From Pre-Founding to Founding: Understanding the drivers, barriers, and strategies for Dutch Deep-Tech Startups in the Sustainable Energy sector.

By

Onno Hopmans

4913701

MSc. Complex Systems Engineering and Management

Examiners

Elif Çelik | Hans de Bruijn | Sander Smit

Abstract

The study seeks to develop a better understanding of the unique drivers and barriers encountered by Dutch Deep-Tech Startups (DTS) in the Sustainable Energy (SE) sector during their pre-founding to founding stages. The aim is to identify effective strategies employed by entrepreneurs to navigate these challenges and to leverage the drivers. Despite their potential to address major societal challenges, these startups often face high failure rates due to inherent complexities and dependence on heavy R&D. To gain a better understanding of the drivers, barriers, and strategies, the study utilizes literature review and semi-structured interviews. Key findings highlight supportive academic culture, regulatory environment (RE), business networks, entrepreneurial factors, and personal motivations as drivers, while identifying barriers such as academic-commercial divergence, regulatory complexity, investor discrepancies, entrepreneurial factors, market research (MR) challenges and personal barriers. Strategies for success include forming cross-disciplinary teams, leveraging academic resources, strategic funding opportunities, adapting to market needs, and maintaining resilience and motivation. A conceptual framework is proposed to guide future entrepreneurs.

The study aims to benefit future DTS entrepreneurs, by offering practical strategies and insights for overcoming barriers and leveraging drivers. Besides DTS entrepreneurs, the study also provides valuable insights for universities and policymakers. The research offers policymakers insights on optimizing the regulatory environment to better support DTS. It suggests the need for streamlined regulations and targeted funding initiatives. For universities, the findings highlight the importance of embracing an entrepreneurial culture and providing support systems for DTS, including access to specialized resources and mentorship programs. Overall, the study contributes to a deeper understanding of the factors that influence the success and failure of DTS, offering practical recommendations for enhancing their viability and impact.

Acknowledgements

After two years, since the start of my Masters Complex Systems Engineering and Management (COSEM), I can now present to you my final thesis. With this research, my time at the Technical University of Delft will be concluded. I am grateful for all the opportunities that have been given to me. For example, an exchange to Budapest during my Bachelors, as well as the exchange to Madrid during my Masters. When I talk about where I studied, I feel proud.

Researching the entrepreneurial side of a socio-complex world, gave me a lot of insights into how entrepreneurship works. I valued the conversations I had with these entrepreneurs, and they sparked my interest (even more) on being an entrepreneur myself. I hope this study can help future entrepreneurs with changing their mindset to try the applied side of their already interesting and impactful research. I also hope that this study can shape universities and policy makers towards a more tailored approach on the needs of and entrepreneur.

First, I want to express my gratitude towards my first supervisor Elif. You have been hands-on and helpful in times where it was needed. The personal tone among the professionality is something that I valued. I know it is not ideal to read a paper during your vacations, so thanks again for that.

Second, I would like my second supervisor Sander, who asked critical, but rightful questions about multiple aspects of my thesis. This forced me to look more sharply and critically towards my own work.

Third, I want to thank my third supervisor and chair Hans. Thank you for stepping in when there was a bit of a supervisor chaos in the early stages of the research. I also want to express my gratitude on the extra help on my framework and the critical view on my thesis overall.

Finally, thanks to all the participants who have taken the time to meet and tell me about their interesting startup adventures. Without this, my thesis would have been quite empty and meaningless. This also includes a special word of gratitude to Eva and Justin who helped me find suitable participants in this specific niche, thank you.

Onno Hopmans

August, 2024

Acronyms

ASO	-	Academic Spin-Off
CAQDAS	-	Computer-Assisted Qualitative Data Analysis Software
COSEM	-	Complex Systems Engineering and Management
CSO	-	Corporate Spin-Off
DTS	-	Deep-Tech Startups
EF	-	Entrepreneurial Factors
ICF	-	Interview Consent Form
IE	-	Innovation Ecosystem
IPCC	-	Intergovernmental Panel on Climate Change
MR	-	Market Research
R&D	-	Research and Development
RBSO	-	Research-Based Spin-Off
RE	-	Regulatory Environment
SE	-	Sustainable Energy
TRL	-	Technology Readiness Level
USO	-	University Spin-Off

Table of Contents

List of Figures and Tables

1 Introduction

This chapter gives an introduction and definition for exploration of sustainable energy (SE) deep-tech startups (DTS) in the early stages in the Netherlands. It outlines the research problem, scope, and the specific knowledge gap the study aims to address. The chapter also presents the research questions, research goals, and the relevance of the study, concluding with an overview of the study's structure.

1.1 Background and Problem Statement

Global investments in Deep-Tech Startups (DTS) quadrupled from 2016 to 2020 to a staggering 60 billion dollars in 2020, leading to a combined worth of 700 billion euros in Europe alone in 2021 (Siota & Prats, 2021; von der Leyen, 2021). Despite a significant increase in investments, DTS, with their substantial potential to address major societal challenges, exhibit failure rates exceeding 90% (Schutselaars et al., 2023a). While all new types of new startups face uncertainties, DTS, particularly face additional technology uncertainties due to the unproven challenges that they develop (Blanco, 2007; SADEH & DVIR, 2020; Siegel & Krishnan, 2020; Yang et al., 2024).

A study by (Gozal et al., 2022) highlights the relatively little attention deep-tech received historically seen compared to more consumer-facing innovations that promise quicker returns. With the rise of technologies such as autonomous driving, photonics and artificial intelligence, the term deep-tech exploded in worldwide media channels. This led to an overextended and diluted terminology on what deep-tech is. The study defines deep-tech as innovations rooted in significant scientific discoveries or major engineering breakthroughs. Deep-tech solutions are capable of catalysing transformative changes across multiple sectors. Unlike conventional technologies, deep-tech is characterized by its foundational nature, often requiring extensive R&D before commercial application.

DTS are startups that are founded based on the deep-tech technology. Like academic spin-offs (ASOs), DTS often originate from academic research. While both ASOs and DTS involve high levels of innovation and potential for scientific breakthroughs, DTS require significant R&D and involve substantial technological risks, often higher than those encountered by ASOs (Reisdorfer-Leite et al., 2023). A study by (Schutselaars et al., 2023a) argues that DTS characterises as potentially disruptive technology-based startups, with a broad and transformative impact on industries and societies. It is often critical for the startups to maintain strong academic connections as they enable to leverage scientific expertise and infrastructure that might otherwise be inaccessible.

The strong academic ties that benefit DTS also pose challenges. These startups often prioritize research and development over market readiness. They concentrate on prototype development and scientific publication, rather than crafting business strategies that address actual market demands. This academic focus can result in difficulties adapting to diverse market conditions. This focus can prohibit their commercial success (Roche et al., 2020). University bodies, alongside traditional stakeholders in the startup ecosystem, also play a pivotal role in the success of DTS by providing support mechanisms. These include facilitating access to specialized resources, offering mentorship, and connecting startups with potential investors and partners. This support enables entrepreneurs to transition from theoretical research to practical application; fostering an environment where groundbreaking ideas can be tested and developed into marketable solutions (Fini et al., 2011).

DTS span a diverse range of disciplines, including economics, sociology, engineering, and health, each presented unique barriers and drivers (Romme et al., 2023). While these disciplines share commonalities in the way they rely on advanced research, they differ in their specific challenges and opportunities. This necessitates tailored exploration to understand how specific DTS navigate the landscape filled with these challenges. The study focuses on embracing their potential by mapping out drivers, barriers and strategies, and to structure a framework that aids entrepreneurs to reduce the high failure rate of DTS and nudge their success in translating academic research into impactful market innovations.

1.2 Research Gap

Current literature predominantly focuses on generalized drivers and barriers affecting startups across various industries and geographical contexts (Hossinger et al., 2019; Kaufmann & Ouschan, 2023). These generalized factors include financial constraints, regulatory challenges, and the availability of skilled personnel, among others (Chapter 2.2). The startups that are highlighted are predominantly ASOs, and often lack specific deep-tech related drivers and barriers. Most studies focus on macro-data and do not research industry-specific challenges, like in the Sustainable Energy (SE) sector, or healthcare, or the distinctive innovation ecosystems (IEs) of specific countries, such as navigating complex regulatory landscapes of a particular country. This leads to a lack of detailed insights that can be directly applied to the context of DTS. The complex and hard-to-reproduce technological advances that set them apart from more conventional startups, need a tailored approach when studying their success factors and barriers (Cantner & Goethner, n.d.; Kaufmann & Ouschan, 2023; Noh & Lee, 2019; Visintin & Pittino, 2014).

Studies on deep-tech often do not account for country specific contexts. A literature review by (Yang et al., 2024) shows the barriers, drivers and strategies, but does not take country specific contexts in consideration. A study by (Lin et al., 2006) does research the country's specific context, which takes interaction effects with environment factors into account. This adds to the thoroughness of the analysis. For this research the country specific context of the Netherlands is chosen. The Netherlands is renowned for its robust IE, particularly in sustainability and technology, ranking highly on the Global Innovation Index for entrepreneurship and business environment (Invest in Holland, 2023). Understanding how DTS operate within the Netherlands, can add to the understanding of challenges in relatively well-established environments. It can give understanding for their potential further growth and for providing a framework that can be emulated by other countries.

Existing literature also often generalizes across various industries without addressing specific fields, thereby overlooking the distinctive IEs of different countries (Hossinger et al., 2019; Kaufmann & Ouschan, 2023). The SE ecosystem is particularly relevant and timely given the urgent need for effective climate interventions, as highlighted by the 2022 Intergovernmental Panel on Climate Change (IPCC) report. Dutch government policies strongly support SE, with ambitious targets to increase the share of SE to 16% by 2023 and nearly 100% by 2050. This proactive approach is detailed in the Energy Agenda (Government of the Netherlands, 2024). This sector is a high priority on both global and academic agendas due to its potential to mitigate climate change through innovative solutions.

According to the Technology Readiness Levels, phase 4 to phase 7 is where most startups struggle. This phase encompasses the pre-founding to founding stage. This is where innovations move from proof of concept to early-stage commercialization. During this period, startups must navigate technological, financial, and operational hurdles (Manning, 2023; Schutselaars et al., 2023). The pre-founding to founding stage is especially challenging due to the need to transition from theoretical research to viable business models and market-ready products. These challenges are further compounded by the high-risk nature of deep-tech ventures, which require substantial resources and strategic support to bridge the gap to market readiness.

Therefore, this phase demands a tailored approach to ensure that DTS can successfully overcome these hurdles and achieve commercialization. This thesis aims to address these gaps by focusing on the specific drivers and barriers encountered by Dutch DTS in the SE sector during the pre-founding to founding stages (Cleyn & Braet, 2009; Gübeli & Doloreux, 2005; Manning, 2023; Müller-Wieland et al., 2019a; Schutselaars et al., 2023a).

This research aims to address the research gap, which can be interesting to multiple parties, including entrepreneurs, policymakers and academic institutions. By identifying drivers, barriers, and strategies for entrepreneurs within the unique context of the Netherlands, the research sought to offer practical insights that can enhance the support structures for these startups, an increase in effective collaborations between academia and entrepreneurs, and entrepreneurial factors that must be kept in mind. The research aimed to contribute to the reduction of high failure rates among deep-tech startups by offering actionable recommendations that can be applied within the Dutch context.

1.3 Research Purpose & Questions

The purpose of this study is to investigate the unique barriers & drivers faced by Dutch DTS in the SE sector during their pre-founding to founding stages. By focusing on the Dutch context, this research aims to provide insights and strategies that enhance the transition of academic research into successful transitioning of startups to the founding stage. The findings will inform guidelines tailored to the specific needs of DTS in the Netherlands, contributing to a more robust and supportive IE. To address this purpose, the research is guided by a main question and several sub-questions that explore different dimensions of the problem:

"What are the main drivers and barriers for Dutch deep-tech startups in the sustainable energy sector during the pre-founding to founding stage, and what strategies do they employ to navigate these challenges?"

Linked to the main research question, the following sub research questions of this study are intended to be answered:

"What are the specific drivers and barriers for the pre-founding to founding stages in the field of deep-tech sustainable energy in the Netherlands?"

This question aims to identify and categorize the unique factors influencing the early development of DTS in the Dutch SE sector, including academic, regulatory, networking, entrepreneurial and personal factors.

"What strategies are employed by entrepreneurs to overcome the main challenges faced in the pre-founding to founding phase?"

This question explores the practical approaches used by entrepreneurs to address the identified barriers during the early stages, providing insights into successful tactics and strategies for securing funding, team building, market research (MR) and personal development.

"How can a framework assist future entrepreneurs in navigating the drivers and barriers of deep-tech sustainable energy startups in the Netherlands?"

This question focuses on creating a light framework that integrates insights on drivers, barriers, and effective strategies, offering practical guidance for future deep-tech entrepreneurs to systematically address challenges and leverage opportunities.

The questions are systematically addressed with a literature review as a background and with semi-structured interviews for additional data gathered by entrepreneurs themselves. This data will then be linked in the discussion chapter. The figure below gives the breakdown of the different tasks that need to be fulfilled

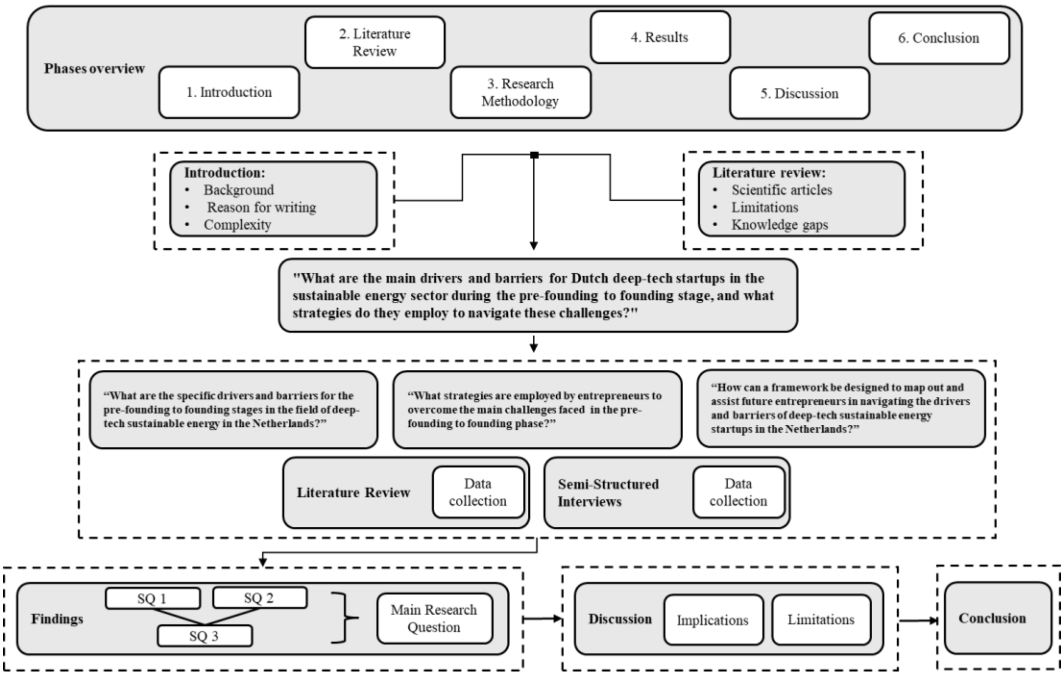

Figure 1: Research Flow Diagram

1.4 Relevance of the Research

The research aimed to provide a contribution to the literature on DTS, particularly in the early stages within the Dutch SE sector. The research addressed a gap by focussing on the unique drivers and barriers faced by the startups in this specific context. By offering insights into the pre-founding to founding stages, this study broadened the understanding of commercialization processes in deep-tech entrepreneurial development. It brought forward new, hands-on perspectives on how academic institutions and the regulatory landscape in the Netherlands influence the startup process, thus enriching the field of technology transfer and entrepreneurial ecosystems.

In practical terms, the research offers guidelines for stakeholders involved in the development and support of DTS. For entrepreneurs, it provides strategies to navigate the complex landscape of funding, RE, MR and the mental state change that is often required. This helps them manage the early challenges they face in the early stages of bringing their innovative solutions to market. For academic institutions, the findings highlight the need effective support mechanisms that can enhance the commercialization of research practices. These insights can be effective for universities aiming to improve their technology transfer processes and better support their spin-offs. Policymakers can also benefit from this research by gaining a clearer understanding of which policies and regulatory practices are effective and which areas need improvement, informed by direct experiences from deep-tech entrepreneurs.

The research delved into the complex socio-technical landscape in which DTS operate, where social dynamics, economic conditions, and technological advancements intersect. It examines factors such as the impact of policy measures, the accessibility and sufficiency of funding, the complexity of the technologies being developed, and the unique characteristics of the Dutch energy sector. By providing an understanding of how these elements collectively influence the formation and growth of DTS, this research offers a holistic view of the operational environment.

Navigating this landscape requires interaction among a diverse range of stakeholders. The universities that play a pivotal role in fostering innovation and technology transfer, academic entrepreneurs who drive the commercialization of mostly new inventions, and government bodies that shape the regulatory framework and provide necessary support mechanisms.

The relevance of this research is significant within the Complex Systems Engineering and Management (COSEM) program, where the focus is on integrating and managing complex, interdependent systems. The research explores how the interaction between the stakeholders influences the DTS, and what the regulatory landscape in the Netherlands does to aid these startups. The research provides a detailed exploration of challenges where factors can be optimized to enhance innovation and development outcomes. Additionally, the study's emphasis on SE aligns with the Energy & Industry specialization, highlighting the practical applications of managing technological, political, and industrial transformations to address energy challenges.

1.5 Outline

This thesis is structured into five chapters, addressing the research questions in the Dutch DTS in the SE sector. The first chapter introduces the central research topic and the problem it seeks to address, it outlines the scope of the study and presents the research questions.

Chapter two describes a literature review that is conducted to provide a theoretical foundation for understanding DTS. This chapter summarizes key findings from existing literature on the definition, drivers, barriers, and strategies to navigate through the startup process of DTS.

Chapter three outlines the research methodology, elaborating on the strategic approach adopted in this study. It describes the use of semi-structured interviews as the primary method for data collection, explaining the rationale for selecting this method, and the process of conducting and analysing these interviews. Ethical considerations and the steps taken to ensure the validity and reliability of the research are also discussed.

Chapter four illustrates the empirical findings derived from the semi-structured interviews conducted with entrepreneurs of Dutch DTS in the SE sector. It analyses the data to identify the main drivers and barriers these startups face and explores the strategies they employ to overcome challenges. The findings are synthesized into a conceptual framework that maps out practical guidelines influencing the success of these startups.

Chapter five summarizes and compares the key findings to the literature and discusses their implications for both theory and practice. This chapter revisits the research questions and evaluates how well they have been addressed through the study. It also discusses the limitations of the research.

Chapter six concludes the study by concluding the findings and suggests directions for future research, offering practical recommendations based on the insights gained.

2 Literature Review

The previous chapter provided an overview of the background and problem statement, as well as the formulation a research gap. In this chapter the existing literature is reviewed on Deep-Tech Startups (DTS), particularly those in the Sustainable Energy (SE) sector. This section aims to provide a detailed understanding of the key factors that influence their commercialization during the pre-founding to founding stages.

The review starts by defining DTS, distinguishing them from academic and university spin-offs, and highlighting their reliance on advanced scientific research and technological innovation. This foundational understanding is necessary for contextualizing the unique challenges and opportunities these startups face.

While exploring the drivers and barriers to the commercialization of DTS, it becomes evident that much of the existing literature does not clearly distinguish between DTS and academic spin-offs. Therefore, only papers that suffice to the characteristics of DTS, explained in the upcoming section, are considered. This focus is relevant for understanding the landscape of drivers and barriers. The interviews conducted in this study will provide a more detailed analysis of the unique drivers and barriers faced specifically by DTS in the Netherlands, addressing gaps not fully covered by the existing literature.

Additionally, this chapter examines phase-specific drivers and barriers, providing background on how these factors affect startups' progression from early development to successful commercialization. This phase-specific focus helps to illuminate the transitions that DTS must navigate.

The data gathered from the literature review will be used to identify key themes and factors to inform the design of the semi-structured interviews and the overall research methodology. By understanding what has already been studied and where the gaps lie, this research aims to build upon existing knowledge and provide new insights specific to the early-stage Dutch SE context.

2.1 Definitions of Deep-Tech in the Early-Stage Entrepreneurship

There is no clear consensus in the literature on the exact definition of DTS. However, certain common characteristics emerge when these startups are studied. A recent study (Noh & Lee, 2019) explains the term university-based academic entrepreneurship and technology transfer, with a broader term of technology transfer to explain scientific discoveries that moved from their origin into practical applications encompassing the wider economy or society. While related, DTS and academic spin-offs (ASOs) are distinct concepts. DTS are characterized by their high technological risk, long development cycles, and the need for substantial investment in R&D.

Academic spin-offs (ASOs) and university spin-offs (USOs) originate from academic institutions but typically involve the commercialization of existing academic knowledge rather than the creation of new impactful technologies, as is the case with deep-tech. These spin-offs are part of the "third mission" of universities, which emphasizes their role in economic and social development through the transfer of academic research into commercial applications (Visintin & Pittino, 2014). While ASOs, USOs and DTS benefit from robust R&D capabilities, they often face challenges in translating this knowledge into marketable products or services. Their success can depend vastly on their ability to build effective networks and collaborations with their parent institutions (Kaufmann & Ouschan, 2023).

The differentiation between DTS and conventional startups is marked by their technological resources. DTS typically possess substantial technological assets, including larger patent portfolios and high R&D investments. This technological focus distinguishes them from conventional startups, which may not prioritize patented technologies or R&D as heavily. Additionally, human capital in DTS tends to be more oriented towards research and development expertise rather than commercial experience, setting them apart in their operational approach (Cantner & Goethner, 2011)

A study about the foundation of deep-tech (Gozal et al., 2022) discusses five dimensions of characteristics for deep-tech. Fundamentally, deep tech is rooted in significant scientific discoveries or engineering advances that go beyond mere business model innovation, typically emerging from academic or research institutions (Scarrà & Piccaluga, 2022). These innovations are not only complex, requiring a synthesis of diverse knowledge domains, but are also distant. They often require long development timelines that need considerable upfront capital and pose higher risks compared to more iterative digital startups (dealroom, 2021). Deep-tech also acts as a foundational layer beneath more visible technologies, enabling various downstream applications that often remain hidden from end-users (Bresnahan & Trajtenberg, 1995). The profound impact of deep tech is hard to measure, as it targets societal challenges, like climate change, that are beyond the scope of current technological solutions, making its benefits difficult to quantify with traditional metrics (Fini et al., 2017; Kuhlmann & Rip, 2018).

This research focuses on the pre-founding to founding stage of DTS. The literature identifies several models that describe the various stages of startup development, each with distinct characteristics. A study conducted by (Cleyn & Braet, 2009) proposes a six-stage model, beginning with the research stage, where new scientific discoveries are made. This is followed by the pre-incubation phase, where basic research evolves into applied research, prototypes are developed, and commercial opportunities are assessed. In the incubation phase, the spin-off is formally established, and the product undergoes market testing. If successful, the company enters the startup stage, where the product is launched on the market, followed by a phase of concerted growth.

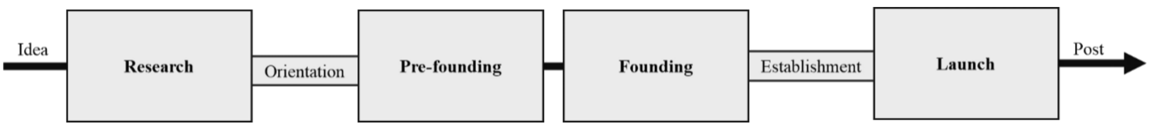

Figure 2: Stages Deep-Tech Startups

Gübeli & Doloreux (2005) offer a simplified model with three stages: pre-founding, which occurs before the company is officially formed; founding, when the company is established; and post-founding, which follows the birth of the spin-off. A study by Müller-Wieland et al. (2019b) describe a four-phase process that includes the research phase, orientation phase, pre-founding phase, and establishment phase, spanning from the initial idea to the formal establishment of the company.

In this study, the emphasis is on the pre-founding to founding stage. This stage is critical for transitioning a business idea into a commercial entity. It involves key activities such as engaging with the parent university and other stakeholders, including industry partners and investors (Gübeli & Doloreux, 2005). This stage is critical for evaluating the commercial potential of research and technological innovations. As DTS move towards the founding stage, the focus shifts to formalizing business aspects, such as establishing legal structures, refining business models, and engaging with external stakeholders (Cleyn & Braet, 2009). The aim is to connect the experience from interviews with entrepreneurs to identify what they find most important.

2.2 Drivers, Barriers and Strategies

A systematic review by (Yang et al., 2024) sheds light on the various barriers and risk factors encountered by DTS. These challenges help to understand the unique landscape within which DTS operate. The review also introduces some strategies are introduced to mitigate risks.

Financial risk is one of the main factors that is considered by the literature review that influences the success of DTS. Two prominent elements stand out: lack of resources, and fundraising challenges. These financial related challenges are faced by most startups in some stage of their existence (Lin et al., 2006; Maine & Garnsey, 2006).

Product-market fit is also one of the limiting factors for startups. For a service or product to work, entrepreneurs need to develop products or services that customers are willing to pay for. This often lacks due to the breath of potential applications and the difficulty in understanding customer needs for novel technologies. The process of identifying and validating market opportunities requires extensive experimentation and adaptation, which can strain limited resources (Andries et al., 2021; Maine & Garnsey, 2006; Scaringella et al., 2017a).

Internally, DTS have to try to overcome challenges related to capabilities, knowledge, and reputation. Building a competent team with the necessary technical expertise and managing the liabilities of newness and smallness are some of the internal issues. Additionally, developing a credible market presence despite the early stage of their technologies requires strategic management of firm capabilities and stakeholder relationships (Pahnke et al., 2015; Partanen et al., 2014).

DTS also face external risks such as regulatory hurdles, competition, and environmental risks. Navigating complex regulatory landscapes, particularly for technologies that impact multiple industries, poses challenges. Moreover, competition from established players and external shocks can disrupt the development and market entry strategies (Carayannis et al., 2000; Colombo et al., 2021).

Table 1: Barriers Literature Review

Barriers	Subcategories	Source
Financial risks	Lack of resources, fundraising challenges	(Lin et al., 2006; Maine & Garnsey, 2006)
Product-market fit	Breath of potential applications, customer needs, extensive experimentation and adaptation	(Andries et al., 2021; Maine & Garnsey, 2006; Scaringella et al., 2017a)
Internal challenges	Capabilities, knowledge, reputation, credible market presence	(Pahnke et al., 2015; Partanen et al., 2014)
External risks	Regulatory, competition, environmental risks	(Carayannis et al., 2000; Colombo et al., 2021)

The literature review also introduces some risk-mitigation strategies that are based on the reviewed literature. These risk mitigation strategies form a basis for the second research question that explores different strategies employed by entrepreneurs to overcome their main challenges. These strategies are shallow and will be further explored by firsthand experience by deep-tech entrepreneurs themselves (Chapter 4.2).

Entrepreneurs should be able to prioritize and focus their development efforts. This can be achieved by focusing on the most promising opportunities. They also need to be prepared to pivot regarding on the early market feedback. This strategy can optimize the resource allocation and reduce the overall risk (Furr et al., 2012; Maine et al., 2012; Scaringella et al., 2017b).

Another introduced strategy is about the exploration of alternative business models. As is highlighted by (Yang et al., 2024): “not all business models are appropriate for all firms“. (Chammassian & Sabatier, 2020; Maine et al., 2012).
Startups should also focus on customer insights and market validation by conducting research and gathering customer feedback. Early customer engagement helps refine the technology and align it with market needs, thereby enhancing its value proposition (Andries et al., 2021; Pahnke et al., 2015). Diversifying funding sources and attracting risk-tolerant investors can provide financial stability. This can include specialized venture capital and government grants that support deep-tech innovations (Maine et al., 2012; Piazza et al., 2023).

Recruiting experienced professionals and leveraging networks for advice and mentorship can also strengthen the firm's capabilities and market reputation (Page West & Gemmell, 2021; Pahnke et al., 2015), just like forming strategic partnerships with other firms, research institutions, and industry players, to gain access to complementary resources and expertise (Ansari et al., 2016; Hampton et al., 2011). Adapting strategies based on the specific context and market conditions is essential. Not all business models or strategies will fit every DTS, so tailoring approaches to the unique characteristics of the technology and market helps to a successful commercialization (Fabian & Ndofor, 2007).

Although Yang et al. (2024) provides insights into main barriers and strategies for DTS, this review extends those findings by identifying key stages in the startup lifecycle and examining the corresponding drivers and barriers. This approach helps to explain the specific factors at each stage, enhancing the understanding of the dynamic environment faced by deep-tech entrepreneurs.

The initial stage in the lifecycle of a DTS is characterized by intense research and development, thus it is mentioned as the research phase. This phase is crucial but comes with a number of challenges. Funding one of the main issues, as startups often grapple with a scarcity of capital and limited access to venture capitalists. Universities frequently become the early financial supporters during this phase, helping to bridge the gap in funding that is needed to perform the research (Arora et al., 2024; Badzińska, 2021; Khodaei et al., 2022). In addition to financial barriers, knowledge gaps are also mentioned as being main barriers in the research phase. Many researchers find themselves ill-equipped with the necessary market knowledge and commercialization skills required to advance their discoveries. This lack of expertise holds them back, further complicating their path to commercialization (Calderón-Hernández et al., 2020; Khodaei et al., 2022). Valuation of early-stage intellectual property also proves challenging, as it complicates efforts to attract further investment. There is also a challenge in the assessing of the value if early-stage intellectual property in deep-tech, since it is often unclear on what to patent and how, due to the complexity of the solution (Badzińska, 2021).

There are also drivers within the research phase that help propel startups forward. Universities play a key role, not only as funders but also as incubators and facilitators of networking within the academic context (Kruachottikul et al., 2023; Messina et al., 2022). Mentorship from experienced individuals in handling entrepreneurial aspects such as IP strategy and regulatory navigation is also vital (Badzińska, 2021; Khodaei et al., 2022)’. Additionally, the potential for a supportive ecosystem can drive the early stages of startup development, though its absence is often noted as a barrier (Badzińska, 2021).

As startups transition from the research phase to the pre-founding and founding stages, they encounter a new set of challenges. Funding remains a main issue, particularly the 'valley of death’, which is the gap between research funding and commercial market entry, which is notoriously difficult to bridge, especially for high-risk DTS (Kruachottikul et al., 2023). This phase also faces resource scarcity, which can be explained by a lack of access to prototyping facilities, lab space, and specialized equipment, since universities might be focused on the research, not its transition (Kruachottikul et al., 2023; Parmentola & Ferretti, 2018). Regulatory hurdles become more evident within the pre-founding to founding stage for SE DTS.

In these stages the startups become subjective to the complex regulatory landscape of its country. A successful navigation through the complex regulatory pathways is a prerequisite for progress (Khodaei et al., 2022; Kruachottikul et al., 2023). Another barrier is the difference team skill gaps, within the academic context. There is often a lack of business and market understanding, which is something 'true' entrepreneurs are specialized at but lacks within the academics since this is not their specialty (Calderón-Hernández et al., 2020).

Despite these challenges the literature also states several factors that help to drive the transition into the founding stage where the product/service is launched. Dedicated programs within universities or closely related instances that support prototyping, market validation and team development is crucial and is therefore considered a strong driver (Kruachottikul et al., 2023). The specialty about being related to a university can also be seen in the driver in which universities can facilitate partnerships with potential customers or industry players who can provide valuable feedback and validation in this stage (Khodaei et al., 2022; Messina et al., 2022). Universities can also provide advisors that have expertise that is crucial to be able for startups to navigate through the complex system. Some instances where expertise are needed, are often IP strategy, regulatory hurdles, and potential markets that are specific for DTS (Calderón-Hernández et al., 2020; Khodaei et al., 2022). A well-defined IP strategy, continuing from earlier stages, helps to attract investment and secure the DTS competitive advantage (Roche et al., 2020). The literature also highlights the need for targeted funding mechanisms, these are grans or programs explicitly designed for the risks and needs of pre-founding DTS (Kruachottikul et al., 2023). Overall, A thriving deep-tech ecosystem with industry partnerships, policy support, and a talent pool would be a major driver of success in this stage (Badzińska, 2021; Khodaei et al., 2022; Messina et al., 2022).

The final phase that is the launch phase. This stage presents its own unique barriers and drivers. Market adaptation challenges emerge as deep-tech solutions often face longer sales cycles due to their novel and potentially disruptive nature (Arora et al., 2024). This study also identifies that scaling costs can escalate unexpectedly, straining financial resources during the phase of growth. The drivers are mostly built up through the previous stages. One of them is investor confidence, which is crucial for securing the funding necessary for the launch stage (Arora et al., 2024). Strong market validation, evidenced by positive customer feedback, also acts as a potent driver, attracting further investment and enabling scaling that is needed shortly after the founding stage (Kruachottikul et al., 2023).

The results gained from the literature review provide a foundation for designing and characterizing the semi-structured interviews in the research methodology. Some key themes emerge, like the stage-specific barriers and drivers, the importance of regulatory environments, the importance of market-research and the role of academic collaboration.

Also, some strategies came forward to overcome certain challenges. These themes will guide the structure of the interviews and ensure that the research addresses the critical areas of concern for DTS in the SE sector. The interview builds forward on the existing literature, but will expands on the strategies that are deployed, the specifics of the barriers and drivers, but also to tailor the research towards the pre-founding to founding stage of SE DTS in the Netherlands.

Table 2: Phase-Specific Barriers & Drivers

Phases	Category	Definitions and examples	Source
Research Phase	Financial Barriers	Scarcity of capital, limited access to venture capitalists, universities as early financial supporters	(Arora et al., 2024; Badzińska, 2021; Khodaei et al., 2022)
	Knowledge Barriers	Lack of market knowledge and commercialization skills	(Calderón-Hernández et al., 2020; Khodaei et al., 2022)
	IP Valuation Challenges	Difficulty in valuing early-stage intellectual property	(Badzińska, 2021)
	Academic culture drivers	University funding, incubation, and networking support	(Kruachottikul et al., 2023; Messina et al., 2022)
	Network drivers	Mentorship in IP strategy, regulatory navigation, supportive ecosystems	(Badzińska, 2021; Khodaei et al., 2022)
Pre-founding & Founding	Financial Barriers	'Valley of death' funding gap, recourse scarcity, lack of access to prototyping facilities, lab space, and specialized equipment	(Kruachottikul et al., 2023; Parmentola & Ferretti, 2018)
	Regulatory Barriers	Complex regulatory landscape for SE DTS	(Khodaei et al., 2022; Kruachottikul et al., 2023)
	Team Barriers	Lack of business and market understanding within academic teams	(Calderón-Hernández et al., 2020)
	Academic culture Drivers	University programs, prototyping, market validation, and team development, University-facilitated partnerships with potential customers or industry players, Access to advisors with expertise (e.g. IP strategy, regulatory hurdles, and specific markets)	(Calderón-Hernández et al., 2020; Khodaei et al., 2022; Kruachottikul et al., 2023; Messina et al., 2022)
	Financial Drivers	Targeted grants or funding programs for pre-founding Deep-Tech Startups	(Kruachottikul et al., 2023)
	Ecosystem Drivers	Thriving ecosystem with industry partnerships, policy support, and a talent pool	(Badzińska, 2021; Khodaei et al., 2022; Messina et al., 2022)
Launch Phase	Market Adaptation Barriers	Longer sales cycles due to novel and disruptive nature	(Arora et al., 2024)
	Financial Barriers	Unexpected escalation of scaling costs	(Arora et al., 2024)
	Investor Confidence Drivers	Securing funding through strong investor confidence	(Arora et al., 2024)
	Market Validation Drivers	Positive customer feedback attracting further investment and enabling scaling	(Kruachottikul et al., 2023)

3 Research Methodology

The previous chapter laid the foundation for understanding the characterisations, drivers and barriers faced by deep-tech startups in the sustainable energy sector, based on existing literature. This chapter provides an explanation of the methodological approach employed in this research. It outlines the specific research strategies, techniques used for data collection, and methods of analysis. Additionally, it addresses considerations related to ethics, validity, and reliability, ensuring that the research findings are robust and credible.

The literature review addressed several key themes that influenced the structuring the research methodology. These themes include the importance of selecting specific participants who have direct experience in the pre-founding to founding stages of deep-tech startups, as well as the need to consider factors such as funding, market research, team forming, and academic dependency when designing and conducting semi-structured interviews. The purpose of this research is to contribute to the existing literature, by deep-diving into the hands-on experience by entrepreneurs themselves. Therefore, it is interesting to keep an open view to uncover additional barriers and drivers. The research also aims to find additional strategies that are deployed by entrepreneurs to overcome their challenges, but also leverage their drivers.

3.1 Research Strategy

The aim of this study was to explore the commercialization challenges faced by Dutch Deep-Tech Startups (DTS) in the Sustainable Energy (SE) sector during their pre-founding to founding stages. Given the unique regulatory and institutional landscape of the Netherlands and the specific characteristics of DTS, a qualitative research strategy was adopted. As was highlighted in the literature review, the Netherlands is known for its robust innovation ecosystem (IE). This opens the opportunity to explore how the IE can be optimized and how it can be set out to be an example to other countries.

According to Williams (2011), qualitative methods are particularly suited for gaining in-depth insights within a real-world context, allowing for a deep exploration of complex phenomena. In contrast, quantitative methods focus on the collection and statistical analysis of data to test hypotheses or quantify trends (Modding et al., 2016). In the context of this research, the qualitative approach was chosen to allow for the inclusion practical knowledge that allows data from hands-on experiences and the exploration of potentially overlooked success factors or unique obstacles faced by these startups. This approach aligns with the theory-building goal of the research, as it aims to uncover new understandings and insights into the commercialization processes of DTS in the Netherlands (Saunders et al., 2007).

A multiple-case study methodology was employed to provide a detailed examination of several DTS. This method facilitated an in-depth understanding of each startup's specific context and experiences while allowing for cross-case comparisons to identify common themes and unique differences. Cases were selected to represent a variety of experiences within the Dutch SE sector, ensuring a broad perspective on the drivers, barriers, and strategies faced by these startups (Yin, 2003).

3.2 Case Selection and Data Collection

Data for this study were collected using semi-structured interviews, a method chosen for its ability to gain in-depth and nuanced information on the drivers, barriers, and strategies experienced by Dutch DTS. It aligns with the need to deep-dive into specific contexts as is highlighted in the literature review (Chapter 2). The flexibility within semi-structured interviews allows for a guided yet adaptable questioning into the specific experiences and strategies of the participants. Unlike structured interviews, which use a fixed set of questions, semi-structured interviews provide the flexibility to explore topics in depth and adapt to the interviewee's responses. This flexibility helps to better understand the complex and varied experiences of DTS. Unstructured interviews were not chosen because they may lack focus on multiple relevant themes, instead providing a broader exploration of a single idea (Saunders et al., 2007).

In this study, non-probabilistic sampling was preferred due to its focus on depth over breadth. This approach aimed to obtain rich, nuanced perspectives from selected participants rather than broad generalizations, which is the goal of probabilistic sampling. The literature review already highlighted some of the main drivers, barriers and a few strategies, but the study aimed to explore this further, by finding practical examples interviewing deep-tech entrepreneurs. Unlike probabilistic sampling, which aims for generalization, non-probabilistic sampling was more appropriate for targeting SE DTS entrepreneurs in the Netherlands, a specific and not easily accessible group (Saunders et al., 2007).

Participants were selected based on criteria that verifies the connection to SE DTS in the Netherlands. This selection criteria are based on the literature review that explains DTS as being dependent on advanced scientific research, high technological risk, long development cycles, and substantial R&D investments (Kaufmann & Ouschan, 2023; Noh & Lee, 2019). Three types of participants were targeted: established founders provided insights from their successful SE startups, particularly in early commercialization; entrepreneurs who had unsuccessful SE ventures offered perspectives on barriers and systemic issues; and current entrepreneurs in the pre-founding to founding stages contributed valuable insights into early-stage challenges.

In addition to these specific roles, participants were required to meet several broader criteria to ensure relevance to the study's focus. Interviewees needed to be actively engaged in the SE sector, aligning with the thesis's focus on deep-tech innovations within the Dutch regulatory context. Therefore, participants were based in or had their business operations primarily within the Netherlands. Candidates also need to understand the Dutch regulatory landscape. This included direct experience with Dutch innovation systems and familiarity with various funding mechanisms, such as investment rounds, grants, or other financial supports. Another criterion was the candidates' connection to academic or university bodies. These relationships are key to understanding the unique ecosystem surrounding DTS, particularly how academic collaborations influence startup development.

After considering various non-probabilistic sampling methods, snowball sampling was chosen as the most effective approach for this study. DTS in the SE sector operate within niche networks that are difficult to access through conventional methods. Snowball sampling allowed the study to reach these networks by starting with well-connected individuals who could then refer other potential participants, thereby expanding the candidate pool (Berndt, 2020; Saunders et al., 2007). Initial contacts for this study were established through university bodies and entrepreneurial support organizations, such as those involved in startup incubation and acceleration, were helpful in identifying potential participants. Purposive sampling was also employed alongside snowball sampling to ensure the inclusion of participants based on specific criteria relevant to the study. This included their involvement in the pre-founding to founding stages of DTS, active engagement in the SE sector within the Netherlands, familiarity with the Dutch regulatory landscape, and connections to academic or university bodies. Purposive sampling was more viable for startups that were already founded, as this was easier to identify on their mission and criteria.

The goal was to reach saturation in the interview data. Conducting around 10-15 interviews is often recommended to achieve data saturation, where no new information or themes are observed. According to Guest et al. (2006), saturation can occur within the first 12 interviews, with key themes emerging as early as six interviews. In this study, significant thematic saturation was approached with 8 interviews. Key themes and insights became evident early on, and subsequent interviews confirmed and enriched these themes. The depth and richness of the data from these 8 interviews provided a robust foundation.

3.3 Semi-Structured Interview

To maintain consistency across interviews while allowing for in-depth inquiry, an interview guide was developed. This guide included open-ended questions aimed at gaining detailed responses regarding the startups' experiences, particularly focusing on academic collaborations, encountered challenges, strategic approaches, and key drivers in their development journey. The literature review introduced several key themes to keep in mind, including financial, market-fit, knowledge, and academic barriers and drivers. The guide ensured that while these themes were consistently addressed, there was enough room to explore unique or unexpected topics that emerged during the interviews.

Within the interviews questions to get more information about knowledge gaps were also asked. Questions were asked that went into the specifics of the Dutch context to get an overview on the RE of the Netherlands and within the SE sector. There is also a lack of knowledge on the crucial pre-founding to founding phase, where most DTS fail to get through. Questions were probed towards the early-stages to get information that explains the drivers, barriers and strategies in these stages. The complete guide can be found in Appendix A2.

The table below lists the participants of this research, primarily founders and co-founders. It also shows the stage, and type of the startup, but also the key area of expertise of the participant within the startup.

Table 3: Interview participants

Participant ID	Role/Position	Stage of the startup	Type of startup	Key Areas of Expertise
P1	Founder	Founded	Energy Storage	Technology Development
P2	Co-Founder	Founding	Solar Energy	Business Development
P3	Founder	Founded	Sustainable Architecture	Holistic Role
P4	Co-Founder	Founding	Wind Energy	Technology Development
P5	Founder	Pre-founding	Applied Material to Sustainable Solutions	Holistic Role
P6	Co-Founder	Founded	Applied Material to Sustainable Solutions	Product Development, Personal Relations
P7	Co-Founder	Failed	Renewable Energy	Business Case Analysis
P8	Co-Founder	Failed	Energy Storage	Customer Relations and Product Development

The interview guide was developed based on the research questions and findings from the literature review. It was designed to encourage detailed responses and facilitate a deep understanding of the participants' experiences. The guide covered several key themes for exploring the commercialization challenges faced by DTS.

The first theme, entrepreneurial journey and motivation, focused on understanding the origin and evolution of startup ideas, particularly the motivations behind launching DTS in the SE sector. This included examining the personal and professional factors driving the founders.

The second theme, challenges and barriers, aimed to identify specific obstacles encountered during the pre-founding to founding stages. It also explored how these barriers compared to those faced in other sectors or regions, highlighting unique challenges within the SE sector.

The third theme, strategies for overcoming barriers, investigated the approaches employed by startups to navigate and overcome the identified challenges. This theme covered practical tactics providing insights into how startups address challenges, and leverage drivers.

The fourth theme is focused on the dynamics within networks of key stakeholders, including investors, academic collaborators, and industry partners. This theme focussed on to understand how these relationships either supported or challenged the growth of startups.

Interviews will be conducted either face-to-face or via Microsoft Teams, depending on the preference of the participant and logistical considerations such as location and availability. Face-to-face interviews will be arranged in settings such as office spaces or meeting rooms that ensure privacy and minimal disturbance. For participants preferring remote interviews, Microsoft Teams will be used, which allows for a flexible and accessible interview environment. Each interview session is expected to last approximately an hour, providing enough time to explore the topics in depth. With the consent of the participants, all interviews will be audio-recorded. This ensures accuracy in data collection and aids in the transcription process. For transcription, the use of automatic transcription software will be employed. Tools such as Otter.ai or Microsoft Teams' built-in transcription feature will be utilized, which offer high accuracy in converting speech to text and can streamline the analysis process. The full interview can be found in Appendix A2.

3.4 Data Analysis

For the qualitative data analysis, a three-step approach is employed to analyse the data in a structured manner after the data is collected. This method systematically extracts insights from the qualitative responses, identifying themes and patterns that interconnect.

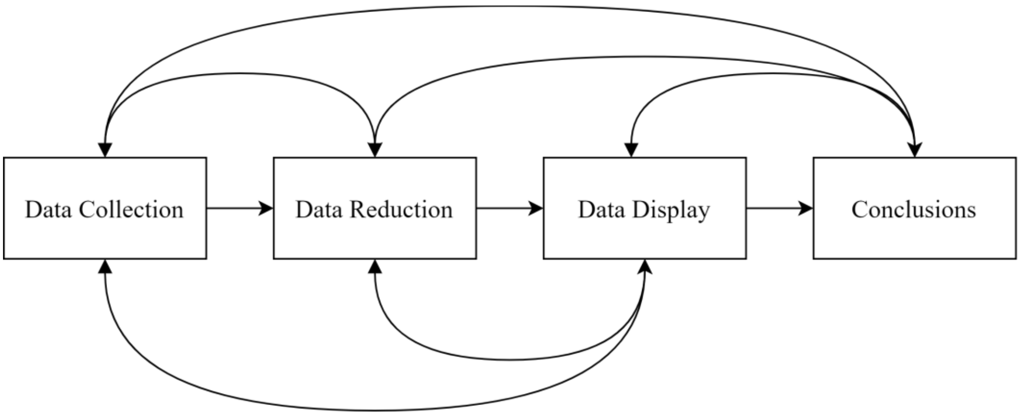

Figure 3: Data Analysis Steps

Data reduction

The data reduction is done through coding and categorisation, aimed at the analytical process of reducing, rearranging, and integrating data to form a theory. Coding is used to be able to link concepts and draw sensible conclusions from large amounts of data. It isdone by the labelling units of texts, called codes. These code units vary in length, from words to complete sentences, but represents one specific theme. These codes are then grouped, and categories are formed (Sekaran, U. and Bougie, 2016).

In this research a middle-ground coding approach is chosen, as it offers a balanced analysis between the flexibility of the loose approach, which allows for inductive generation of codes directly from the data, and the structured guidance of the tight approach, which applies a predetermined set of codes based on existing theoretical frameworks (Charmaz, 2006). An initial coding list was used as a basis for the coding process. The list was created by the factors that were identified in Chapter 2: literature review. An overview of the codes informed by theory is given in the table below (Table 4).

Table 4: Theory Informed List

Factors that are experienced by founders of Deep-Tech Startups	
Lack of Resources	University Programs
Fundraising Challenges	Team
Breath of Potential Applications	Partnerships
Customer Needs	Mentoring & Support
Extensive Experimentation & Adaptation	Credible Market Presence
Team Capabilities	Regulatory Hurdles
Business and Market Understanding	Competition
Reputation	Environmental Risks

The application of the list was to use the codes for the coding, but also to remain flexible, allowing these codes to evolve or to add onto the existing codes once new data were analysed. This hybrid approach mitigates the risk of getting lost in the data inherent in the loose approach while avoiding the rigidity of the tight approach (Miles & Huberman, 1994). By starting with a theoretically informed code list and adapting it based on empirical findings, the study aims to provide a robust and context-sensitive analysis of main factors influencing these startups (Corbin & Strauss, 2015)

The first phase of the coding was open coding. It is "the process of breaking down, examining, comparing, conceptualising, and categorising data" (Corbin & Strauss, 2015). By using open coding, a list of codes is created from the interview transcripts. The initial list existed of 157 individual codes. Before moving on to the second phase, the codes were checked on redundancy. Redundant codes or codes that explained the same principle were listed as one code, which brought back the coding number to 135 individual codes. This was achieved after a few iterations through the entire code book.

In the second phase, once the initial codes are established, the analysis progresses to a more detailed examination of the assigned codes. This phase involves axial coding, which is a technique used to analyse relationships between the initial codes (Corbin & Strauss, 2015). The aim of this phase is to start seeing connections and patterns in the main topics or themes. This is organized into categories and sub-categories, which are reflective of the underlying themes of the research. After multiple iterations, the main categories in figure 4 emerge:

Figure 4: Main Themes Data Analysis

In the final phase of the data reduction process, selective coding was employed to identify a core theme that encapsulated the overall narrative of the data. This core theme served as the focal point, around which all other categories and codes were organized, providing a cohesive narrative of the findings. The core theme that emerged was: Navigating DTS in their pre-founding to founding stages. This step involved the refinement of the narrative and the drawing of intermediate conclusions (Charmaz, 2006; Corbin & Strauss, 2015).

Data display

After coding the qualitative data, the next step is to present it in an organized manner, which is an important aspect of qualitative data analysis (Miles & Huberman, 1994). In the results section (chapter 4), the data is displayed using frequency tables to illustrate how often different themes or were mentioned. This helps to understand the importance the most common barriers, drivers and strategies discussed by the participants. Additionally, the data is introduced in a structured manner. Each key theme is presented with an introduction, followed by insights supported by quotes from the interview transcripts. These quotes help to support the findings, providing direct voices from the participants.

Drawing conclusions

The conclusions and results were finalized and perfected, to be presented in chapter 4: results.

3.5 Ethical Considerations

Ethical considerations in semi-structured interviews require researchers to maintain a delicate balance between obtaining valuable insights and safeguarding participants' rights and welfare. Informed consent is fundamental, ensuring participants are aware of the research's purpose, data usage, and their rights, including withdrawal at any time (Husband, 2020). Another key point is the confidentiality of the data that is being used. Therefore, the data must be anonymized, and storage secured, making it only accessible for academic purposes (Lehr et al., 2007).

To communicate these points clearly and openly, before each interview, participants will be asked to sign an interview consent form (ICF) that details the purpose of the research, the use of the data collected, and the confidentiality measures in place. This form will also give them the right to withdraw from the study at any time. To maintain confidentiality, all interview recordings and transcripts will be anonymized, with any identifying information removed through coding. Data will be stored securely by storing it locally on a computer and backing it up on TU Delft’s OneDrive used by the researcher. The data will be used solely for academic purposes and will be deleted one month after the deadline of the thesis. Details on data handling and the ICF are available in Appendix A1.

3.6 Validity and Reliability

For the data analysis it is crucial to ensure validity and reliability of the research findings. Validity refers to the precision in which the findings reflect the data, whereas reliability withholds the consistency of the findings, accounting for personal and research method biases that could potentially have influenced the findings (Noble & Smith, 2015).

Given the use of non-probabilistic sampling methods, such as snowball sampling, there is an inherent risk of bias in the selection of participants. To mitigate this, ongoing critical reflection was conducted throughout the research process to ensure that the data collection and analysis remained relevant and sufficiently deep. This reflection helped to identify and address any biases that could influence the findings.

Detailed records were also maintained at every stage of the research, in the form of journaling within the CASDAQ. By keeping track of all the decisions, the documented data allows for transparency in the interpretation of data. Consistent and transparent documentation of decisions throughout the research process enhances the reliability of the study. During data analysis, a clear and systematic approach was followed, ensuring that the thought processes and interpretations were also logical. This clarity helps to ensure that the findings are based on a thorough and unbiased analysis of the data.

To support the findings, verbatim descriptions of participants were included within the coding process. This provided background descriptions and direct insights into the participants' perspectives, thereby enhancing the validity of the results. The quotes used within the results section are also verbatims from the participants.

4 Results

Previous chapter detailed the methodological approach employed in this research. This formed the foundation for this chapter, as it presents the empirical findings derived from the semi-structured interviews conducted with entrepreneurs of Dutch Deep-Tech Startups (DTS) in the Sustainable Energy (SE) sector. The chapter starts by providing an overview of the data collected. It then delves into the main drivers and barriers identified through the interviews, highlighting the unique challenges faced by these startups in their pre-founding to founding stages. The chapter also examines the strategies employed by entrepreneurs to overcome some of the challenges, offering insights into tactics that have facilitated their progress. Additionally, a framework is introduced, that focuses on practical guidelines

4.1 Drivers and Barriers

In this section the main drivers and barriers are presented that are obtained through the interviews. The findings are categorized and supported by a frequency table and qualitative quotes from the participants.

The interviews introduced main themes of drivers and barriers that entrepreneurs face in the early-stages of their DTS. An overview of the main drivers and barriers is given in the figure below.

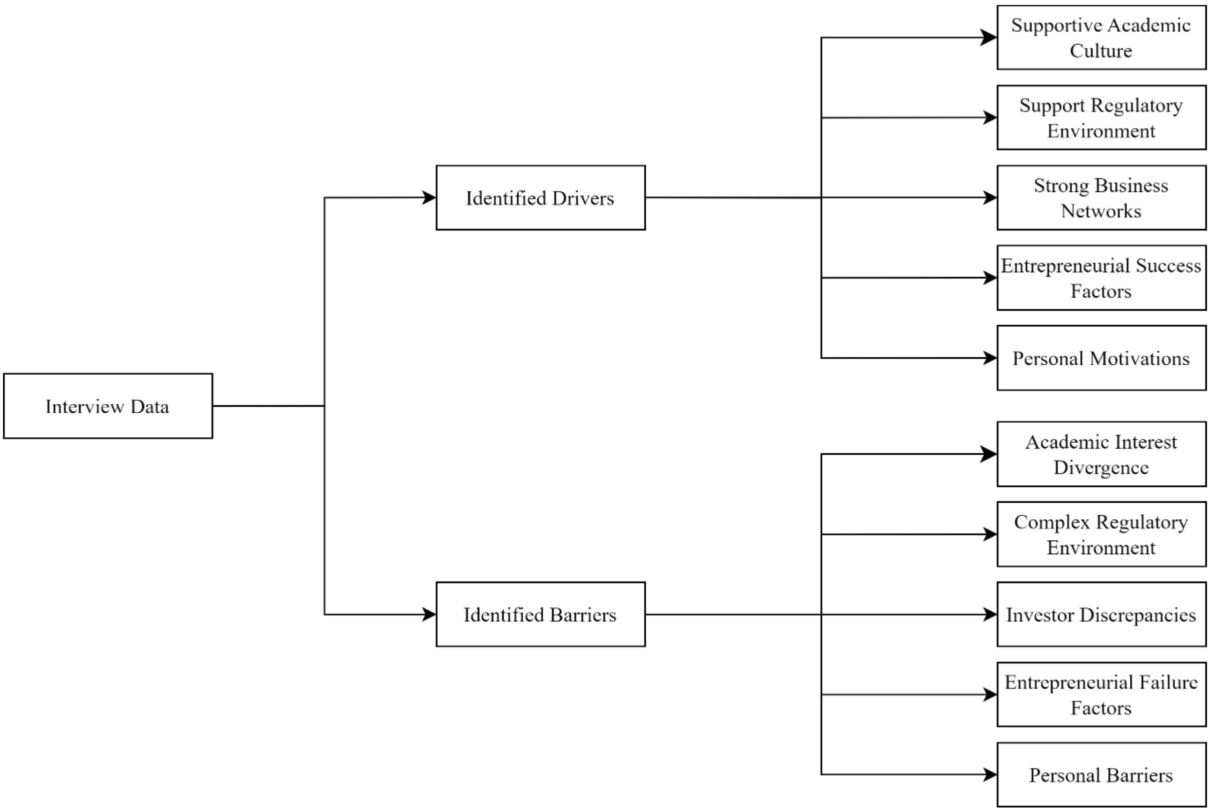

Figure 5: Identified Barriers & Drivers

4.1.1 Identified Drivers

For the drivers a frequency table is constructed to find the number of times that a concept is mentioned during the interview. The frequency gives a sense of the importance of the concept regarded by the participant. As a sidenote it is important to understand that the frequency can often be higher due to the extensive usage in a short passage in the interview.

Table 5: Frequency Table Identified Drivers

Concept	P1 E (Energy Storage)	P2 E (Solar Energy)	P3 E (Sustainable Architecture)	P4 E (Wind Energy)	P5 E (Applied Material)	P6 E (Applied Material)	P7 F (Renewable Energy)	P8 F (Energy Storage)	Total Frequency
Supportive Academic Culture	2	6	1	8	8	4	4	3	36
Supportive Regulatory Environment	3	5	4	7	6	7	3	3	38
Strong Business Networks	9	2	6	6	0	5	2	2	32
Entrepreneurial Success Factors	8	3	4	6	4	4	2	4	35
Personal Motivations	8	4	3	3	2	4	2	5	31

E: Existing at time of interview
F: Failed startup

Supportive academic culture

One of the themes that occurred, is the close ties and support from academic bodies or resources. This is highlighted by multiple interviewees as the R&D often gets more and more applied with an increase in details. Academics within depth knowledge can help within this process. Participants frequently mentioned (36 times in total) how collaboration with academia enabled them to navigate the complex challenges of adapting their research for commercial use. The knowledge base within universities offered a rich resource pool. As participant 2 highlighted:

> **P2:** The access to experienced people like teachers and academics that really know their way around, you know like super bright minds. These things have made it possible for us to get as far as we are right now.

This view on the academic culture was echoed by several other participant, making academic relationships a key factor in the interviews.

Another insight gained from the interviewees on academic collaborations is that initial ideas for deep-tech products rarely emerge in isolation. Deep-tech, being closely related to R&D practices, often involves collaboration with colleagues within a research team or across different teams. The transition from research to applied services or products often rely on the boldness and strength of these academic connections.

P4: I would say the original idea came from colleague (X). He always saw potential in this method for energy harvesting. So, he actually formed the initial research team. It was a bit of an idea that many people thought was completely crazy.

This insight highlights the importance of connecting and sharing ideas with other colleagues. This can lead to new insights or opportunities that is enabled by a fresh perspective. An example of a lack of exchanging ideas and knowledge can be found by participant 7. A colleague of this participant was working with a material that could have added to the success of the initial product.

P7: In hindsight we should've gone to colleague X at the beginning. With his PCM technology we could've possibly succeeded in terms of the application.

A takeaway for researchers is to step out of their comfort zone and discuss potential ideas or challenges with colleagues.

Access to specialized equipment and lab space provided by universities also benefits DTS. However, it is important to note that university lab spaces are typically designed for lab-scale research and can be challenging to scale up to industrial levels. While this issue lies outside the immediate scope of the pre-founding to founding stage, it remains an important consideration for future development. Among others participant 2 highlights the importance of the lab equipment with a special regard to costs:

P2: Access to the labs and the equipment that we have received is ideal, it couldn't have been possible to get this far withing receiving specialized funding, if it wasn't because of the university.

Lab equipment can often be used or rented against good terms. This can help startups, especially in the early phases to test out complex technologies on a lab scale.

Supportive Regulatory Environment (RE)

For the RE a few distinctions are made. One focus is on the funding part, since this already seems to be one of the main focusses coming forward within the interview. The funding part consists of funding received from multiple sources. An overview of sources is highlighted in chapter 4.2.3. Almost all interviewees had different approaches and programs for their funding. This could mean that there is an abundance of types of funding, or that some opportunities are left out due to a lack of knowledge and understanding on these opportunities. Participant 6 shorty discussed how one of these funds work.

P6: We got the NVO fund and, yes, it's a two-phase fund. So basically, you first need a proof of principle or feasibility study to get to know if this idea is doable or not. You prove that and if you succeed, then you can get another phase two and you get a loan to start your company. The loan is beneficial in terms, and you get quite a sizable amount of money to start to hire people and start to really build a company.

There are many different programs with their own characteristics, terms, and challenges. But the interviews highlight that there is an abundance when it comes to deep-tech solutions. From the interviews and the many different strategies that were used, it seems that not all possibilities seem to be familiar to all entrepreneurs.

Many papers mention the specific research field as being a driver. This is due to its many possibilities and opportunities because of the high urgency on climate change. There are many specific funding opportunities for investors that want to step on the climate change train, and market opportunities as the market is not saturated yet.

P3: We see a real opportunity to make an impact because the need for energy-efficient solutions is growing, and the market for sustainable products is only increasing and not fulfilled yet.

This finding dives into the specific sector in which the deep-tech startups are located. It is such a specific field that narrows down responsible parties and likewise stakeholders that can help. However, since there is a high urgency, especially at the time of writing (August, 2024), there is a favourable RE for these kinds of startups.

Strong Business networks

For many entrepreneurs networking is part of their success. Although each entrepreneur's network and 'luck' finding the right people are unique, the importance of networking emerged as a common theme in many interviews. This type of networking is separate from academic networks, which are also considered a driver. Business networks often provide valuable feedback and new insights on how others have succeeded. Engaging with like-minded individuals or entrepreneurs who have had similar experiences can be helpful, frequently leading to new perspectives or adaptations of existing ideas. Participant 1 describes that networking and going to events can open up the opportunity to discuss with likeminded people.

> **P1:** There are so many stakeholders you are dependent off, and going to events gives a good display on how big it actually is. There you can also discuss with likeminded people on their adventure.

This insight follows the saying: “Experience is the best teacher, but someone else's experience is the cheapest”. It emphasizes the value of learning from others’ experiences to avoid making the same mistakes.

Entrepreneurial success factors

Entrepreneurial success factors are aspects where the entrepreneur feels a direct responsibility, such as team formation, the adaptability and flexibility of the team, preparations, market research (MR), and other entrepreneurial tasks within the pre-founding to founding stages. The results highlight the importance of having a flexible yet structured approach that contributes to a successful transition to the founding stage and beyond. Setting incremental goals and keeping an overall perspective, rather than delving too deeply into every detail, also contributes to overall success. Additionally, the implementation of early prototypes is crucial as it drives the specification and practical application of the product. This improves communication within the market, but also within the team. Participant 5 highlights the mental picture of how the entrepreneurship is viewed.

> **P5:** You really need to just start and then take it step by step. And then each time that you reach a milestone you have to set a new milestone for yourself. Make a good plan then just divide it into little bits that you can adjust, but also comprehend.

The findings on the entrepreneurial success are resulting from a mindset change from research to entrepreneurship. In the strategies this is elaborated on a deeper level (Chapter 4.2.5).

Finding the right multi-disciplinary team is also responsible for the success of DTS. A well-rounded team should ideally encompass a range of expertise that allows the team to tackle the various challenges that arise during the pre-founding to founding stages, an overview of the expertise is given in chapter 4.2.1. Participant 8 gives his view on the team in hindsight:

> **P8:** Looking back, focusing more on technical expertise within the team would have been crucial. The co-founders' lack of technical background made it difficult to understand the complexities of bringing the product to market.

Personal motivations

The emotional support from relatives gave most participants the edge to continue when things got more difficult. Whether they ultimately failed, succeeded, or are still in the early phases, all the entrepreneurs interviewed expressed no regrets about choosing the DTS path. The journey itself, with all its new experiences and connections, was seen as worth it. This adventure was often driven by personal motivations as is quoted by participant 3.

> **P3:** The one sentence or the one quote is: if I'm not going to do it now, I will regret it the rest of my life. Yeah, that was for me the turning point of I'm going to do it because she's right. If I don't, I will continue my job, which is fine, but I will regret the rest of my life thinking about what my life would've been if I had done this.

This is an important example that is experienced by many entrepreneurs. The fear of missing out on what could have been acts as a motivator, pushing them to take risks and pursue their DTS with passion.

Personal motivation also comes from a clear mission that contributes to the will of entrepreneurs to continue to make the world a better place. It is often a clear mission that is able to change society for the better, as this a characteristic for DTS. Participant 2 explains what her future vision is on their technology.

> **P2:** I'm sure that we're going to see a lot of different companies jumping on the bandwagon as soon as people realize that our technology is the future. It's something that we need as a society and for future generations. The possibility of changing the world for the better motivates me.

This quote highlights the competition that is met in the SE sector, but it also shows the willingness to take that for granted to make the world a better place.

4.1.2 Identified Barriers

For the barriers another frequency table is constructed to find the number of times that a concept is spoken about during the interview. The frequency gives a sense on the importance of the concept regarded by the interviewees. As a sidenote it is important to understand that the frequency can often be higher due to the extensive usage in a short passage in the interview.

Table 6: Frequency Table Identified Barriers

Concept	**P1 E (Energy Storage)**	**P2 E (Solar Energy)**	**P3 E (Sustainable Architecture)**	**P4 E (Wind Energy)**	**P5 E (Applied Material)**	**P6 E (Applied Material)**	**P7 F (Renewable Energy)**	**P8 F (Energy Storage)**	**Total Frequency**
Academic Interest Divergence	0	2	1	4	5	4	2	2	20
Complex Regulatory Environment	4	2	2	5	3	6	2	4	28
Investor Discrepancies	5	0	4	2	4	2	1	5	23
Entrepreneurial Failure Factors	7	6	4	5	3	5	7	6	43
Market Research Challenges	4	4	5	1	1	6	3	4	28
Personal Barriers	1	0	4	0	4	3	4	6	22

E: Existing at time of interview
F: Failed startup

Academic Interest Divergence

A reoccurring theme is the discrepancy between the academical culture and the entrepreneurial culture. Academic institutions often emphasize research and publication, prioritizing theoretical advancements over practical applications. This focus can create challenges for startups that need to develop their product and move on to the next stages to achieve the founding stage and beyond. In the entrepreneurial world, entrepreneurs need to look at the bigger picture and move forward even if not everything is perfect. Participants state it as a change of mindset and thinking. Participant 3 highlights the difference between academic theories and real-world applications.

> **P3:** We have a strong academic background but turning that into a commercially viable product was a different story. It was hard to align the academic theories with real-world applications.

This barrier is rather specific for DTS, as there is often a transition from a researcher to an entrepreneur. For other startups this is often not the case, since a lot of entrepreneurs have a stronger commercial background than deep-tech entrepreneurs or researchers. Theory often goes into details focusing on what could be possible under ideal conditions, but when it comes to practical implementation, the realities of the market and the need for a functional product take a different approach. More on this can be found in chapter 4.2.5.

Complex Regulatory Environment

Another barrier is navigating through the complex RE. While the RE provides drivers, it also imposes barriers. Startups endure administrative challenges that take longer than initially expected. For startups in the pre-founding to founding stages this time delay can be particularly detrimental, as this is a stage in which many things are done in a relatively short time horizon with high-risk conditions and with limited resources. Teams within DTS are often subject to a lot of risks concerning the complexity and need for funding of the solutions. A setback in time can therefore be of major impact. Participant 4 gives an example of the time horizon it can take to receive the actual funding.

> **P4:** We applied for the EU for this specific grant. And they agreed okay we pay your team for another five months to finish this proposal. And then if that proposal is successful, you have your funding. But once the grant was provided and could be used it took some time. It takes really half a year before the EU big administrative process gets this thing going.

In addition to these time delays, complying with various regulations divert attention and resources away from core business activities. There is a need for specialized knowledge and expertise in navigation through the regulatory landscape, as is highlighted by participant 3.

> **P3:** The process of getting the governmental grant was positive but also quite detailed and slow. We had to come before an expert panel and prove that our technology could work and was unique. This took our time away to focus on our core product.

The quote shows one the many responsibilities that come forward in a DTS. There are many disciplines to consider trying to make a DTS successful.

Investor Discrepancies

The discrepancy between investor expectations and the deep-tech development cycles is also one of the barriers. This misalignment often comes from differences in priorities and knowledge. The difference in expectations leads to funding and support challenges for the startups. This is a result that can be found in all types of startups but is often enlarged in deep-tech. Communication is more difficult due to the complexity of the technology, and development times are often longer. Investors often want to see quick results, which is often not possible in deep-tech. Participant 4 highlighted this issue:

> **P4**: A lot of investors see there is money to be made in sustainable energy. They start investing but they are expecting results within two years which is not realistic. You need longer development times. And what you see is that a lot of times investors back out when there is not yet the desired results.

Additional to the time horizon difference, to satisfy the investors, entrepreneurs often have to adjust their reasons and pitches to align with the investor's wishes for the product. These adjustments sometimes led to strategic compromises that makes the future and next stages more difficult or outside the core idea in the eyes of the entrepreneurs.

> **P3:** We had to adjust our pitch and focus based on what investors were looking for, but often their priorities didn't align with our vision for the product.

This leads to unsatisfactory compromises that hinders the development in the next stages. This can also be a motivation disabler, if the enthusiasm of the entrepreneurs disappears.

Entrepreneurial Failure Factors

The entrepreneurial failure factors are the challenges that also can be brought back directly to the feeling of responsibility of the entrepreneur. One of the failure factors have to do with the formation of the team that has been introduced as a driver in this chapter. Often it is difficult to find the team with the right expertise. This is especially vivid for DTS as they need to cover multiple fields of expertise, including technology and business, but also areas like regulatory compliance and MR. In case of the right team participant 8 encountered difficulties due to a lack of specific technological knowledge within the initial team forming.

> **P8:** The first mistake was that my co-founders were not technical. So, they could not assess properly what it takes to bring a product which is based on complex technology to the market. If you want to fill every gap with expertise, there are so many people you need to hire.

This problem in team formations, is especially vivid for deep-tech solutions. For many startups a team can consist of a few commercial specialists, whereas DTS need a wide range of team members to fulfil multiple important disciplines as can be found in the strategies in chapter 4.2.1 about multi-disciplinary team forming.

Building forward on the entrepreneurial failure factors, communication with potential customers and investors is also a key challenge. Since deep-tech solutions are complex clear communication is needed to convince customers and investors that the idea is worth exploring, as is highlighted by participant 6.

> **P6:** Our technology is very niche and complex, which makes it challenging to clearly communicate its benefits to potential customers and investors.

For a product or service to work, there should be a strong customer base that is willing to use that product or service. In the case of deep-tech solutions, the costs and complexities can prohibit clear communication on the advantages or implications to potential customers. If communication is not successful investors and customers can pull out which leaves the team often with a lack of resources, especially in the early stage where there is not a big money pot yet. This happened to participant 7 among others.

> **P7:** Our finances were just gone, so I couldn't continue working for long. When I wouldn't get paid anything anymore, I could keep that up for a few months, but at some point, you just give up. There are basic needs in life that just cost money.

Market Research Challenges

MR challenges were a significant topic in the interviews and need to be taken as a distinctive theme. It highlights the complexities and obstacles that startups face in understanding and penetrating their target markets. In the pre-founding to founding stage, not a lot of actual market penetration is done, but the research and finding a niche and customers is something that has high priority in these stages. The complexity and recent hype within the SE landscape in the Netherlands poses opportunities, but also challenges. This is appointed by participant 6:

> **P6:** We are operating in a very complex technical market with many established competitors and evolving regulations. This makes it difficult to position our product.

Within the SE field, there are many competitors. It is a hot topic where a lot of companies want to focus on. This means the competition and speed of new entries in the field are relatively high. Not only the players increase rapidly, also regulations and market dynamics add another layer of complexity to the MR.

> **P7:** The rules are constantly changing, and evolving, and keeping up with these require significant resources and adaptions, which is not nice so to say.

The rapid changes in regulation are difficult to document and comprehend as a starting entrepreneur. For deep-tech there are often no technologies that follow the same route. This uniqueness frequently precludes the use of existing case studies as guides, leaving entrepreneurs to navigate a largely uncharted regulatory landscape. It necessitates a proactive strategy to anticipate and adapt to regulatory shifts that could impact its development and market introduction.

Personal Barriers

Personal challenges also emerged from the hands-on interviews, revealing various difficulties faced by entrepreneurs on a personal level. One common issue is self-doubt and the struggle to find a viable idea. Entrepreneurs often second-guess their ideas, worrying about their feasibility, the competition, or their own ability to develop them. This self-doubt can hinder progress, as entrepreneurs may discard potentially good ideas due to a lack of confidence in their own capabilities or concerns about market competition. A personal experience is shared by participant 3:

> **P3:** I had multiple ideas but every time I was like hmm this is not good enough or this is too hard to develop, or you know there's too much competition on it. In retrospect, I think some ideas were also good, but you know you have to find something that you're good at and just do it at some point.

Support from family and friends is crucial, yet often lacking when starting a business (even though this is also mentioned as a driver). The entrepreneurial journey can be stressful and demanding, and the absence of a supportive network can intensify these challenges. Entrepreneurs frequently need emotional and sometimes financial support from their close circles to sustain their motivation and well-being. However, this support is not always available, adding to the pressures they face.

> **P5:** You know you need support from your family and friends but it's often lacking when you are trying to start a business.

Many entrepreneurs, especially those with technical backgrounds, are used to focusing on detailed, specific aspects of problems. However, entrepreneurship requires a shift to a broader view, considering how various elements of the business interconnect and affect each other. This transition from a detail-oriented mindset to a strategic, big-picture perspective can be difficult and significant adjustments. This thought is shared by participant 6:

> **P6:** So basically, we have this trend to be precise, to be kind of looking to the details, to mine the core of the question. However, as I said, I mean, entrepreneurship is totally different. Your focus is on another spectrum, everything, other side of the spectrum. You are more looking at the big picture, how is it affecting your plan? How is it kind of influence your relationship with other parties.

It closely related to the change in mindset that is also described in the academic interest divergence, but it highlights again how a development in skills, focus and mindset are needed to be able to adapt to a complete new entrepreneurial environment.

4.2 Strategies Employed to Overcome Challenges

The interviews introduced the subject of strategies to overcome challenges and to leverage drivers to strengthen or steer the startup into the right direction. The strategies closely align with the introduced drivers and barriers in the previous section. Some of these drivers and barriers will reappear in this chapter, but they will be reviewed from the perspective of their use as strategies. By asking participants questions about what they would have done differently in the past, and probing into their challenges, some strategies emerged. It is worth noting that not all strategies are applicable to every scenario in the early stages of a DTS. However, it explains reoccurring themes and guidelines on what work best for certain interviewees.

Table 7: Occurrence Identified Strategies

Concept	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
Cross-Disciplinary Team Forming	X	X	X	X	X	X	X	X
Leveraging Academic Resources and Expertise		X		X	X	X	X	X
Strategic Pivoting Within the Funding Landscape		X	X	X	X		X	X
Adapting to Market Needs and Feedback	X	X	X	X	X	X	X	X
Entrepreneurial Mindset	X	X	X	X	X	X	X	X

4.2.1 Cross-Disciplinary Team Forming

Team formations are a main theme in each of the conducted interviews. All participants highlighted the importance of having a team that is cross-disciplinary and with expertise. Forming a team, especially in deep-tech, can be highly complex due to the inherent complex nature of the technical solutions. A deep-tech culture often exists out of researchers, but often lacks the expertise of setting up a successful startup. Having some expertise on the business sides is a key strategy successful startup employed to be able to get further. However, being interwoven with an academical culture does not make it easy to find partners that can help. Expertise is often sought for in close networks, but wat deems to be helpful is to talk to other entrepreneurs and going to ventures and gatherers, to find likeminded people that can give information on how they experienced the early stages of their DTS. This is also a way to make the startup known to the entrepreneurial society.

Another problem that is faced by deep-tech solutions is the complexity of the product itself. It is difficult to team up with experts in other fields, if they do not understand the core of the technical solution. Deep-tech often relies on heavy R&D, which has often only been introduced to a couple of experts, which cannot be easily explained to new team members. A way to cope with this is to keep clear boundaries on what needs to be understood to be able to get to other aspects, like MR or investor relationships, and what is abundant information that is needed for the research but does not need to be fully understood by the other team members.

This need for the clear way of communication within the team is also needed for the communication to society. Due to the complexity of deep-tech solutions, potential customers drop-out. Participant 4 highlights the importance the alignment with other stakeholders on the expectations.

> **P4:** A big realization was that expectations for quick results from investors are often unrealistic in deep-tech fields. Longer development times are just necessary, and aligning investor expectations with this reality is a must.

This is often misunderstood, since the will to be able to get the investment and to make potential customers interested sometimes overpowers the view on reality. Eventually, making promises that cannot be kept, backfire at some point in the process. This overestimation often results as a bias towards the entrepreneur's own product or can be due to a lack of knowledge on what to expect. The latter is especially vivid for DTS. This overestimation is also highlighted by participant 7:

> **P7:** We loved our product too much. I think we had a bit of tunnel vision. We kept pushing the same idea even though there wasn't a realistic vision on the timeline.

According to the interviews multiple expertise are mentioned that are valuable as an addition to the team in the early stages of a startup. While it may not be financially viable to have an expert in every area, some roles can be fulfilled by individuals with multiple skills. In figure 6 the main fields of expertise are highlighted according to the interviews. An example of a hindsight view on this is shared by participants 3 and 6.

> **P3:** Establishing stronger partnerships earlier would have provided more stability and resources, helping us to navigate challenges more effectively.

> **P6:** Hindsight is, that we should have prioritized creating a more focused business plan from the start, aligning our funding projects with clear milestones to better utilize our resources.

These quotes emphasize the importance of customer relations and financial management. Early expertise in these areas, among others, was mentioned as points of improvement in hindsight for improving success.

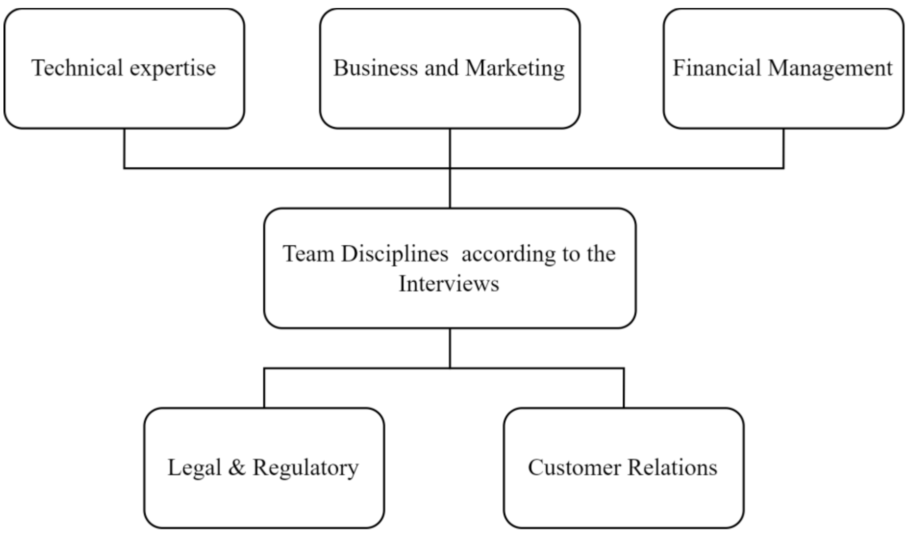

Figure 6: Team Disciplines

4.2.2 Leveraging Academic Resources and Expertise

A connection to academic resources, mentoring and expertise helped participants to propel forward. All participants except for P1 and P3 highlight the importance of the connection to academic instances. The main themes that are discussed are academic funding programs, mentoring and expertise from colleagues, access to specialized research equipment and a strong network with specialists in multiple research fields that can be a possible addition to the team.

The funding programs are often closely related to other funding opportunities and will therefore be introduced in the next section: strategic pivoting within the funding landscape. The main takeaway for the academic funding opportunities is that a university as a funding organ, is more related and understanding of the academic culture and complex research practices, compared to private investors or governmental investors.

Specialized research that happens in deep-tech practices often needs advice from other specialists. A strategy of building up a strong academic network is highlighted in multiple interviews. In most cases there is a two-way interest for the entrepreneur and researcher. In most cases these are (PhD) students that benefit from intensive research in a specific field to publish papers, whereas the entrepreneur benefits from the help by increasing the performance of the product. Since a lot of startups have funding problems, a bilateral benefitting situation that does not cost money is preferable to hiring specialists that need a salary. Participant 2 elaborates on how this helped in the early stages.

> **P2:** We had over 50 people working for us over the past two years. As volunteers, as interns, as thesis students, just people purely putting in their time because they believe in the mission and vision of what we're trying to achieve. And that I think would never have been possible if we hadn't been based or in close ties with the university where we just met so many students. We were able to provide this kind of structure and this playground for students to come and put their help in at trying to revolutionize the solar industry.

Another benefit of an academic network is the possible pool of team members. Considering interviews P5, P2, P4, P5, most team members are from academic networks that add on to the expertise within a team. A possible pitfall is that the expertise becomes too one-eyed, which decreases the chances of other expertise that contribute to the success of an academic startup.

Deep-tech initiatives often rely on heavy R&D that need specialized equipment for it to be successfully researched. Universities often have labs with specialized equipment that are hard to found elsewhere. With access to the specialized equipment labs, different scenarios, materials and optimizations for product can be tested on lab-scale. However, it is worth noting that a change from lab scale to commercial scale can influence the outcome and costs, as is discussed by participant 7. This is something that is overlooked in some instances where DTS tend to fail because of this change.

> **P7:** Collaboration with the university's research department allowed us to access specialized equipment and expertise that were definitely helped in developing our product. ….. What works on a lab scale doesn't always work on a commercial scale. We found that scaling up introduced new challenges that we hadn't anticipated, which significantly impacted both the cost and the feasibility of the technology.

Unless the scaling problems from lab research to commercial scale, tests and experiments for many deep-tech solutions can be tested in university labs. This aspect that necessitates a bit of dependence of the university is not always considered by the entrepreneurs.

4.2.3 Strategic Pivoting Within the Funding Landscape

One of the main discussed topics was about funding opportunities, since funding is often a barrier for DTS at some point in time. Strategies to pivot the funding landscape is directly discussed by all participants except P1 and P6. In this section types of funding options that have been used by the participants in the early stages of their DTS are discussed.

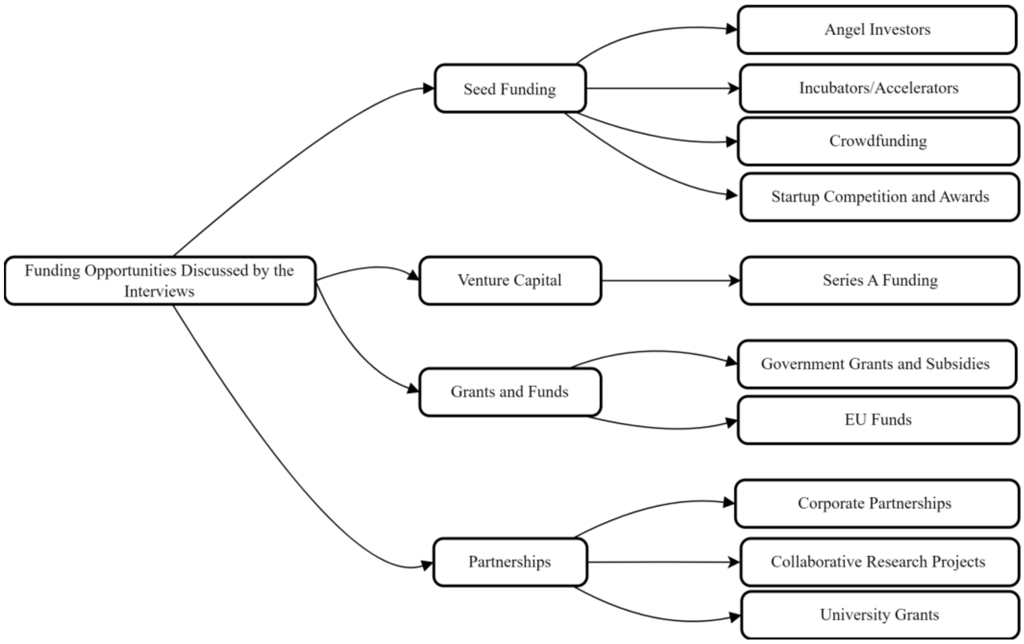

Figure 7: Funding Opportunities

Seed funding is a main source of income for early-stage DTS, as this is often where the first investments come from. Here investors provide capital in exchange for ownership equity. Multiple types of seed funding came forward in the interviews. For DTS there are targeted competitions where price money can be won.

> **P2:** We did win a bunch of startup competitions pretty regularly and those like have cash prizes, which add up in the long run.

Another option that is often overlooked by the DTS entrepreneurs is crowdfunding. It seems generic, but participant 4 is the only one that specifically talked about using it as a form of income. This was an option that was not considered at the very start of the startups, but was used as a last resort option for funding.

> **P4:** The crowdfunding actually really shifted our chances on success to positive side.

Since DTS often need more significant investments besides only seed funding, venture capital series A funding came also forward in the interviews. This is typically the first round of venture capital funding a startup or company receives after seed funding. There are also more rounds (series B, C etc), but this often comes at a later stage in order to expand business or scale up businesses. This funding option was used by participant 2 among others.

> **P2:** Then we went to Germany to get more funding and we did our rounds of going to investors together, to see which venture capitalists wanted to work with us.

Grants and Funds were also a main source of income for the entrepreneurs, with some initiatives like the EU horizon grant, Dutch Research Council (NWO), and Thematical Technology Transfer (TTT). Besides the national and European initiatives, there were also regional and municipal initiatives. Participant 7 gives these options as an example.

> **P7:** We had two main pots of money; one was from TTT, and the other was from the NWO, which shows there are definitely tailored programs available…We won a large EU grant, that was the EU's Horizon. It's a research framework program which is a very widespread big program. They had this funding instrument that was called Fast Track to Innovation.

The last-mentioned category that came forward in the interviews were the partnerships with companies, collaboration research projects with different universities over the world and university grants.

> **P8:** Then also the university funds got involved; They invested in two trenches and then there was a private investor who invested in total also around a quarter of a million.

The funding options in this section seem rather general. However, the interview results showed that only few options are considered by every participant. Sometimes the most prevailing options are overlooked due to a directional bias where participants focus too much on going one path instead of exploring other possibilities.

4.2.4 Adapting to Market Needs and Feedback

Market readiness and adapting to market needs and feedback is one of the main challenges that DTS experience. This is also where a difference in strategies between participants are highlighted. The main result from the qualitative data analysis is that there needs to be a balance between sticking to the original plan without getting too much distraction and the focus on what the market needs. Deep-tech solutions differ from conventional startups when it comes to MR. Most conventional startups start to exist based on a gap in the market that can be fulfilled implementing a service or product that fills this gap with a specific target audience (Reisdorfer-Leite et al., 2023). SE DTS often lack this conventional method and addresses big challenges that can have an impact on society. This makes is difficult to adapt deep-tech solutions to a specific audience or finding a niche that can be commercially viable in the long term.

The research into fulfilling the market can be challenging and overwhelming due too many different pieces of advice, possible customers, and applications. Therefore, participants (P3, P6) state that it is important to keep the original idea very close and try to adapt as little as possible. Sometimes it cannot be neglected to listen to experts in the market culture, to receive funds and a vision for the future. In the early stages of a DTS the technology is often not fully matured, which makes it possible to adapt in ways in which the core technology does not get lost. Other participants highlight the importance of being as flexible and adaptable as possible. This led to the success of moving on to the founding stage after some iterations for participants (P1, P2, P5).

> **P3:** You get a lot of advice from a lot of people, and they all are different advice. And as a founder I found it sometimes hard because people give you introductions... And then you have another person, and you know he's also well known, and he says: no, you're doing it all wrong. You must do this this and this and this. And you ask 100 people, you get 100 different pieces of advice.

> **P5:** We started quite broad. I mean we were thinking of the automotive we were thinking of yeah non-residential buildings or residential buildings finding it as a retrofit to existing glass or going more for new glass products. And along your way you will find that there are some technical limits that's why certain market roads work better. But also, just to talk a lot with the industry because they have done this market research already so they can tell you a lot.

Unfortunately, there is no blueprint for finding the perfect balance between adapting to market needs and feedback and sticking to the original idea. Every company and technology is different. Some participants regretted not doing enough market research (MR), while others felt that too much MR distracted them from developing their original ideas, causing time delays in the high-risk early stage of deep-tech development. Despite these differing experiences, every participant emphasized the importance of MR and their personal experiences with it. Therefore, MR is a critical aspect that should be considered by DTS entrepreneurs.

4.2.5 Entrepreneurial Mindset

There is also the entrepreneurial mentality, which is highlighted in every interview. Participants 6 and participant 2 specifically described the difference between a researcher and entrepreneurial mentality. This change in mentality, where a starting entrepreneur is focused on perfection rather than seeing the big picture can influence the focus within the startup to achieve to a successful start. An entrepreneur needs to see the startup experience as a number of milestones that need to be tackled one by one or sometimes more at once.

> **P6:** Transitioning from academia to entrepreneurship involves a significant mindset change, focusing more on practical and collaborative aspects. In academia, it's about going beyond 100% to publish, while in entrepreneurship, it's about hitting deadlines and delivering 80%.

> **P2:** The real moment is that I thought okay what are you doing? Maybe you can just run this. But you know yeah. And there are a lot of hurdles that you can see in the beginning, but you really need to just start and then take it step by step. And then each time that you make reach a milestone you need to set milestones for yourself make a good plan then just divide it into little bits that you can adjust.

The quotes highlight the shift of mindset to let go of the perfection and constant iterations that are often seen in researcher's activities to try to perfect the research every step of the way.

Another mentality factor has to do with perseverance and readiness to take risks and go beyond feeling comfortable. Participants highlight the difference between close relatives that work steady jobs and entrepreneurs that often worry about getting paid or things done to reach a level of satisfaction. This mental difference is something that thrives the entrepreneurs into proving what they are capable of and learning many new things along the way. In the interviews there was no entrepreneur that regretted his/her decision to try to overcome the early stages of their DTS. Not even the failed startup participants. This is highlighted by the mentioned learning curve and experiences that were completely new and cherished them as experiences that added to their personal toolbox of life.

> **P3:** The one sentence or the one quote that kept me going was: if I'm not going to do it now, I will regret it the rest of my life. That was the turning point for me.

As perseverance is hard to translate as this works differently for almost everyone, a level of thoroughness, willingness to learn and adapt, and personal motivations to changing society for the better is something that is highlighted by many participants.

> **P5:** Yeah, you have to be really adaptable and willing to learn new things all the time. That's what kept me going, the idea that what we were doing could really make a difference in the world.

4.3 Framework

This section aims to give a practical guideline for (future) entrepreneurs that are interested in the navigation through the early stages of a SE DTS. This is a light framework that sets out the common challenges and enablers in the pre-founding to founding stage, but it will also give a guidance that recommends strategies to overcome certain challenges. It is a practical implication of the results. The figure below is a visualization of the dynamics of a DTS to navigate the early-stages.

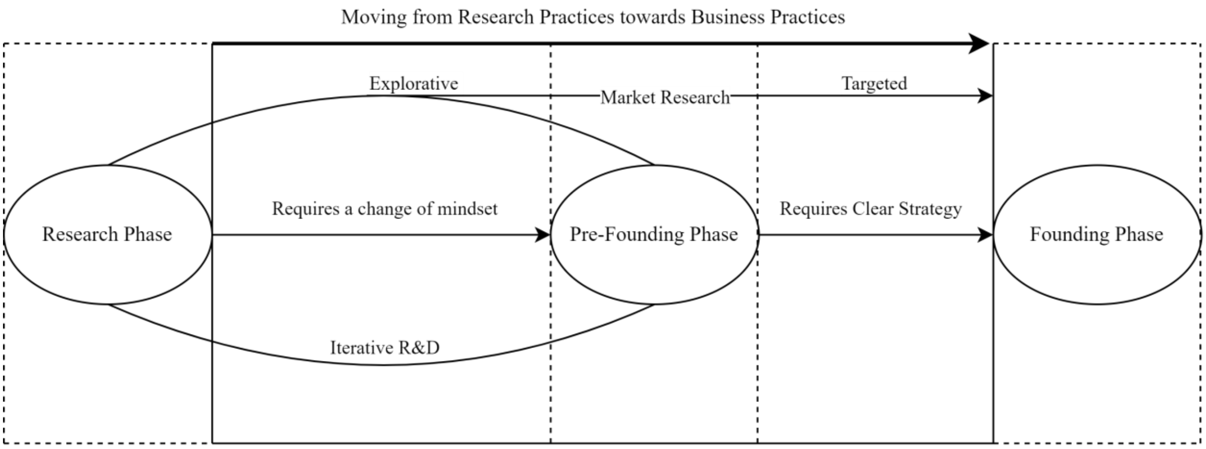

Figure 8: Navigational Early-Stage Deep-Tech Startup Framework

Framework for Navigating Early-Stage Deep-Tech Sustainable Energy Startups

This framework aims to guide entrepreneurs through the early-stages of a DTS, providing insights into the challenges they may face, the enablers that can support their progress, and the key actions necessary to navigate this complex landscape effectively.

---

1. Transitioning from the Research Phase to the Pre-Founding Stage

Transitioning from the research phase to the founding phase of a DTS involves significant changes in mindset, goals, and operational strategies. The research phase focuses on publishing papers and deep-specialised research. The transition to make the research more applied asks for a change mindset, and procedures. This shift transitions from research practices to applied technological development. For DTS this means that there remains a close link to R&D practices that need to be iterated for the application to take form.

Enablers for Success:

- Close (academic) network to explore the idea
- Supportive Ecosystem
- Possible collaborative research opportunities
- Personal motivation
- Draft financial and business plan

Challenges:

- Clear communication of the application strategy of the technology
- Building an interdisciplinary network of knowledge
- Finding the motivation to start exploring the applied side of an idea
- Interest discrepancy between the university and personal goals

Key Actions:

Create a draft business and financial plan: Develop initial plans to communicate key aspects of the startup. The complexity of the technology must make place for clear communication to be able to engage with multiple stakeholders in this stage of development.

Engage with close (academic) networks to explore the applicability of the idea and to find possible team members or co-founders. This engagement is mostly focused towards a deep-tech applied solution rather than a deep-tech theoretical solution. Therefore, the need for expert and pinpointed knowledge is preferable.

Gain an initial explorative understanding of the position of the idea within the sustainable-energy market and other markets if applicable. As literature points out, deep-tech solutions can be disruptive and make their way into multiple markets. An initial idea or scenario analysis could help to prepare (Schutselaars et al., 2023b).

Be willing to change your mindset from academic to practical approaches, focusing on setting milestones rather than detailed perfection.

Note on the Mindset:

The study suggests that a change of mindset can be achieved by setting milestones rather than detailed plans. An entrepreneurial mindset focuses on the overall picture and not on the many details and perfection needed like when publishing a paper.

---

2. Exploration of the Pre-Founding Stage

As startups enter the pre-founding stage, they encounter a new world filled with exploration opportunities. This phase involves introducing the startup to potential funding sources, researching the practical applications of their deep-technology, and balancing the use of academic and corporate resources. There is also a needed shift to a multi-disciplinary understanding of the idea and its possible implications.

Enablers for Success:

- Access to various funding opportunities
- Building a team with diverse skills to cover different disciplines
- Utilizing market feedback to refine business strategy

Challenges:

- Navigating the RE
- Many different advice
- Interest discrepancy between the university and business goals
- Complex MR

Key Actions:

Strengthen team dynamics, by enhancing team capabilities and disciplines. The need for expanding can help in communicating towards potential customers and investors. A discipline that is not only technology based, but specialises in market research, communication practices among others. The most mentioned team disciplines are highlighted in chapter 5.3.1 Cross-Disciplinary Team Forming.

Utilize early-stage funding opportunities. This is explored in Figure 7: Funding opportunities in chapter 4.2.3 Strategic Pivoting Within the Funding Landscape. Light funding is mostly done through seed funding opportunities, grants and funds, research projects, and university grants. For deep-tech solutions these funding opportunities are more vital than for other startups. This has to do with the overall longer and more financial intensive development times.

Refine your business and financial plans based on feedback while staying true to your original vision and maintaining your core motivation. The innovations are often groundbreaking and subjective to many different opinions and stakeholders.

Strategically evaluate and secure intellectual property rights to safeguard the deep-tech innovations. This protection is essential for maintaining a competitive edge and capitalizing on a unique technological product or service.

---

3. Transition to Founding Phase

Moving from the pre-founding to the founding phase involves shifting MR from an exploratory approach to targeting specific customer niches. The disruptive nature of deep-tech solutions can make this overwhelmed and complex, since there are often more markets that are influenced. This stage demands larger funding for prototyping, securing patents, and a reduced emphasis on R&D in favour of market applications.

Enablers for Success:

- Securing patents to safeguard innovations
- Implementing and targeting a clear business strategy
- Maintaining or expanding multi-disciplinary team

Challenges :

- Defining and targeting specific customer segments and market niches
- Increasing funding requirements to demonstrate product viability
- Establishing visibility and credibility in the market

Key Actions:

Transition the focus of the team even more on applied business skills and a bit more away from intensive R&D practices. Once the technology reached an applied state, less research has to go in.

Seek larger investments through series A funding and other instruments like grant and funds, and corporate partnerships as an addition to the other funding opportunities (chapter 4.2.3 Strategic Pivoting Within the Funding Landscape)

Create or refine prototypes to showcase the product's potential to attract investments and customer interest.

---

5 Discussion

Last chapter elaborated on the empirical results that came forward in the interviews. In this chapter a discussion is provided of the findings presented in Chapter 4. It starts by interpreting and comparing the results in the context of existing literature, exploring how the identified drivers, barriers, and strategies align with or differ from the reviewed literature. The chapter also delves into the implications of these findings for various stakeholders, including entrepreneurs, academic institutions, and policymakers. Additionally, it discusses the limitations of the study.

5.1 Interpretation of Results

The problem addressed by this research revolves around the high failure rates of DTS despite their potential to tackle significant societal challenges through innovative solutions. The literature on DTS shows a generalisation across various industries without addressing specific fields and countries. The purpose of the study was to investigate the unique barriers and drivers faced by Dutch Deep-Tech Startups (DTS) in the Sustainable Energy (SE) sector during their pre-founding to founding stages. The results are aimed to add new and tailored insights that are applicable to entrepreneurs and other stakeholders in the deep-tech Dutch SE world in the early stages. The research was set up to answer the following main question:

"What are the main drivers and barriers for Dutch DTS in the sustainable energy sector during the pre-founding to founding stage, and what strategies do they employ to navigate these challenges?".

To answer the main question, sub questions were constructed to break the main question up into separate questions dividing the main question into drivers & barriers, strategies, and a framework. By answering the questions, a practical guide is constructed that can be consulted by entrepreneurs. The questions also cover drivers, barriers and strategies that are related to the regulatory and academic environment. For each question, the possible implications of the results and their connection to the literature are discussed.

For the first question, “What are the specific drivers and barriers for the pre-founding to founding stages in the field of deep-tech sustainable energy in the Netherlands?”, the results section presented various drivers and barriers based on the experiences of different entrepreneurs in the SE sector.

The formation of diverse teams with a mix of multiple fields of expertise, was highlighted as a main driver. The participants stressed the importance of having team members who can bring different perspectives and skills to the table. Existing literature supports this finding emphasizing that multidisciplinary teams enhance innovation and problem-solving capabilities, as was highlighted by Visintin & Pittino (2014) and Hossinger et al. (2019). For deep-tech multiple disciplines are particularly important since deep-tech innovations are often initially only accessible to a small community that has the appropriate knowledge of the technology. Having an expert in customer relations and marketing to be able to reach a bigger segment of customers and investors increases the liability of the startup.

Another theme obtained from the interviews is the importance of access to academic resources and collaboration possibilities with universities. This finding is supported by existing literature, which gives a general understanding of the importance of having academic connections that can help guide the startup through the difficult phases of the startup (Kruachottikul et al., 2023; Messina et al., 2022). The interviews contribute to the literature by stating that university connections often involve knowledge transfers rather than financial costs. Deep-tech relies on heavy R&D for which resources can be exorbitant when they need to come from external sources. Being able to collaborate by transferring knowledge between parties in the academic culture, prevents draining scarce financial resources.

Additionally, the interviews highlight that being an entrepreneur does not always have to do with having a good idea yourself. Many ideas are thought of by research teams or colleagues, which again adds on to the importance of having a good academic network. A problem that exists within the academic setting often has to do with the difference between academic research purposes and entrepreneurial purposes. Participants highlighted that a change of mindset is needed to let loose of the detailed view that is required for academic research purposes, and embrace the bigger picture with setting milestones, goals or missions that need to be fulfilled. This finding can be of importance to university bodies that work in close collaboration with DTS founders. It is a gap in which many entrepreneurs must navigate independently, often without sufficient support. The Dutch academic environment is reviewed as favorable by the participants, because of the possibility of exchanging knowledge rather than financial resources and freedom within the operation of their startups. However, there can be an improvement of the guidance that is necessary to facilitate the entrepreneurial mindset shift. This could involve tailored training programs, mentorship initiatives, or collaborative workshops designed to bridge the divide between academic and entrepreneurial thinking.

The regulatory environment (RE) in the Netherlands came forward as both a driver and a barrier. While existing literature discusses regulatory frameworks, the interviews provided specific insights into the Dutch SE context. Participants noted numerous funding options available, specifically for SE DTS due to the urgency of climate change. DTS founders often need to bridge long-term visions of the deep-tech solutions, with short-term milestones to gain support from investors and other stakeholders (Gozal et al., 2022). This can often cause a delay in assets that is very hard to overcome of no other funding options are available. Therefore, the many funding options in the Netherlands can bridge that gap better. Unfortunately, participants noted lengthy administrative processes and the need for specialized knowledge to navigate regulatory requirements. The lengthy processes are something that can be devastating especially in the early-stages since there is no buffer and testing and prototyping deep-tech solutions are capital intensive. For policymakers, these findings suggest the need to streamline regulatory processes and provide more accessible guidance and resources for entrepreneurs. Simplifying administrative procedures and offering targeted training on regulatory compliance could reduce the burden on startups, allowing them to focus more on innovation and less on bureaucratic hurdles.

The study also identified several entrepreneurial success factors that align with and extend the existing literature. The importance of a structured yet adaptable approach to startup management was emphasized by participants. This aligns with literature highlighting the need for flexibility and strategic planning in entrepreneurship (Furr et al., 2012; Maine et al., 2012). The practical insights from the interviews revealed that setting incremental goals and maintaining an overall strategic vision are critical for navigating the early stages of a startup. On the other hand, there are also entrepreneurial failure factors that hinder progress. This often has to with team formations and communications within and outside the team. These challenges are well-documented in the literature, but the interviews provide how these barriers manifests in practice. Examples of this are like the lack of expertise within teams, or the difficulty finding potential customers and investors (Calderón-Hernández et al., 2020; Pahnke et al., 2015).

Market research challenges were also highlighted as a main theme within the barriers. The interviews revealed the complexities startups face in understanding and penetrating their target markets, which are compounded by the high competition and rapidly evolving regulations in the SE sector. Existing literature emphasizes the importance of market research in achieving product-market fit (Andries et al., 2021; Scaringella et al., 2017b). However, it often overlooks the practical difficulties faced by startups in this dynamic environment. Participants explained how these challenges play out, citing the need to constantly adapt to changing market conditions and regulatory frameworks. This aligns with literature on the dynamic nature of high-tech markets (Pahnke et al., 2015). For deep-tech innovations, market research and target markets are not easy to identify. It often involves a new type of technology that has the potential to create an application that hits across multiple industries, making the process of defining a clear market segment challenging. This ambiguity requires entrepreneurs to be exceptionally flexible and forward-thinking.

The last theme in the drivers and barriers are the personal factors. Personal motivation emerged as a driver, with participants highlighting the importance of passion, resilience, and a sense of purpose for the idea to work. These intrinsic motivations were seen as critical for sustaining effort through the challenging early stages of a startup. On the other hand, personal barriers such as self-doubt, lack of support from family and friends, and the difficulty in transitioning towards a big picture mindset came forward. This experience by the participants offered an understanding of these internal challenges faced by entrepreneurs.

The strategies introduced in the results section are a new addition to the existing literature. It focusses on the second question: “What strategies are employed by entrepreneurs to overcome the main challenges faced in the pre-founding to founding phase?”.

The literature introduced some strategies like the prioritization of their development efforts and focusing on the most promising opportunities. It suggested that entrepreneurs also need to be prepared to pivot regarding early market feedback (Furr et al., 2012; Maine et al., 2012; Scaringella et al., 2017b). This closely relates to the difficulty in finding a market entry, because of the nature of deep-tech solutions as being highly complex and often ahead of current market trends and needs. In the results section this is also explored as “adapting to market needs and feedback”. It highlights both the necessity for pivoting, but also a possible distraction that can delay the progress in the early-stages. The results discussed the significance of incorporating market research (MR) as a fundamental component in the strategic planning of deep-tech startups. However, the results also highlighted that there is no universally applicable blueprint or standardized methodology that guarantees success in market entry and development. Instead, the effectiveness of market research approaches can vary significantly depending on specific industry contexts, technological complexities, and evolving market dynamics. Therefore, it is essential for deep-tech startups to adopt a flexible and adaptive market research strategy that can be tailored to meet their unique needs and circumstances. This approach should involve continuous market scanning and feedback integration to refine products and business strategies dynamically, aligning them with real-time market demands and opportunities.

The literature also introduced the need for the exploration of multiple business models (Chammassian & Sabatier, 2020; Maine et al., 2012). However, this recommendation is not strongly echoed in the firsthand experiences shared by entrepreneurs in the study's results section. Feedback from the participants revolved more around adapting to market needs and feedback rather than experimenting with various business models. This disparity may stem from the inherent complex nature of deep-tech startups, which often use complex technologies that limit their agility and ability to pivot quickly.

The shift to an entrepreneurial role involves moving away from a focus on perfection and embracing perseverance through setbacks and challenges. However, this mentality adjustment is not directly linked to the need for exploring multiple business models as highlighted in the literature review. Instead, the practical challenges faced by deep-tech startups, require entrepreneurs to concentrate on refining a single, well-suited business model that aligns with their technology.

Other strategies introduced by the literature such as customer insights, market validation, diversifying funding sources and strategic partnerships and recruitments of the team, are considered important strategies that can help a DTS succeed (Andries et al., 2021; Ansari et al., 2016; Hampton et al., 2011; es Maine et al., 2012; Page West & Gemmell, 2021; Pahnke et al., 2015; Piazza et al., 2023). For the team the results suggest there is a need for multiple disciplines in order increase the chances of succeeding. The participants suggested the following fields of expertise: technical, business & marketing, financial management, legal & regulatory and customer relations. The team needs to be able to have clear communication within all disciplines to succeed. For the funding opportunities the results map out a diagram that highlights the methods that are explored by the participants to see what kind of options are available in the landscape of the Netherlands and in the early-stages. Four main categories were identified that helped entrepreneurs gain funding. There are seed funding, venture capital, grant and funds and partnership opportunities to receive funding that is needed at the early stage of the deep-tech technology. This funding can be used for a variety of applications, ranging from the salary of the team, to building early-stage prototypes to gain more trust from investing parties.

In the last question on how a framework can assist future entrepreneurs in navigating the drivers and barriers of deep-tech sustainable energy startups in the Netherlands, the drivers, barriers and strategies are taken together to make a practical guide.

The designed framework is made to aid entrepreneurs by showing the practical steps they can take to ensure some of the most important steps in the early-stage of their deep-tech SE startups are not overlooked. It is needless to state that there is no blueprint on what an entrepreneur could do to succeed and move on to a founding stage, but the framework aids to show entrepreneurs what factors need to be understood to increase success, based on entrepreneurs who have been in their shoes before.

The framework discussed a change of mindset that most entrepreneurs had to experience to move forward successfully. This mindset is something that takes a deep-tech researcher out of their comfort zone by letting go of perfection and completeness, and by letting go of risk-free and working steady jobs.

As highlighted by the participants, most people do not understand what it takes to be an entrepreneur, even close relatives. But what all participants embraced is that they did not regret their choice this far. Even the failed ones did not. Being an entrepreneur is an adventure in where the entrepreneur must throw himself into the deep to explore the unknown. This is challenging at first, but also often life changing. New networks, new information about multiple disciplines that have not been explored before, and working for something that can influence society as a whole. This is what kept and still keeps the participants striving to success.

The study contributes to the existing body of knowledge on deep-tech and deep-tech entrepreneurship. The research addressed several gaps in the literature on DTS particularly within the Dutch context and the SE sector. By focusing on the unique challenges and strategies specific to DTS in SE this study provides targeted insights that enhance the understanding of the localized drivers and barriers these startups face. It distinguishes the nuanced needs specifically for deep-tech. Additionally, the study delved into how these startups navigate the complex regulatory landscapes in the Netherlands, offering insights to manage and recognize some of the challenges in future DTS.

5.2 Implications

It would be convenient if there was a blueprint that could make everyone with a deep-tech invention successful to the founding stage, but in the end the framework highlights that many factors for success come from luck, perseverance, and personal motivations. With insights into common challenges, enablers and strategies to overcome challenges, a future starting deep-tech entrepreneur can be prepared to what is most likely coming their way.

Apart from serving as a practical guide for future entrepreneurs, this research provides insights for universities and policymakers, emphasizing some main elements in the SE deep-tech landscape. The findings reveal various barriers and opportunities, particularly concerning the complex regulatory landscape and the numerous funding opportunities available in this specific field.

For universities, enhancing support structures for student entrepreneurs can help or motivate them to translate research into products or services. Developing robust support mechanisms, such as dedicated funding programs, mentorship opportunities, and access to research facilities, can bridge the gap between academic research and market-ready innovations. Participants highlighted the importance of mentorship in navigating initial challenges and avoiding common pitfalls, underscoring the need for universities to offer guidance to entrepreneurs. Universities should also foster an entrepreneurial mindset among students and researchers. Encouraging a shift from purely academic pursuits to entrepreneurial thinking can be achieved through specialized courses, workshops, and collaborations that emphasize the practical applications of research.

Promoting interdisciplinary collaboration is another implication for academic institutions. Facilitating interactions between different departments and fields can enhance the innovative potential of startups. Participants emphasized the benefits of having PhD students involved in projects, as this collaboration allows startups to push the performance of their products without incurring additional salary costs. This mutually beneficial arrangement provides PhD students with valuable research opportunities while offering startups the technical expertise needed to improve their products.

An implication for policymakers, suggests addressing the complexities of the regulatory landscape that startups navigate. Streamlining regulatory processes and reducing administrative burdens can significantly impact the trajectory of early-stage companies. Participants noted the challenges of dealing with evolving regulations and the strain it places on limited resources.

Policymakers should also consider making tailored funding programs that align with the unique needs of DTS more known. Governmental funding initiatives play a crucial role in supporting these ventures, particularly in the SE sector. Participants highlighted the importance of receiving financial support that is tailored to the academic culture and complex research practices inherent in deep-tech innovation. Aligning funding opportunities with the specific requirements of these startups can enhance their chances of success and drive advancements in sustainable technologies.

5.3 Limitations

One of the main limitations of the study is the generalization between DTS in the SE sector. The participants existed from different operating fields within the SE sector. The distinction between the SE sector and other sectors has been made, but within the SE sector there are also different applications and thus approaches on how to navigate through the pre-founding to founding stage. This variation might have introduced diverse challenges and strategies that are not fully comparable, potentially diluting the specificity of the findings. The decision to group these sub-sectors under the broader SE category was made to provide a more comprehensive view, given the limited existing research on DTS in this sector. However, it may have led to an oversimplification of the unique challenges faced by startups in more specialized fields within SE.

Another limitation is related to the cross-sectional nature of the research. The study captures insights and experiences from entrepreneurs at a specific point in time, which may not fully reflect the dynamic and evolving nature of the startup journey. Longitudinal studies that track DTS from the start to the founding stage would provide a more detailed understanding of how drivers, barriers, and strategies evolve throughout these different stages of the startup lifecycle.

The time constraints of the study also limited the ability to validate the proposed framework. Although the framework is designed to guide and inform future entrepreneurs about the various aspects of the early stages in the DTS journey, its effectiveness and efficiency could not be validated within the scope of this study. The limited timeframe of the research project did not allow for rigorous testing or long-term observation of the framework's application in real world scenarios.

The research methodology also presented some limitations, particularly concerning sample selection and the use of CAQDAS software. A study by (Berndt, 2020) highlighted the drawback of not using random sampling, which could result in a lack of confidence in the interpretation of the data. Therefore, the study interviewed multiple participants using the same strategy to identify patterns and ensure systematic data interpretation.

Another limitation relates to potential bias in snowball sampling, in which the respondents are likely to identify other potential respondents who are similar to themselves, as is highlighted by Saunders et al. (2007). However, this bias is not a significant problem in this research, as the study focuses specifically on the entrepreneurial world within DTS, a relatively small and interconnected community. Thus, the similarity among participants is expected and intentional.

The use of CAQDAS software for qualitative data analysis also presents limitations. A study by Ronzani et al. (2020), explores the pitfalls associated with the use of CAQDAS software, including reflective blindness, rigid analysis and wrong simplifications due to the software's capabilities. This can lead to incorrect code labelling and contextually distancing the researcher from the data. To mitigate these issues, a first reading of the transcript data was done without CAQDAS software to identify possible quotations and codes to ensure a deep understanding of what has been mentioned in the interview. During the coding process in the software, everything was done manually, without the use of automated software or AI, eliminating the potential for incorrect simplifications. The software was used solely for its structured interface and categorization capabilities.

5.4 Future Research

This study has identified several drivers, barriers, and strategies relevant to Dutch DTS in the SE sector. However, further research could benefit the research field by expanding and deepening the understanding of multiple related areas.

Future research could benefit from a more detailed focus on specific sub-sectors within the SE industry. While this study provided a broad overview by grouping various SE sub-sectors together, further research could explore the unique challenges and strategies specific to individual sub-sectors. This approach would allow for a more tailored framework that can be more directly applied to startups within particular niches of the SE sector.

Another possible future research would be to conduct longitudinal studies that track DTS from the pre-founding stage to the founding stage. This would provide a better understanding of how drivers, barriers, and strategies evolve over time. Such studies could offer deeper insights into the dynamic nature of the startup lifecycle, highlighting critical turning points and the longer-term impact of early-stage decisions on startup success. This can also be applied to other stages in the startups that present their own challenges. Investigating these challenges in the same or different contexts of DTS could provide a more comprehensive understanding of the startup lifecycle.

Lastly, future research could aim to validate and refine the framework proposed in this study by applying it in real-world scenarios. This would involve testing the framework with a broader range of startups over an extended period, allowing researchers to assess its practical effectiveness and make necessary adjustments based on empirical data. Such validation would strengthen the framework's utility as a tool for guiding new entrepreneurs in the SE sector.

6 Conclusion

The study aimed to explore the unique drivers and barriers encountered by Dutch Deep-Tech Startups (DTS) in the Sustainable Energy (SE) sector from their pre-founding to founding stages. It also sought to identify effective strategies used by entrepreneurs to overcome these challenges. Many DTS fail, even though they often have large potential to address major societal challenges, especially in the world of SE. This is a climate in which a lot of research is being done nowadays and where a lot of opportunities are presented. The reason for the high failure rates, is subject through multiple factors regarding their unique characteristics, such as high complexity and high unproven transformative impact.

By exploring different questions regarding specific barriers, drivers and strategies the study aimed to map out an overall picture that explores these barriers, drivers and strategies to guide future entrepreneurs, policy makers and universities in navigating through this socio-complex world. The main question that was asked is:

“What are the main drivers and barriers for Dutch DTS in the SE sector during the pre-founding to founding stage, and what strategies do they employ to navigate these challenges?"

This question was cut up into the drivers and barriers, strategies and a framework to encompass all different aspects to be able to connect them together. The results were gained through literature review and semi-structured interviews with entrepreneurs that experienced the early stages of starting a company on deep-tech solutions.

The findings revealed several key drivers contributing to the success of DTS. A supportive academic culture, characterized by close ties with academic institutions, provides access to advanced research, specialized equipment, and expert networks, which are is an enabler for success for developing and validating innovative technologies. Additionally, a supportive regulatory environment (RE) with various governmental and academic funding programs plays a significant role in facilitating early growth. Strong business networks offer valuable feedback and collaboration opportunities, while personal motivations and resilience of entrepreneurs further drive success.

Conversely, several barriers were identified that hinder the progress of DTS. Divergence between academic interests and commercial viability creates obstacles during the transition from theoretical research to practical market applications. The complex RE involves lengthy processes that can delay progress, while misalignment between investor expectations and deep-tech development timelines leads to funding challenges. Internal challenges, like team formation and resource management, and market research (MR) complexities further complicate the early stages. Personal barriers, including self-doubt and the need to shift from an academic to a strategic mindset, also pose challenges.

To navigate these challenges and leverage the identified drivers, entrepreneurs employed several strategies. Forming cross-disciplinary teams that integrate expertise in technology, business & marketing, financial management, legal & regulatory compliance, and MR help to build a team that is ready to address the complex landscape. Utilizing academic resources and expertise through mentoring and collaborations also enhances the startups' capabilities. Entrepreneurs also strategically adapt within the funding landscape by exploring diverse funding opportunities, like seed-funding, venture capital funding, grants & funds and partnership, together with aligning their development milestones with funding requirements. Engaging with potential customers and incorporating market feedback ensures that products remain relevant and market-ready. Additionally, maintaining mental resilience and a positive mindset is was mentioned to navigate the complexities of the startup journey.

Based on the identified drivers, barriers, and strategies, this study developed a conceptual framework to guide future deep-tech entrepreneurs in navigating these challenges. This framework offers practical guidelines for leveraging academic resources, building strong networks, securing funding, and maintaining personal resilience. The framework emphasizes forming cross-disciplinary teams and utilizing academic partnerships for mentoring and specialized resources. Financial agility is crucial, with a focus on diverse funding sources. Also, the importance of taking it step by step, aligning milestones with funding requirements is highlighted. Continuous market engagement ensures product relevance, while personal resilience strategies help entrepreneurs manage stress and stay motivated.

Even though not all barriers, drivers and challenges appeared in all interviews. There were clear themes that came forward. This highlights the fact that not every entrepreneur experienced the same, and that there is no blueprint on how to run a DTS. However, the study adds on specificity and a deeper understanding with examples onto the existing literature. Themes like team forming were specified with highlighting multiple disciplines that came forward in the interviews. Also, specific funding opportunities for early-stage DTS were explored adding on specific examples for a factor that has been already described in the existing literature.

The study gave insights into multiple aspects that come forward in the pursuit of starting a deep-tech SE startup specifically in the pre-founding to founding stage. With this knowledge future entrepreneurs, policymakers and universities can hopefully add on to the success of these society impactful initiatives. As the urgency for sustainable innovations grows, the importance of transitioning from the research phase to practical applications becomes increasingly vital. By leveraging the identified drivers, overcoming barriers, and employing effective strategies, stakeholders can better support the commercialization of deep-tech innovations, thereby addressing significant societal challenges and contributing to a sustainable future.

References

Andries, P., Clarysse, B., & Costa, S. (2021). Technology ventures' engagement of external actors in the search for viable market applications: On the relevance of Technology Broadcasting and Systematic Validation. Journal of Business Venturing, 36(6), 106145. https://doi.org/10.1016/j.jbusvent.2021.106145

Ansari, S. S., Garud, R., & Kumaraswamy, A. (2016). The disruptor's dilemma: TiVo and the U.S. television ecosystem. Strategic Management Journal, 37(9), 1829–1853. https://doi.org/10.1002/smj.2442

Arora, A., Fosfuri, A., & Rønde, T. (2024). The missing middle: Value capture in the market for startups. Research Policy, 53(3), 104958. https://doi.org/10.1016/j.respol.2024.104958

Badzińska, E. (2021). Exploring Critical Factors for Academic Start-ups towards the Development of Technological Entrepreneurship: Preliminary Research Findings. European Research Studies, Suppl. Special Issue 5, 24, 30–47. https://www.proquest.com/scholarly-journals/exploring-critical-factors-academic-start-ups/docview/2639731053/se-2?accountid=27026

Berndt, A. E. (2020). Sampling Methods. Journal of Human Lactation, 36(2), 224–226. https://doi.org/10.1177/0890334420906850

Blanco, S. (2007). How Techno-Entrepreneurs Build a Potentially Exciting Future? Sylvie Blanco. In Handbook of Research on Techno-Entrepreneurship. Edward Elgar Publishing. https://doi.org/10.4337/9781847205551.00007

Bresnahan, T. F., & Trajtenberg, M. (1995). General purpose technologies 'Engines of growth'? Journal of Econometrics, 65(1), 83–108. https://doi.org/10.1016/0304-4076(94)01598-T

Calderón-Hernández, G., Jiménez-Zapata, Y. A., & Serna-Gomez, H. M. (2020). Barriers to University Spin-Off Creation in an Emerging Context: An Institutional Theory of Organizations Approach. Minerva, 58(4), 625–650. https://doi.org/10.1007/S11024-020-09407-4/FIGURES/1

Cantner, U., & Goethner, M. (n.d.). Performance differences between academic spin-offs and non-academic start-ups: A comparative analysis using a non-parametric matching approach.

Carayannis, E. G., Kassicieh, S. K., & Radosevich, R. (2000). Strategic alliances as a source of early-stage seed capital in new technology-based firms. Technovation, 20(11), 603–615. https://doi.org/10.1016/S0166-4972(99)00161-3

Chammassian, R. G., & Sabatier, V. (2020). The role of costs in business model design for early-stage technology startups. Technological Forecasting and Social Change, 157, 120090. https://doi.org/10.1016/j.techfore.2020.120090

Charmaz, K. (2006). Constructing Grounded Theory: A Practical Guide through Qualitative Analysis - Kathy Charmaz - Google Books. https://books.google.nl/books?hl=en&lr=&id=2ThdBAAAQBAJ&oi=fnd&pg=PP1&dq=Charmaz,+K.+(2006).+Constructing+Grounded+Theory:+A+Practical+Guide+through+quality&ots=f-jX7NjEG0&sig=kLIrpk5Ka_yo2ZnldID4glgJAoo&redir_esc=y#v=onepage&q=Charmaz%2C%20K.%20(2006).%20Constructing%20Grounded%20Theory%3A%20A%20Practical%20Guide%20through%20quality&f=false

Cleyn, S. H. De, & Braet, J. (2009). Research valorisation through spin-off ventures: integration of existing concepts and typologies. World Review of Entrepreneurship, Management and Sustainable Development, 5(4), 325. https://doi.org/10.1504/WREMSD.2009.031624

Colombo, M. G., Piva, E., Quas, A., & Rossi-Lamastra, C. (2021). Dynamic capabilities and high-tech entrepreneurial ventures' performance in the aftermath of an environmental jolt. Long Range Planning, 54(3), 102026. https://doi.org/10.1016/j.lrp.2020.102026

Corbin, J., & Strauss, A. (2015). Basics of Qualitative Research: Techniques and Procedures for Developing ... - Juliet Corbin, Anselm Strauss - Google Books. https://books.google.nl/books?hl=en&lr=&id=hZ6kBQAAQBAJ&oi=fnd&pg=PP1&dq=Corbin,+J.,+%26+Strauss,+A.+(1990).+Basics+of+Qualitative+Research+(4th+ed.).+SAGE.&ots=6kLaMAay-1&sig=QCkgrbRiIwxkLFWdOLVWaLmqCrs&redir_esc=y#v=onepage&q=Corbin%2C%20J.%2C%20%26%20Strauss%2C%20A.%20(1990).%20Basics%20of%20Qualitative%20Research%20(4th%20ed.).%20SAGE.&f=false

dealroom. (2021, January 8). 2021: The year of Deep Tech.

Fabian, F., & Ndofor, H. A. (2007). The Context of Entrepreneurial Processes: One Size does not Fit All (pp. 249–279). https://doi.org/10.1016/S1074-7540(07)10010-6

Fini, R., Fu, K., Mathisen, M. T., Rasmussen, E., & Wright, M. (2017). Institutional determinants of university spin-off quantity and quality: a longitudinal, multilevel, cross-country study. Small Business Economics, 48(2), 361–391. https://doi.org/10.1007/S11187-016-9779-9/TABLES/8

Fini, R., Grimaldi, R., Santoni, S., & Sobrero, M. (2011). Complements or substitutes? The role of universities and local context in supporting the creation of academic spin-offs. Research Policy, 40(8), 1113–1127. https://doi.org/10.1016/j.respol.2011.05.013

Furr, N. R., Cavarretta, F., & Garg, S. (2012). Who Changes Course? The Role of Domain Knowledge and Novel Framing in Making Technology Changes. Strategic Entrepreneurship Journal, 6(3), 236–256. https://doi.org/10.1002/sej.1137

Government of the Netherlands. (2024). Central government encourages sustainable energy.

Gozal, A. R., Jonathan, A., Laia, W., Priego, P., Romasanta, A., Ahmadova, G., Wareham, J., & Priego, L. P. (2022). DEEP TECH: UNVEILING THE FOUNDATIONS.

Gübeli, M. H., & Doloreux, D. (2005). An empirical study of university spin-off development. European Journal of Innovation Management, 8(3), 269–282. https://doi.org/10.1108/14601060510610153

Guest, G., Bunce, A., & Johnson, L. (2006). How Many Interviews Are Enough? Field Methods, 18(1), 59–82. https://doi.org/10.1177/1525822X05279903

Hampton, A., McGowan, P., & Cooper, S. (2011). Developing quality in female high-technology entrepreneurs' networks. International Journal of Entrepreneurial Behavior & Research, 17(6), 588–606. https://doi.org/10.1108/13552551111174684

Hossinger, S. M., Chen, X., & Werner, A. (2019). Drivers, barriers and success factors of academic spin-offs: a systematic literature review. Management Review Quarterly 2019 70:1, 70(1), 97–134. https://doi.org/10.1007/S11301-019-00161-W

Husband, G. (2020). Ethical Data Collection and Recognizing the Impact of Semi-Structured Interviews on Research Respondents. https://doi.org/10.3390/educsci10080206

Invest in Holland. (2023, October 23). The Netherlands Named One of The Most Innovative Countries of 2023.

Kaufmann, E., & Ouschan, S. (2023). European Academic Spin-Offs: Exploring the Barriers to Long-Term Success. European Conference on Innovation and Entrepreneurship, 18(2), 988–995. https://doi.org/10.34190/ecie.18.2.1768

Khodaei, H., Scholten, V. E., Wubben, E. F. M., & Omta, S. W. F. O. (2022). The Role of Academic Spin-Offs Facilitators in Navigation of the Early Growth Stage Critical Junctures. IEEE Transactions on Engineering Management, 69(4), 1769–1780. https://doi.org/10.1109/TEM.2020.2995361

Kruachottikul, P., Dumrongvute, P., Tea-makorn, P., Kittikowit, S., & Amrapala, A. (2023). New product development process and case studies for deep-tech academic research to commercialization. Journal of Innovation and Entrepreneurship, 12(1), 48. https://doi.org/10.1186/s13731-023-00311-1

Kuhlmann, S., & Rip, A. (2018). Next-Generation Innovation Policy and Grand Challenges. Science and Public Policy, 45(4), 448–454. https://doi.org/10.1093/scipol/scy011

Lehr, R., Lehr, A., & Sumarah, J. (2007). Confi dentiality and Informed Consent: School Counsellors' Perceptions of Ethical Practices. Canadian Journal of Counselling / Revue Canadienne de Counseling, 41, 1.

Lin, B.-W., Li, P.-C., & Chen, J.-S. (2006). Social capital, capabilities, and entrepreneurial strategies: a study of Taiwanese high-tech new ventures. Technological Forecasting and Social Change, 73(2), 168–181. https://doi.org/10.1016/j.techfore.2004.12.001

Maine, E., & Garnsey, E. (2006). Commercializing generic technology: The case of advanced materials ventures. Research Policy, 35(3), 375–393. https://doi.org/10.1016/j.respol.2005.12.006

Maine, E., Lubik, S., & Garnsey, E. (2012). Process-based vs. product-based innovation: Value creation by nanotech ventures. Technovation, 32(3–4), 179–192. https://doi.org/10.1016/j.technovation.2011.10.003

Manning, C. G. (2023, September 27). Technology Readiness Levels.

Messina, L., Miller, K., & Hewitt-Dundas, N. (2022). USO Imprinting and Market Entry Timing: Exploring the Influence of University Ecosystems. IEEE Transactions on Engineering Management, 69(4), 1712–1727. https://doi.org/10.1109/TEM.2020.2979181

Miles, M. B., & Huberman, A. M. (1994). Qualitative data analysis: An expanded sourcebook (2nd ed.). Sage Publications.

Modding, B., Semmaila, B., & Gani, A. (2016). Effect of Service Quality and Marketing Stimuli on Customer Satisfaction: The Mediating Role of Purchasing Decisions. Journal of Business and Management Sciences, 4(4), 76–81. https://doi.org/10.12691/jbms-4-4-1

Müller-Wieland, R., Muschner, A., & Schraudner, M. (2019a). Academic entrepreneurship: phase-specific constraints and needs. Journal of Enterprising Communities, 13(3), 353–371. https://doi.org/10.1108/JEC-01-2019-0006

Müller-Wieland, R., Muschner, A., & Schraudner, M. (2019b). Academic entrepreneurship: phase-specific constraints and needs. Journal of Enterprising Communities: People and Places in the Global Economy, 13(3), 353–371. https://doi.org/10.1108/JEC-01-2019-0006

Noble, H., & Smith, J. (2015). Issues of validity and reliability in qualitative research. Evidence Based Nursing, 18(2), 34–35. https://doi.org/10.1136/eb-2015-102054

Noh, H., & Lee, S. (2019). Where technology transfer research originated and where it is going: a quantitative analysis of literature published between 1980 and 2015. Journal of Technology Transfer, 44(3), 700–740. https://doi.org/10.1007/S10961-017-9634-4/FIGURES/14

Page West, G., & Gemmell, R. M. (2021). Learning behaviors across levels in new ventures and innovation outcomes. Journal of Small Business Management, 59(1), 73–106. https://doi.org/10.1111/jsbm.12484

Pahnke, E. C., Katila, R., & Eisenhardt, K. M. (2015). Who Takes You to the Dance? How Partners' Institutional Logics Influence Innovation in Young Firms. Administrative Science Quarterly, 60(4), 596–633. https://doi.org/10.1177/0001839215592913

Parmentola, A., & Ferretti, M. (2018). Stages and trigger factors in the development of academic spin-offs. European Journal of Innovation Management, 21(3), 478–500. https://doi.org/10.1108/EJIM-11-2017-0159

Partanen, J., Chetty, S. K., & Rajala, A. (2014). Innovation Types and Network Relationships. Entrepreneurship Theory and Practice, 38(5), 1027–1055. https://doi.org/10.1111/j.1540-6520.2011.00474.x

Piazza, M., Mazzola, E., Perrone, G., & Vanhaverbeke, W. (2023). How does disruptive innovation influence the funding decisions of different venture capital investors? An empirical analysis on the role of startups' communication. Long Range Planning, 56(2), 102293. https://doi.org/10.1016/j.lrp.2022.102293

Reisdorfer-Leite, B., Rudek, M., & Junior, O. C. (2023). Product Lifecycle Management and Open Innovation in the Deep Tech Start-Ups Development (pp. 106–115). https://doi.org/10.1007/978-3-031-25182-5_11

Roche, M. P., Conti, A., & Rothaermel, F. T. (2020). Different founders, different venture outcomes: A comparative analysis of academic and non-academic startups. Research Policy, 49(10), 104062. https://doi.org/10.1016/j.respol.2020.104062

Romme, A. G. L., Bell, J., & Frericks, G. (2023). Designing a deep-tech venture builder to address grand challenges and overcome the valley of death. Journal of Organization Design. https://doi.org/10.1007/S41469-023-00144-Y

Ronzani, C. M., Da Costa, P. R., Da Silva, L. F., Pigola, A., & De Paiva, E. M. (2020). Qualitative methods of analysis: an example of Atlas.TITM Software usage. Revista Gestão & Tecnologia, 20(4), 284–311. https://doi.org/10.20397/2177-6652/2020.v20i4.1994

SADEH, A., & DVIR, D. (2020). THE EFFECT OF TECHNOLOGICAL RISK, MARKET UNCERTAINTY AND THE LEVEL OF COMPLEXITY ON NEW TECHNOLOGY VENTURES' SUCCESS. International Journal of Innovation Management, 24(05), 2050047. https://doi.org/10.1142/S1363919620500474

Saunders, M. N. K., Lewis, P., & Thornhill, Adrian. (2007). Research methods for business students. Financial Times/Prentice Hall.

Scaringella, L., Miles, R. E., & Truong, Y. (2017a). Customers involvement and firm absorptive capacity in radical innovation: The case of technological spin-offs. Technological Forecasting and Social Change, 120, 144–162. https://doi.org/10.1016/j.techfore.2017.01.005

Scaringella, L., Miles, R. E., & Truong, Y. (2017b). Customers involvement and firm absorptive capacity in radical innovation: The case of technological spin-offs. Technological Forecasting and Social Change, 120, 144–162. https://doi.org/10.1016/j.techfore.2017.01.005

Scarrà, D., & Piccaluga, A. (2022). The impact of technology transfer and knowledge spillover from Big Science: a literature review. Technovation, 116, 102165. https://doi.org/10.1016/j.technovation.2020.102165

Schutselaars, J., Romme, A. G. L., Bell, J., Bobelyn, A. S. A., & van Scheijndel, R. (2023a). Designing and Testing a Tool That Connects the Value Proposition of Deep-Tech Ventures to SDGs. Designs, 7(2), 50. https://doi.org/10.3390/designs7020050

Schutselaars, J., Romme, A. G. L., Bell, J., Bobelyn, A. S. A., & van Scheijndel, R. (2023b). Designing and Testing a Tool That Connects the Value Proposition of Deep-Tech Ventures to SDGs. Designs, 7(2). https://doi.org/10.3390/DESIGNS7020050

Sekaran, U. and Bougie, R. (2016). Research methods for business: A skill-building approach, Sixth edition. John Wiley and Sons, New York. Journal of MultiDisciplinary Evaluation, 20, 1–16. https://www.wiley.com/en-us/Research+Methods+For+Business%3A+A+Skill+Building+Approach%2C+7th+Edition-p-9781119266846

Siegel, J., & Krishnan, S. (2020). Cultivating Invisible Impact with Deep Technology and Creative Destruction. Journal of Innovation Management, 8(3), 6–19. https://doi.org/10.24840/2183-0606_008.003_0002

Siota, J., & Prats, J. (2021, September 30). What keeps Chief Innovation Officers up at night when engaging with deep-tech startups.

Visintin, F., & Pittino, D. (2014). Founding team composition and early performance of university—Based spin-off companies. Technovation, 34(1), 31–43. https://doi.org/10.1016/j.technovation.2013.09.004

von der Leyen, U. (2021). Keynote speech by President von der Leyen at the ‘Masters of Digital 2021’’ event.’.

Williams, C. (2011). Research Methods. Journal of Business & Economics Research (JBER), 5(3). https://doi.org/10.19030/jber.v5i3.2532

Yang, K., Menchaca, E., & Esquivel Lizarraga, B. (2024). The Challenges and Strategic Solutions of Emerging Technology Entrepreneurship: A Systematic Literature Review. In Proceedings of the 57th Hawaii International Conference on System Sciences. https://hdl.handle.net/10125/107038

Yin, R. K. (2003). Case Study Research: Design and Method (Vol. 3rd). Sage.

Appendix A: Interview Protocol

A1 Informed Consent

The interviewees were asked to consent to this research by signing an interview consent form (ICF). This form contains an explanation on what measures have been taken to ensure the privacy of the interviewees. The following document is sent to all respondents to be signed and sent back later.

Research Study Consent Form

Study Title: Exploring Drivers and Barriers of Deep-Tech Startups in the Pre-Founding to Founding Stage.
Researcher: Onno Hopmans, Technical university of Delft

Purpose:
You are being invited to participate in a research study on the unique drivers and barriers faced by Deep-Tech Startups in the pre-founding to founding stage. This study is being conducted by Onno Hopmans from TU Delft. The purpose is to identify key characteristics, challenges, and strategies to navigate through the crucial early-stage phase. Your participation will involve a 45-to-60-minute interview where we will discuss your experiences in the early stages of your deep-tech startup adventure.

Data Analysis:
The information you provide will be used for the master thesis for the academic program Complex System Engineering and Management (COSEM) at TU Delft. All data collected during this research will be securely stored and solely utilized for the purpose of this study. The final thesis will be stored in the educational repository and made publicly available. Measures are in place to ensure that your responses remain confidential and anonymous.

Confidentiality Measures:
Confidentiality is maintained by anonymizing your role and company name in any published materials. Any data that could directly identify your company will also not be included in the report. All personal data will be locally and securely stored and will be deleted one month after the project's conclusion expected in August 2024.

Procedure:
During the interview, you will be asked to share your thoughts on the challenges and motivations you've encountered during the early-stages of the startup, particularly around drivers, obstacles, and the support systems you've used. After the interview, your input will be transcribed into a document, which you will have the opportunity to review for accuracy and provide feedback.

Voluntary Participation:
Your participation is entirely voluntary and greatly appreciated. You are free to decline any question or withdraw from the study at any time without consequence.

Consent Statement:
By signing below, you acknowledge that you have read and understood this information and consent to participate in this research study.

A2 Interview Structure

Introduction:

In the introduction the researcher introduces why the research is being conducted. This is backed up by some background information. There is also an emphasize on the fact that the interview data will be anonymized, and that the interviewee is being recorded.

The question that is asked at the end of the introduction is:

Do you have some questions related to my research?

If not, the opening question to gain some background information on the company and the person is chosen as follows:

Can you tell me a bit more about yourself and the company I'm interviewing?

This breaks the ice and feels comfortable for most people to talk about at the start.

The rest of the outline is stated below and goes deeper and deeper within the role and the entrepreneurial adventure of the interviewee. The bullet points are thought points to think about for the researcher during the interview, if probing is wished.

Relation to academic research and scoping the company

What is your background in the academic research?

- Connection with deep-tech
- Background
- What kind of person

Could you take me on your journey of thoughts of actualizing the idea to want to start a deep-tech startup?

- Drivers
- Reasoning
- Thought process

Is there something extraordinary about a deep-tech startup in the sustainability energy field?

- Different startups = different strategies
- We go into the characteristics a bit more later
- In terms of policy, or actors

Barriers

In the pre-founding to founding stage, what were the most significant challenges/barriers you encountered?

- Go into detail, why/how?
- Characterize
- Make a top 3

In your opinion, are the challenges/barriers you face unique to deep-tech sustainable energy startups, or do you feel they are common to most startups?

- Specially for sustainable energy
- Focus on deep-tech
- Which are and which aren't

Drivers and strategies

How did you overcome or navigate through these barriers? If some remain, how are you currently addressing them?

- Only startups in the pre-founding to founding stage
- Strategies
- University relations
- Policies
- Funding methods
- Stakeholder engagement

What were the main stakeholder relationships that helped you navigate through the barriers? And how did they help you?

- What stakeholders did you actively involve with during this process in the pre-founding to founding stage?

Can you describe a time/more times when specific resources or support made a critical difference for advancing your startup?

- What drove you to continue or to surpass?

End notes

If you would've had a time machine and you could go back in time. Would you have done something differently, and if so, what would you have done differently?

- Advice for newborn startups