ecosystem is an additional challenge. Language difference and local laws and legislation.”
Stakeholder 02	”That’s a challenge of how we get it so that there are more slightly later stage investors in the deeptech space locally.”

C.2. Strategies

In this section, tables can be found with additional supporting quotes about the strategies. The tables are divided equally to the ’Results’ chapter.

C.2.1. Bridging Funding Gap

Additional supporting quotes about addressing the funding gap are presented here.

Alternatives

All the additional supporting quotes for the different alternatives for private funding can be found here.

In the table below, additional quotes about non-dilutive funding strategies are presented.

Table C.18: Quotes Non-Dilutive Funding

Source	Quote
Startup 01	”We applied for European funding, we applied for some smaller programmes. Those were not very big checks from 10 to 50k but still, those are some equity-free grant sums that you can use to survive through tough times.”
Startup 03	”So it’s mainly been like bootstrapping, incubator support and national non-dilutive grants for research.”
Startup 03	”We got to significantly larger grants. So that’s really when we’re a bit accelerating let’s say so hiring like two full-time staff. So now, since we have those two national grants, essentially giving us a runway of two years, which is very nice for a change. This kind of reduces a bit of the pressure.”
Startup 04	”In the phase that a startup goes through you start with an idea you check if it is feasible do lab-scale tests and you can go a long way with the subsidies that are available.”
Startup 04	”You can get subsidies in every phase. We just secured a subsidy of 25 million euros. That is quite nice and it can be done at any stage.”
Startup 08	”Subsidies are a way to raise money, development subsidies. There are different pots for this, so to speak, and different phases that we can participate in.”
Stakeholder 02	”There is also quite a lot of non-dilutive funding out there. Companies actually can decrease the amount they are raising because they got more money through non-dilutive means.”

As stated in the text the grant provision has many limitations, the quotes highlighting the strategies employed by the startups to mitigate those limitations are presented below.

Table C.19: Quotes Grant Limitations Strategies

Source	Quote
Startup 01	”Each grant body has different KPIs in mind, some are looking for the impact goals, another is looking at the revenue generation, traction, technology aspects, or energy efficiency of the technology. So, when you apply for the grant, you have to see through who is behind it, who is, what are the goals of this particular grant body, what are the goals of this particular grant programme, how do you formulate your thoughts to show the values of the grantor.”
Startup 01	”You tailor your wording, proposition, and approach to the project, grants are typically not for the company in whole, but strictly for a project with KPIs. You should focus on different aspects of your day-to-day business, but especially how you can achieve those KPIs and show the grant body that you are ready to achieve them, you understand what is needed, and you have the team to do it.”
Startup 01	”We were working with a consultancy firm, because those big grants are not possible to do with no experience. We paid for a firm to help us navigate through the entire process.”
Startup 01	”We applied for European funding, while we applied for some smaller programmes and some awards.”
Startup 02	”Yes, we always did the overlapping applications, so we were always working on a project that was already funded while we were applying for the next one. So that way, you build in time so that even if you get three rejections, you eventually get money at some point.”
Startup 02	”We started adding scientific appendices to prove that it simply isn’t. You can calculate that. There are articles about it that have calculated it.”
Startup 03	”For example for us part of the reason why we started in this country was that kind of competitive landscape we saw that we can get grants relatively easier than for example if we were in France or something.”

Additional supporting quotes of the strategy of generating alternative, early revenue streams to sustain startups are presented below.

Table C.20: Quotes Alternative Revenue Streams

Source	Quote
Stakeholder 02	”You can set up this really interesting industry report from all your customer discoveries, create some report out of that and charge for that report.”
Stakeholder 02	”In the meantime, what they can do is actually sell a small batch to make money just by producing some of these vaccines, for example, and selling them to various clients.”
Stakeholder 02	”I think there is an opportunity if companies just do basic consulting, like we’re going to consult the money we make is going to fund the company.”

One of the strategies to mitigate immediate funding constraints is bootstrapping as seen in the interviews. Additional supporting quotes describing this strategy are shown below.

Table C.21: Quotes Bootstrapping

Source	Quote
Startup 02	”So what we are now forced to do is have quite a turnover in the company, which we are not currently supplementing so that our burn rate goes down.”
Startup 02	”We are looking at whether a part of what we have pre-financed without subsidies, we have built all the hardware. In the next test, we will use that hardware again.”
Startup 03	”The incubator is a big support because from there we can get like engineering staff part-time, some facilities that otherwise you know it would be very expensive.”
Startup 03	”We had only part-time staff besides myself. For example, we had a couple of interns that were national scheme sponsored, so we didn’t have to pay.”
Startup 05	”We really did gather an army of interns, about six because there are only two of us.”
Startup 06	“So, for example, some machines, instead of spending 20K, we’ve got them done internally for 1K, which is saving money.”

The following quotes serve to illustrate the judgement calls when employing bootstrapping strategies.

Table C.22: Quotes Bootstrapping Challenges

Source	Quote
Startup 06	”Sometimes that decision can also backfire. So, if it takes you six months to do it, then you actually lose the burn rates.”
Startup 06	”We did the wrong mistake where we said we’re always going to DIY it, and then we realized we just wasted years in one situation, for example, and actually had to employ more people just because the machines we were building weren’t as efficient as what we bought off the shelf.”
Startup 06	”If we can do it so it’s always having that judgment quality because sometimes DIY can take you in the wrong direction.”
Startup 06	”Bootstrapping comes with a lot of judgment calls as well, where you need to and where you can’t.”

Investor Engagement

All the additional supporting quotes for investor engagement to increase funding probabilities are found here.

In the table below, quotes regarding the strategy of engaging with value-based investors are presented.

Table C.23: Quotes Value-Based Investors

Source	Quote
Stakeholder 02	”Especially, in the beginning, and leading up to the Valley of Death, there are those types of people if they really are on board with your vision and what you’re trying to do, I think those are the people that will be more on board with actually staying on because they want you to succeed.”
Stakeholder 02	”I think a different thing to realise is that a certain element of investment is dealing with monetary gain. But there are many, many other forms of value. And people can make investments based on these other forms of value.”

One of the strategies for increasing funding probability is leveraging feedback from investors. Additional quotes describing this strategy are shown below in the table.

Table C.24: Quotes Investor Feedback

Source	Quote
Startup 02	”We are Startup X with an entrepreneur who has done it many times before. Take a look and especially the conversation we had last week help us to make the story so that you would find it investment-worthy. It helps us fill in the missing storylines so that we can actually make ourselves a bit better if we were to pitch it to you or your colleague or someone in your sector.”
Startup 06	”You need to do a market fit with your investors. So it’s approaching the investor, getting the know if you have to, but understanding why that investor is telling you no. One, there can be a completely different fit, and that’s not the investor for you, so don’t waste your time.”

C.2.2. De-Risking and Sustainable Growth

Additional supporting quotes about de-risking and ensuring sustainable growth for cleantech ventures are found in this section.

Market

All the additional supporting quotes for the strategies regarding the market are presented here.

In table below, additional supporting quotes on deployment-led innovation are presented.

Table C.25: Quotes Deployment-Led Innovation

Source	Quote
Startup 01	“Those doses [of financial injections] were possible only because we were showing results, we were showing that we were doing experiments.”
Startup 04	“You have to be very strict on execution ensuring that the work you do is well-supported and done methodically so that you don’t waste time. Why we succeed is because we consistently show that we meet our milestones and do what we promise thereby making progress.”
Stakeholder 01	”Then deployment-led innovation. So, scaling, demonstrating real milestones in the real world while you’re continuing to build out the end state perfect product.”

Additional quotes describing the customer discovery strategy are presented below in the table.

Table C.26: Quotes Customer Discovery

Source	Quote
Startup 06	”We’ve sent samples to all the big players in the industry. Everyone has replied with really positive results already. So to all manufacturers and chemical partners. As their data is usually better than ours, so we’ll bank on that as well now.”
Stakeholder 02	”You have to watch the market very closely from the start. And have a certain view of a feasible business case quickly.”
Stakeholder 02	”If companies could consistently get to speak with over 50 customers then if let’s say all 50 customers will say the same thing a problem will start to emerge.”
Stakeholder 02	”You’ll get 20 of them or 25 of them will start to converge on similar ideas and that’ll probably give you an insight.”

The table below presents two additional quotes regarding the formation of strategic partnerships.

Table C.27: Quotes Strategic Partnerships

Source	Quote
Stakeholder 03	*”They should make smart agreements with industry if possible. With pilots or with cooperation programmes or joint development programmes.”*
Stakeholder 03	*”They should work very well with research institutes or universities to gain access to smart people and new innovations. Maybe also to be able to share facilities there, for example. So that it becomes easier to develop your product or that it is cheaper.”*

The quotes below further illustrate an early commercialisation strategy by Startup 07.

Table C.28: Quotes Early Commercialisation

Source	Quote
Startup 07	”We don’t have partners with big corporations because if we were waiting for this, we would wait another hundred years. So, we decided to go to individual clients.”
Startup 07	”Our first client from Amsterdam, he found us somewhere on YouTube and he’s allergic. So, he took his car and he drove 1,500 kilometres from Amsterdam to Warsaw to our office and he said, I was looking for this mineral natural-based solution because I am allergic. This was our first client from Amsterdam.”

The table below shows additional supporting quotes on leveraging recognition initiatives.

Table C.29: Quotes Leveraging Recognition Initiatives

Source	Quote
Startup 01	”It was important to show that we are active in acceleration programmes, community members, that we are listening to the workshops, participating, taking time to do the homework.”
Startup 07	”We won all the competitions, we won the competition in Poland, in Paris as well.”

Team

All the additional supporting quotes for the strategies regarding team building can be found here.

Table C.30: Quotes Team

Source	Quote
Startup 06	”It’s that kind of decision [making judgment call on bootstrapping strategies]. And we do have some experience. Again, we had another startup doing that for a number of years.”
Stakeholder 02	”I think if we actually promote more of these people, especially considering that there’s fewer and fewer academic jobs available.”
Stakeholder 03	”And then also keep them captivated and bound for the long term. Smart ways to keep well your culture in your company but also making sure they are well rewarded.”