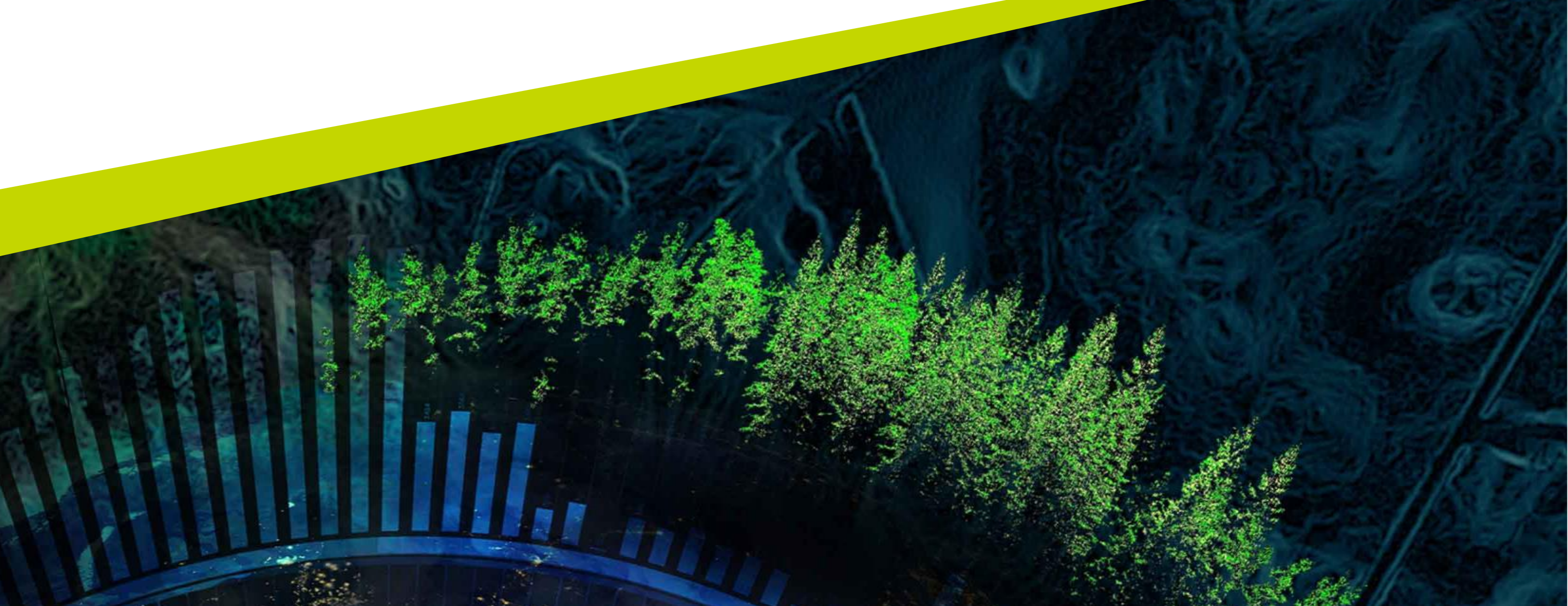
Driving Geothermal Innovation in the EU's Energy Transition

Understanding the Role of Venture Capital

Mariana Cimbalistová

Degree project/Independent project • 30 credits
Swedish University of Agricultural Sciences, SLU
Faculty of Natural Resources and Agricultural Sciences/Department of Economics
Environmental Economics and Management
Degree project/SLU, Department of Economics, 1639 • ISSN 1401-4084
Uppsala 2025



Driving Geothermal Innovation in the EU's Energy Transition. Understanding the Role of Venture Capital

Mariana Cimbalistová

Supervisor:	**Per-Anders Langendahl, Swedish University of Agricultural Sciences, Department of Economics**
Examiner:	Karin Hakelius, Swedish University of Agricultural Sciences, Department of Economics

Credits:	30 credits
Level:	Second cycle, A2E
Course title:	Master thesis in Business Administration
Course code:	EX0904
Programme/education:	Environmental Economics and Management
Course coordinating dept:	Department of Economics
Place of publication:	Uppsala
Year of publication:	2025
Copyright:	All featured images are used with permission from the copyright owner.
Title of series:	Degree project/SLU, Department of Economics
Part number:	1639
ISSN:	1401-4084
Keywords:	venture capital, geothermal energy, energy transition, energy innovations, transition intermediaries

Swedish University of Agricultural Sciences

Faculty of Natural Resources and Agricultural Sciences

Department of Economics

Abstract

The transition to a low-carbon energy system in the EU depends on scaling innovative energy technologies like geothermal energy. Despite its potential as a reliable and low-carbon energy source, geothermal innovation faces persistent barriers to finance and market integration. This thesis addresses this by investigating what affects the interest of investing in and scaling of geothermal energy technologies within the context of EU's energy transition. Drawing on the Multi-Level Perspective (MLP) and the conceptualization of venture capitalists as a transition intermediaries, the study examines how investment structures, norms, and actors shape the development of geothermal energy innovations. The empirical analysis is based on semi-structured interviews with venture capitalists, energy experts, and industry stakeholders. The findings from thematic analysis show that prevailing investment norms – such as short-termism or risk aversion – function as regime-level selection mechanisms that systematically disadvantage capital-intensive, long-horizon innovations like geothermal. At the same time, the study finds that specialized or strategically positioned venture capitalists can act as legitimators, risk absorbers, and expectation coordinators, helping geothermal technologies gain credibility and visibility. However, their transformative influence is limited by the relatively small scale of the VC sector compared to other investor groups, e.g., institutional investors, as well as by the mismatch between geothermal's complexity and the financial logics that dominate innovation funding. This study concludes that while VC can act as a driving force, broader systemic change in financial priorities requires coordinated support from public policy, long-term capital, and institutional reform to reshape financial market priorities and enable decarbonization.

Keywords: venture capital, geothermal energy innovations, energy transition, multi-level perspective, transition intermediaries

Table of contents

List of tables 7

List of figures 8

Abbreviations 9

1. Introduction 10
1.1 Background 10
1.2 Problem Statement 13
1.2.1 Empirical Problem 14
1.2.2 Theoretical Problem 14
1.3 Aim and Research Questions 15
1.4 Delimitations 16
1.5 Outline of the Thesis 16

2. Literature Review 17
2.1 Venture Capital 17
2.1.1 Role of Venture Capital in Innovation Financing 17
2.1.2 Venture Capital and Energy Innovations 18
2.2 Multi-Level Perspective on Low-Carbon Transitions 19
2.2.1 Core Concepts of the MLP 19
2.3 Conceptual Framework 23
2.3.1 Embedding Finance in the MLP 23
2.3.2 Venture Capitalists as Transition Intermediaries 24
2.3.3 Synthesis 28

3. Methodology 29
3.1 Research Design 29
3.2 Case Selection 29
3.3 Units of Analysis 30
3.4 Data Collection 30
3.5 Data Analysis 31
3.6 Quality and Ethics 32

4. Empirical Data and Analysis 34
4.1 Case background 34
4.2 Empirical data 34
4.2.1 Respondent A – Generalist VC Investor 34
4.2.2 Respondent B – Energy Sector Expert 35
4.2.3 Respondent C – Specialized Geothermal VC Investor 35
4.2.4 Respondent D – Geothermal Project Investor 36
4.3 Analysis 36

4.3.1 Theme 1: Systemic Barriers to Financing Geothermal Innovation 37
4.3.2 Theme 2: Venture Capital’s Role in Early-Stage Geothermal Innovation 39
4.3.3 Theme 3: Importance of Scale, Experience, and Market Maturity 42
4.3.4 Theme 4: Regulatory Support and Policy Clarity as Investment Enablers .. 44
4.3.5 Theme 5: Importance of Narratives and Expectations 47
5. Discussion 50
5.1 What shapes the interest of investing in geothermal energy technologies in the EU? 50
5.2 How do European venture capitalists understand their role in supporting clean energy innovations like geothermal? 52
6. Conclusion 55
References 57
Appendix 1 62
Popular science summary 63

List of tables

Table 1: Overview of interview respondents, including their professional roles and geographic locations 31

Table 2: Codes and Themes from Interview Data Analysis 32

Table 3: Quality Criteria for Qualitative Research (Lincoln & Guba 1985) 32

Table 4: Summary of key themes and insights from the thematic analysis of interview data 36

List of figures

Figure 1: Annual global investments into fossil-fuel and renewable energy for the period 2019-2022 (source: IRENA 2023a) ... 11

Figure 2: Annual Global Investment in Renewable Energy Technologies in USD Billion for the period 2019–2022 (source: IRENA 2023a) ... 12

Figure 3: Role of Venture Capital in Innovation Financing (based on Polzin et al. (2017) and Bocken (2015)) ... 18

Figure 4: Multi-Level Perspective on Low Carbon Transitions (based on Geels 2011) ... 22

Figure 5: Conceptual framework developed for this thesis (own illustration) ... 28

Abbreviations

Abbreviation	Description
EU	European Union
MLP	Multi-Level Perspective
R&D	Research and Development
RE	Renewable Energy
VC	Venture Capital

1. Introduction

This chapter sets the foundation for the thesis by outlining the background, relevance, and scope of the research. It introduces the empirical and theoretical problems, formulates the aim and research questions, and explains the delimitations. The chapter concludes with an overview of the structure of the thesis.

1.1 Background

The urgency of transitioning to a low-carbon energy system has become increasingly evident in the face of climate change. Global efforts, such as the Paris Agreement and the European Green Deal, highlight the necessity of reducing greenhouse gas emissions and increasing the share of renewable energy sources in the energy mix (European Commission n.d.). Yet, as shown in *Figure 1*, global investment trends from 2019 to 2022 (IRENA 2023a) reveal a persistent imbalance where fossil fuel investments have consistently exceeded those in renewable energy. This highlights a gap between political ambition and financial allocation, suggesting that current capital flows are still misaligned with the goals set out in major international agreements.

Achieving sustainable energy goals requires not only scaling existing renewable energy technologies like wind and solar but also fostering innovative solutions that can address gaps in the current energy system (IRENA 2023a). One of the key challenges in this transition is the need for technological advancements that can make renewable energy sources more reliable and cost-effective (Gaddy et al. 2017). While progress has been made in solar and wind power, some other energy sources remain underdeveloped due to financial, regulatory or technical barriers (IRENA 2023b). This is also the case for geothermal energy, which is the focus of this thesis.

Geothermal energy is a renewable, low-carbon, and continuous energy source that can complement intermittent renewables like wind and solar (Adalı et al. 2022). It offers significant advantages, including baseload power generation – ability to provide a stable supply of power to the electrical grids – low environmental impact, and diverse applications, such as electricity production, industrial processes and direct heating and cooling (U.S. Department of Energy n.d.). Despite these benefits and advantages, its role in the energy transition has been limited so far and "is often referred to as a niche technology that is too localized, too small or too expensive to make much of a difference in how renewable energy will be supplied in a fully decarbonized future" and "has been undervalued in terms of what it could provide" (Tester et al. 2021, p.1).

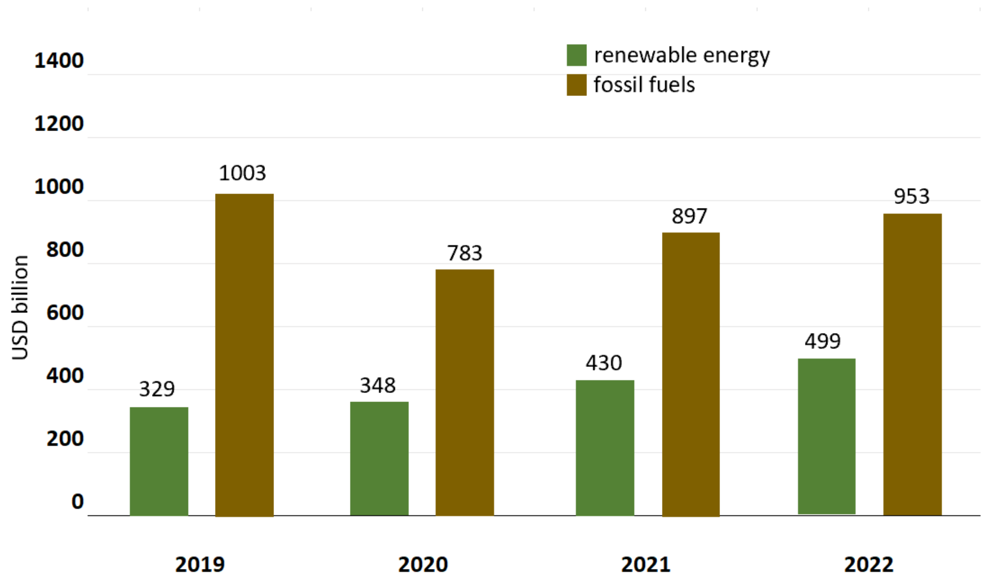


Figure 1: Annual global investments into fossil-fuel and renewable energy for the period 2019-2022 (source: IRENA 2023a)

According to statistics, geothermal energy contributed 2,8 % to the overall renewable energy mix of the European Union (EU) in 2021, while its potential with current technologies reaches up to a 25 % share in heating and cooling applications, and around 10 % in electricity production (European Parliament 2023). However, its adoption remains limited due to challenges such as high upfront costs and risks during the exploration phase (ibid.). Notably, the drilling stage alone represents up to 50 % of total project costs (Laenen et al. 2019). While wind and solar applications have experienced dramatic cost reductions due to innovation and strong policy support (Beiter et al. 2021), geothermal energy has lagged behind (Tester et al. 2021).

Emerging technologies, particularly advancements in drilling, have the potential to lower costs and increase resource accessibility, making geothermal energy more competitive. Additionally, novel applications of geothermal systems, such as lithium extraction from geothermal brines, demonstrate the broader value of these innovations (Weinand et al. 2023). Yet, despite these promising advancements, investment in geothermal innovations remains insufficient as compared to other renewable energy technologies (*Figure 2*). Bridging this funding gap requires a deeper understanding of the financial systems and their mechanisms that drive capital allocation to emerging energy technologies.

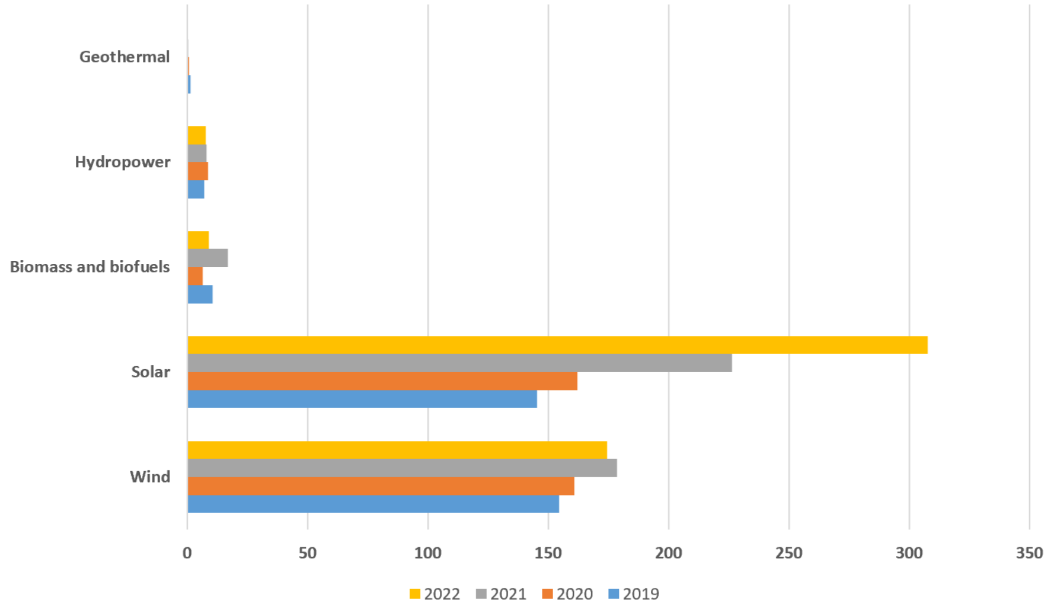


Figure 2: Annual Global Investment in Renewable Energy Technologies in USD Billion for the period 2019–2022 (source: IRENA 2023a)

Financial systems are sets of institutions, financial markets, instruments, and actors (e.g., governments, banks, venture capitalists) that facilitate the allocation of capital, manage risks and support economic growth within an economy (CFI n.d.). They play a significant role in supporting new technologies and practices, subsequently accelerating the transition to a sustainable energy future (Geddes & Schmidt 2020). While public funding, grants, and subsidies have been essential in supporting research and development (R&D), they are often insufficient to scale up and commercialize new energy technologies (Gaddy et al. 2017). This gap is particularly evident in high-risk emerging technologies – those that face technical, financial, and market uncertainties – which, despite still being in their early stages, already demonstrate potential benefits. At this stage, commercialization requires significant investment, but public funding mechanisms generally do not support activities associated with profit generation, leaving a critical financing gap for market deployment (Muscio et al. 2023). Thus, private capital investment is essential in bridging the gap between technological development and market deployment, i.e., commercialisation (ibid.). Institutional investors, banks, and venture capitalists are all important actors in this space, providing the financial resources needed to scale up innovative renewable energy solutions (Polzin & Sanders 2020). However, not all renewable energy technologies receive equal attention from such private investors. While solar and wind have attracted substantial funding (83 % and 65 % share of private investments respectively), geothermal energy technologies remain funded mostly by the public sector (32 % share of private investments), which does not have the necessary capabilities to commercialise these technologies (IRENA 2023a). To overcome these funding barriers, a robust financial ecosystem – comprising of elements such as funding mechanisms, actors, and policies – is necessary to support the development and commercialization of innovative geothermal technologies (Leanen et al. 2019).

In the diverse financial ecosystem that supports the scaling of energy innovations, venture capital (VC) represents one of the sources of funding for such solutions. VC is a form of private equity financing that specializes in high-risk, high-reward investments in innovative startups and emerging technologies, offering the potential to scale innovations rapidly (Polzin 2024). VC has played a crucial role in the development of disruptive industries, particularly in sectors such as information technology and biotechnology (Metrick & Yasuda 2021), while in the energy sector, VC investment has been instrumental in scaling up solar and battery storage technologies (Polzin 2024). However, VC engagement in geothermal energy remains limited, particularly for innovative solutions that focus on the technological advancements of accessing the geothermal resources (Pratty 2022). Despite the current status of VC investment in geothermal, VC could play a role in unlocking geothermal energy's potential, especially in scaling the innovative startups developing breakthrough technologies. Its ability to take on risk, coupled with its focus on innovative and scalable solutions, makes it an ideal partner for accelerating the commercialization of these technologies (Polzin 2024).

With technological advancements in drilling and lithium extraction from geothermal brines, new business models are emerging that could attract VC interest. In addition, a favourable policy environment has recently developed around geothermal energy by the EU, which may bring even more interest from the private investment sector (Council of the EU 2024). Therefore, it is important to explore the VC involvement in geothermal innovation, especially in the context of current transformations in the sector, which can provide valuable insights into the future prospects for scaling and deploying geothermal energy.

1.2 Problem Statement

This section outlines the key empirical and theoretical gaps that motivate the research. It distinguishes between the lack of empirical insight into VC's role in geothermal innovation and the underdeveloped theoretical treatment of financial systems in sustainability transition frameworks.

1.2.1 Empirical Problem

There is a growing interest in understanding the mechanisms through which VC investments contribute not just to innovation development, but also to broader transformations in the energy sector (Wang 2024).

The renewable energy sector – and geothermal energy in particular – has attracted relatively limited VC investment compared to other sectors like biotech or IT (Wang 2024). While the innovations in the RE sector face distinct challenges including high capital intensity, long development timelines, and uncertain regulatory environments, geothermal energy startups remain particularly underexplored in empirical research. This opens opportunities to investigate how VC engages with geothermal innovations and what implications it can have on the growth of the sector.

Existing studies have shown that VC can play a transformative role in scaling new technologies in other industries like IT (Michelfelder et al. 2022), but it remains unclear whether, and how, VC can similarly facilitate the development and commercialization of geothermal energy technologies. Moreover, while solar and wind sectors have received considerable research attention regarding private investment mechanisms, geothermal energy remains comparatively neglected. Understanding the role of VC in advancing geothermal technologies can provide valuable empirical insights into how private finance adapts to support less conventional areas of the clean energy transition.

1.2.2 Theoretical Problem

The theoretical gap lies in the underexplored role of financial systems in transition studies (Dordi et al. 2022; Steffen & Schmidt 2021). While technological, regulatory, and policy dimensions are central to popular transition frameworks – such as the Multi-Level Perspective (MLP) and Technological Innovation Systems (TIS) – financial systems are often underrepresented or lack a deep exploration within these frameworks. This gap leaves important dynamics between financial mechanisms, innovation systems, and energy transitions insufficiently addressed. Moreover, this lack of focus prevents a comprehensive understanding of how financial flows and actors influence the scaling of innovations needed for a transition. Therefore, researchers emphasize the need to better conceptualize financial systems within such frameworks (Steffen & Schmidt 2021; Egli et al. 2022).

While the need to integrate financial systems into transition studies is increasingly recognized, doing so requires acknowledging a distinctive logic that governs how these systems evolve. According to the MLP framework, dominant socio-technical systems – such as fossil fuel-based energy – must be disrupted to enable the replacement with new, sustainable alternatives (Geels 2002). However, according to Geddes and Schmidt (2020), financial systems do not follow the same pattern of disruption and replacement. Instead, they propose understanding changes in financial systems as processes of adaptation and restructuring that can enable and support sustainable transitions. Unlike energy systems, where fossil fuels can be substituted with renewables, or mobility systems where combustion vehicles can be replaced by electric ones, the foundational structures of financial systems are not easily replaced. This distinction is important, as overlooking the evolving nature of financial systems can limit the understanding of how investment practices and financial actors can reshape the systems to support capital-intensive, high-risk innovations that are needed for energy transition.

The recognition that financial systems adapt rather than undergo disruption creates space to explore how various actors can contribute to such reconfiguration over time – since such change does not happen automatically but requires active advocacy and deliberate effort. Therefore, this perspective highlights the role of financial actors in actively reshaping norms, expectations, and resource flows within the existing financial system. Venture capitalists, operating at the intersection of the financial system and entrepreneurial innovation, represent a particularly relevant phenomenon to be explored. Examining their perspectives, behaviours, and practices can offer deeper insights into the roles of financial actors in financial systems evolution within sustainability transitions, as well as their significance in supporting innovation development.

This study contributes to business studies by offering a new way to understand how actors engage with sustainability challenges. Business research often focuses on how individual firms develop strategies for sustainability. However, this approach can miss how actors like venture capitalists operate within and influence broader systems. By looking at them through a systems-thinking lens, this study helps expand business research beyond the firm level and shows how financial actors can play a role in driving larger-scale transitions.

1.3 Aim and Research Questions

To address the identified theoretical and empirical gaps, the aim of this thesis is to contribute to the understanding of the role of financial actors in sustainability transitions. The following research questions guide the study:

1. What shapes the interest of investing in geothermal energy technologies in the EU?
2. How do European venture capitalists understand their role in supporting clean energy innovations like geothermal?

1.4 Delimitations

This case study setting focuses on the EU for examining the energy transition from fossil-based to renewable energy technologies, with a particular emphasis on geothermal energy. The EU's shared policy framework and regulatory environment provide a unique context for understanding how VC interacts with clean energy innovations. The EU's Green Deal and renewable energy targets offer a cohesive landscape for examining how financial actors engage with emerging energy technologies within a region characterized by collaborative policy development and integration across member states. As such, country-specific effects are not considered within the scope of this research, as the focus is on overarching EU-level dynamics.

Additionally, this research focuses specifically on scalable geothermal innovations with the potential for widespread adoption, rather than on large-scale infrastructure projects like geothermal power plants. By emphasizing scalable technologies, the study aims to examine how venture capital can support innovations that not only offer technological breakthroughs but are also well-positioned for market uptake and commercial growth within the energy transition.

1.5 Outline of the Thesis

This thesis is organized into six main chapters, each addressing a key aspect of the research. The first chapter introduces the research problem, objectives, and relevance of the study. Chapter Two provides a literature review of VC and the MLP framework, and develops the conceptual framework by positioning financial actors within the MLP as well as introducing the notion of venture capitalists as transition intermediaries. Building on this foundation, the third chapter outlines the research design, including data collection and methods used to analyse the data. Chapter Four presents the empirical findings derived from interviews with investors and sector experts, organized around central themes. These findings are further interpreted in Chapter Five, which is structured to directly address the research questions and discusses the results in relation to existing literature and theoretical perspectives. Finally, Chapter Six concludes the thesis by synthesizing key insights, reflecting on the role of VC in accelerating clean energy innovation, and suggesting directions for future research.

2. Literature Review

This chapter reviews the existing literature on venture capital and the Multi-Level Perspective framework. It outlines the role of VC in supporting innovation and introduces the MLP as a framework for understanding socio-technical transitions. The chapter concludes with a conceptual framework section, which explains the analytical lens used to examine the phenomenon and address the research questions.

2.1 Venture Capital

VC is a type of private equity financing that is provided to high-potential startups and emerging companies in exchange for equity stakes (Metrick & Yasuda 2021). It plays an important role in fostering innovation by bridging the funding gap between R&D and commercialization stages (Ghosh & Nanda 2010). VC investments – structured as funds that are managed by VC firms – are characteristic for their high risk, but they offer substantial returns if the ventures succeed (Kaplan & Lerner 2010). These funds typically have a time horizon of five to ten years, which is supposed to reflect the period needed for startups to achieve significant growth and reach exit events (Metrick & Yasuda 2021). Beyond financial funding, VC firms provide essential added value that increases the growth chances of their portfolio companies. These contributions include strategic guidance, mentorship, network access, and operational support (Gompers & Lerner 2001; Bocken 2015).

2.1.1 Role of Venture Capital in Innovation Financing

Financing innovation is a dynamic process involving several different types of financiers (*Figure 3*). Each is appropriate at different stages of development of innovations, as they differ in the variation of risk, technological maturity and potential returns at certain points in time. In initial R&D, funding is primarily provided by public grants, R&D subsidies, and governmental research initiatives. Public support plays a crucial role in sustaining research as most of the private capital tends to avoid high-risk, pre-commercial technologies (IRENA 2023a; Laenen et al. 2019).

As technologies move beyond laboratory research or demonstration in real-world settings and approach the stage of commercialisation, their financial needs increase significantly, while revenue generation often remains limited. This stage between R&D and commercialisation is typically characterised by negative cash flows, creating the so-called "valley of death" – a critical funding gap where technologies struggle to attract investment to be scaled (Gaddy et al. 2017; Muscio et al. 2023). The stage is where technologies are too developed for public research funding but not yet commercially viable (Polzin & Sanders 2020; Migendt et al. 2017). While some public support continues, VC often steps in to provide financial backing in return for equity stakes, given the high-risk, high-reward potential (Polzin & Sanders 2020). VC is influential throughout the entire commercialisation phase, which may involve supporting the creation of niche markets, guiding early deployment, and enabling the broader diffusion of the technology into mainstream markets (Polzin et al. 2017). As the technology matures and reaches widespread adoption, the role of VC diminishes, and institutional investors, banks, and corporate financiers become the primary sources of capital. The transition from VC to large-scale financing is necessary to integrate the innovation into the socio-technical regime and drive cost reductions through economies of scale and learning effects (ibid.). This switch in financiers is closely linked to the exit strategies employed by venture capitalists (IPOs, acquisitions, etc.), as successful exits are crucial for these investors to realize returns on their high-risk investments and recycle capital into new ventures (Gompers & Lerner 2001).

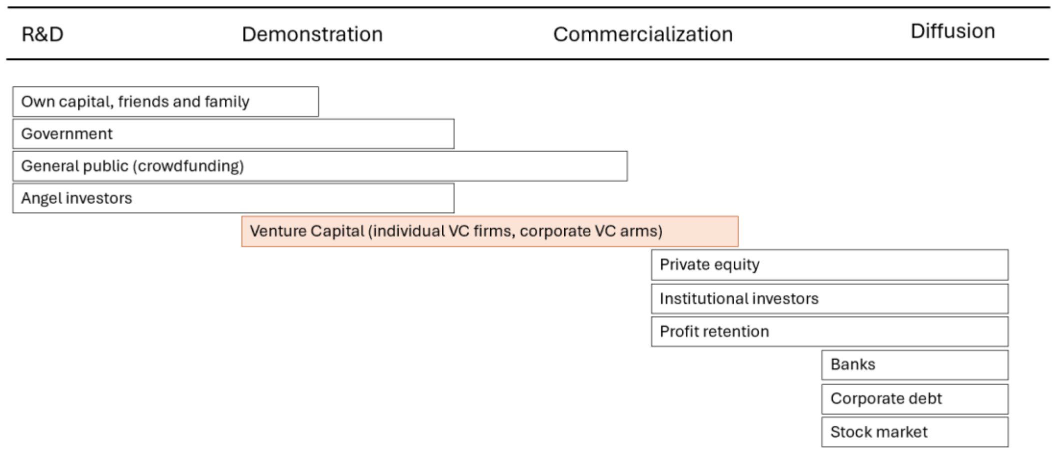


Figure 3: Role of Venture Capital in Innovation Financing (based on Polzin et al. (2017) and Bocken (2015))

2.1.2 Venture Capital and Energy Innovations

The intersection of VC and energy innovations has gained increased attention, mainly due to intensifying efforts to transition towards low-carbon energy systems. As Wang (2024) emphasizes, private equity and VC investors are especially important in this space due to their higher risk tolerance compared to traditional financiers. Their involvement helps make it possible for renewable energy startups to enter the market, iterate on their innovations, and contribute to long-term societal and environmental benefits. Unlike mature RE technologies such as wind and solar – where financing is currently secured mainly through banks or corporate investors – emerging solutions coming from geothermal require early support from actors willing to invest before market validation. This makes VC an essential funding source for scaling such innovations.

Despite the strategic importance of VC in energy and cleantech innovation, the sector has faced fluctuations in investment patterns. In the period around the mid-2000s, a lot of VC funding was flowing into cleantech, especially in energy storage and biofuels. However, due to the disappointing returns that these ventures generated, many VC firms withdrew their investments from such capital-intensive energy technologies and did not invest in them further (Gaddy et al. 2017). Recently, however, there has been a renewed interest in these areas, mainly due to technological advances, electrification of industries, and above all, escalating support from policymakers and regulators who are pressing for the decarbonization of society (IEA 2023).

The impact of VC on energy innovations varies significantly across regions. While the U.S. has developed a strong VC ecosystem that has contributed to the scaling of major public companies (Gornall & Strebulaev 2021), European VC markets face structural challenges. Many European countries rely heavily on banking-oriented financial systems, which limit the role of external financing in supporting cleantech startups (Leogrande et al. 2021). This suggests that public intervention may be necessary to achieve higher investment levels in cleantech and renewable energy technologies. Moreover, European investors tend to exhibit a more risk-averse investment culture, which favours investments in later stages of technology development with more predictable returns, whereas in comparison, U.S. investors are more willing to fund high-risk energy ventures (ibid.). This difference in risk preference can hinder energy innovation in Europe.

2.2 Multi-Level Perspective on Low-Carbon Transitions

The MLP is a widely used framework for analyzing socio-technical transitions, particularly in the shift toward low-carbon solutions (Yudha et al. 2022). As illustrated on the *Figure* 4, it conceptualizes transitions as processes that unfold over time and across multiple levels of interaction (Geels, 2004). Rather than focusing solely on firm- or sector-specific innovation, the MLP emphasizes socio-technical systems – integrated configurations of technologies, institutions, economic structures, and cultural practices that together enable societal functions (ibid.).

2.2.1 Core Concepts of the MLP

A socio-technical system consists of the interconnected elements that are required to fulfil societal needs – such as energy production, transportation, or communication – including artifacts (technologies), knowledge, capital, labor, institutions (norms, regulations), and cultural meaning (Geels, 2004). While traditional innovation system approaches focus mainly on the production side of technologies, socio-technical systems also integrate their diffusion and use (ibid.). According to Geels et al. (2017), these systems do not function in isolation but emerge from the co-evolution of technology and society, a process shaped by human actors embedded in social networks. The structure of these systems leads to path dependence, where existing technologies and institutional structures resist change and favour incremental improvements rather than radical transformations. Therefore, incumbent actors within these systems often work to maintain, defend, and improve existing structures (ibid.).

MLP distinguishes between three analytical levels – innovation niches, socio-technical regimes, and the socio-technical landscape – which interact to shape transition pathways (Geels & Schot 2007). These levels do not represent strict hierarchies but rather conceptual layers of configuration, where each influences innovation and system (in)stability in different ways (Yudha et al. 2022).

The Niche Level (Micro-Level)

Niches are protected spaces where radical innovations can develop outside the constraints of dominant socio-technical regimes (Yudha et al. 2022). These spaces provide opportunities for experimentation, learning, and early adoption, which protects innovations from direct competition in mainstream markets (Geels 2004). At this level, supporting networks – including research institutions, policymakers, and early market adopters – play a crucial role in fostering innovation (Yudha et al. 2022). Strategic Niche Management (SNM) highlights how actors intentionally nurture niches by creating experimental settings for technology development (Geels 2004). For example, renewable energy technologies, such as geothermal energy, often begin in niche markets where subsidies, pilot projects, and research grants provide the necessary space for their development (Geddes & Schmidt 2020). However, niche innovations face significant challenges in breaking into the mainstream due to their misalignment with existing socio-technical regimes (Geels 2004). The misalignment between niche innovations and regimes occurs because these regimes are stabilized by a combination of technologies, infrastructures, institutions, regulations, user practices, and market structures that favour incumbent solutions, i.e., solutions that are mainstream and present in the regime (ibid.). For transition to occur, these innovations must not only demonstrate technical and economic viability but also align with changes at the regime and landscape levels.

The Socio-Technical Regime Level (Meso-Level)

Within socio-technical systems, socio-technical regimes represent a specific and structured subset, referring to the stabilized rules, routines, and networks of actors that maintain the system's current trajectory (Geels 2004), e.g. current electricity generation system mostly dependent on fossil fuels. It encompasses the dominant technologies, structures, institutions, and practices that shape an existing system (ibid.) and form the "deep structure" that stabilizes socio-technical systems (Geels & Schot 2007). While socio-technical systems as a whole evolve dynamically, regimes within these systems resist radical change due to their deep-rooted coordination between actors and structures, which makes transitions a complex and multi-level process.

A regime includes various interdependent actors and institutions, such as firms, regulatory bodies, users, and financial systems, all of whom contribute to maintaining the status quo (Geels et al. 2017). The perseverance of socio-technical regimes can be explained by path dependency and lock-in mechanisms, which arise from a combination of technological, economic, institutional, and cognitive factors (Geels 2004). Path dependency implies that past decisions shape future possibilities and limit alternative trajectories. For instance, in the energy sector, historical reliance on fossil fuel-based infrastructures limits the rapid adoption of geothermal energy, even when it becomes technologically viable. Lock-in mechanisms further reinforce stability by making it costly or difficult to shift away from incumbent technologies. Therefore, regimes tend to favour incremental innovation, improving existing systems rather than adopting disruptive changes (ibid.).

Fossil fuel-based energy systems are maintained by a complex web of technological investments, economic incentives, and political institutions that reinforce their dominance (Geels et al. 2017). This results in a situation, where actors continue to support existing technologies due to sunk costs, market advantages, and regulatory frameworks that benefit incumbents (Geels 2004). However, internal pressures – such as technological inefficiencies, regulatory shifts or activities of actors – can create windows of opportunity for niche innovations to enter the regime (ibid.). If these pressures align with landscape-level changes, a transition may become possible.

The Socio-Technical Landscape (Macro-Level)

The socio-technical landscape represents the broad exogenous factors that influence both niches and regimes and shape long-term transition dynamics (Geels & Schot 2007). Compared to regimes – which can be actively influenced by actors – landscape developments are structural trends and external shocks that can neither be changed at will nor changed in the short term (Geels 2004). Van Driel and Schot (2005) identified three types of landscape developments – slow-changing trends (e.g., climate change, demographic shifts), long-term socio-economic transformations (e.g., industrialisation, urbanisation), and sudden external shocks (e.g., financial crises, wars, natural disasters). These landscape developments act as "gradients of force", making certain transitions more likely or pressing, even though they do not directly determine change (Geels & Schot 2007). The landscape level thus plays a crucial role in shaping the timing and feasibility of transitions, as niche innovations are more likely to succeed when landscape pressures weaken the regime stability, which then allows alternative technologies to gain momentum (Geels et al. 2017). For example, climate change and global energy policies create pressures that may destabilize existing fossil fuel regimes, making way for renewable alternatives like geothermal energy.

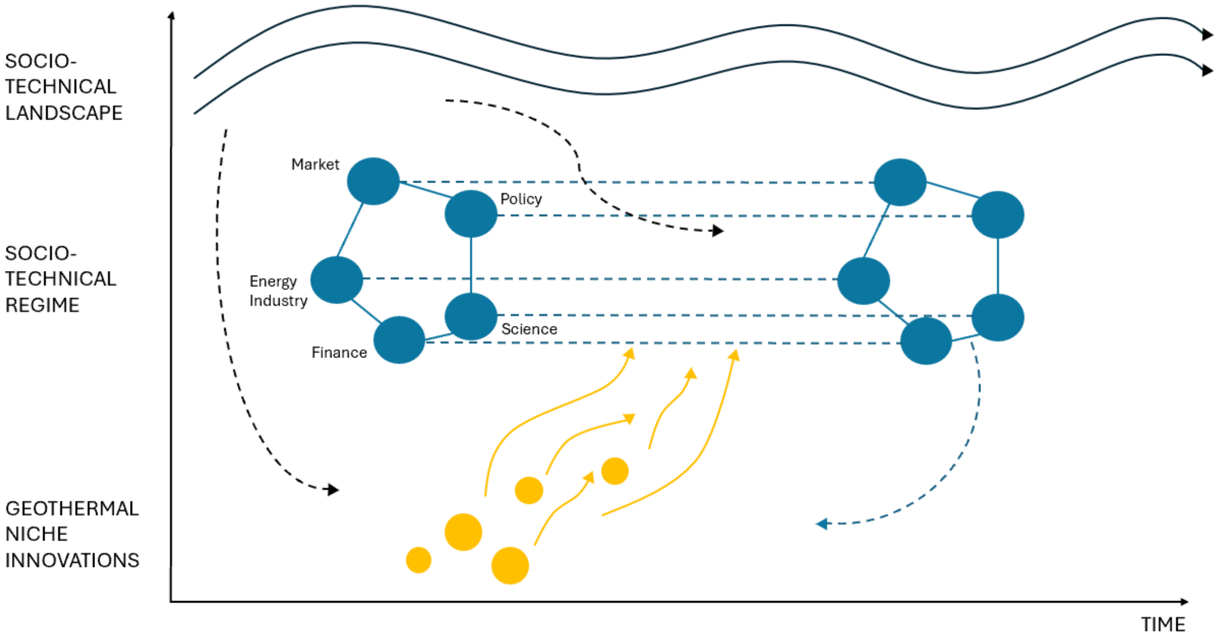


Figure 4: Multi-Level Perspective on Low Carbon Transitions (based on Geels 2011)

Figure 4 illustrates the MLP framework as applied to the dynamics of geothermal energy innovations. The diagram is structured along two axes: vertical levels representing different socio-technical layers – landscape, regime, and niche – and a horizontal axis representing time. At the bottom, geothermal innovations emerge within protected niche spaces, where experimentation and learning occur. Over time, some of these innovations (yellow circles and arrows) begin to mature and interact with elements of the socio-technical regime that is comprised of interlinked parts such as market, policy, science, finance, and industry (blue nodes). The regime is typically stable but can gradually evolve or be destabilized due to external landscape pressures (e.g., climate change, geopolitical shifts), shown at the top as fluctuating waves. These pressures may weaken regime stability (dashed arrows) and create windows of opportunity for niche innovations to scale up and integrate into the regime. The MLP framework emphasizes the co-evolution between niche innovations and regime structures within broader landscape developments that shows how transitions unfold over time.

2.3 Conceptual Framework

The conceptual framework provides the analytical lens that guides the empirical investigation of this study. Its purpose is to position financial systems within the MLP framework and to explain the factors contributing to their stability. Furthermore, it introduces the conceptualization of venture capitalists as transition intermediaries, aiming to explore their role in enabling financial systems evolution and in the development of geothermal technologies.

2.3.1 Embedding Finance in the MLP

The financial system can be analytically understood as distinct socio-technical regime within sustainability transitions. Like other regimes, such as energy, mobility, or food systems, finance is characterized by stable institutions, formal and informal rules, dominant logics, actor networks, and shared routines (Geddes & Schmidt 2020). This financial regime performs a selection function by influencing which innovations receive funding and are subsequently able to integrate into mainstream markets (Geels 2013). However, the degree of influence of the financial regime is shaped by broader landscape developments, such as different varieties of capitalism and the increasing financialization of the economy (Geddes & Schmidt 2020). It is composed of diverse actors, institutions, norms, and heuristics for decision-making processes that collectively determine the flow of capital into different technological niches (Geddes & Schmidt 2020). These actors include institutional investors, banks, insurers, venture capitalists, and financial regulators. Together, they shape investment decisions by reinforcing norms around what constitutes a viable or bankable technology.

Within the broader financial system, investments and financial markets in particular are shaped by strong path dependencies and lock-in effects. These dynamics influence how capital is allocated and limit the adaptability of financial actors to emerging technological opportunities (Geddes & Schmidt 2020). One key manifestation of this is the dominance of neoclassical economic theory widely used in the investment practices – the Efficient Market Hypothesis – which assumes that all financially relevant information is already incorporated into asset prices, implying that financial markets allocate capital efficiently to the most promising opportunities (Hiremath & Kumari 2014). However, insights from evolutionary economics challenge this notion by emphasizing that financial actors are not purely rational, but rather they exhibit risk aversion and rely on established investment patterns, which can lead to passivity and hinder the financing of promising innovative technologies (Dosi 1990). This is particularly relevant for geothermal energy that requires long-term, capital-intensive investments that do not always fit conventional financial models (Polzin 2024).

The financing challenges that niche innovations face can be further traced to what Louche et al. (2019) call *dominant investment logics* in financial markets – short-termism, risk aversion, reliance on historical data and predictability, the assumption of price efficiency, and the emphasis on risk-adjusted returns. First, financial markets prioritize short-term returns, which leads to investment horizons that are misaligned with the long-term nature of geothermal energy projects. Frequent portfolio turnover and reward structures that incentivise immediate gains discourage patient capital, which is essential for new energy solutions (ibid.). Second, financial markets are characterized by a high degree of risk aversion, especially when it comes to unfamiliar or emerging technologies. Geothermal innovations, which often involve uncertain returns, are perceived as high-risk and fall outside the comfort zone of many conventional investors. Third, financial actors rely on historical data and quantitative models to assess future investment risks and returns. However, the uncertainties associated with climate change and emerging clean technologies make it difficult to incorporate long-term sustainability risks into financial decision-making (Louche et al. 2019). This results in inaction, as investors struggle to integrate climate-related risks into standard financial assessment models (Stern 2006). Fourth, the belief that market prices reflect all available financial information overlooks the significance of climate risks, which are often excluded from traditional valuation models (Fama 1970). This exclusion weakens the financial case for long-term investments in clean technologies like geothermal energy, which have benefits that extend beyond traditional valuation metrics. Lastly, traditional investment evaluation methods focus on financial risks that can be measured, while neglecting non-financial risks like regulatory and environmental risks (Louche et al. 2019). As a result, current models fail to capture the potential for long-term profitability in clean energy investments, which further discourages financial support for promising innovations.

In response to these limitations, alternative financial mechanisms are emerging to bridge the gap between conventional investment assessments and the risks caused by climate change. Carbon pricing, ESG (Environmental, Social, and Governance) certifications, and climate-related financial risk disclosures are becoming increasingly relevant in changing preferences of investors and encouraging capital flows toward sustainable energy technologies (Louche et al. 2019). By incorporating alternative investment logics – such as long-termism, active ownership, and ESG integration – financial regime actors could rearrange incentives and create stronger conditions for financial markets to more engage with promising innovations needed to combat climate change (Dumas & Louche 2016).

2.3.2 Venture Capitalists as Transition Intermediaries

The conceptual framework is intended to investigate the potential role of venture capitalists in the energy transition by approaching them as *transition* *intermediaries*. This conceptualisation draws on the idea that such actors may be involved in facilitating the movement of innovations from niche toward socio-technical regime (Kanda et al. 2024). To further examine the ways in which this intermediary role could be enacted, the framework incorporates two complementary theoretical perspectives – *expectation management* and *institutional entrepreneurship*. These perspectives offer tools for exploring how venture capitalists might engage in shaping expectations around emerging technologies and how they could interact with or influence institutional structures within the financial systems.

Intermediaries in Sustainability Transitions

Transition intermediaries are actors or platforms that facilitate sustainability transitions by connecting different stakeholders, resources, and ideas to accelerate the adoption of innovations (Kanda et al. 2024). Within the MLP framework, intermediaries serve as bridging entities that help align the interests of niche innovators and regime actors to create momentum for systemic change, i.e., a transition. They also play a key role in addressing system failures, such as inefficient collaboration and resource mobilization, that often hinder innovation diffusion (Célia & Marie-Benoît 2023; Kanda et al. 2020). Their role is to enable, support, and assist other actors in achieving transition goals (Kanda et al. 2020).

Traditionally, transition research has focused on public and non-profit intermediaries, such as technology transfer offices, industry associations, and government agencies, while private financial actors have received less attention (Kanda et al. 2024). However, financial intermediaries, particularly venture capitalists, can also be positioned within this framework. Venture capitalists are market-based intermediaries that connect high-risk technological innovators with financial resources that would otherwise be difficult to secure through conventional financial institutions (Peng et al. 2014). By doing so, they facilitate the commercialization of new technologies and bridge the funding gap between research and market deployment (ibid.).

Within the MLP, venture capitalists can be conceptualized as regime-based transition intermediaries, i.e., actors embedded within the incumbent financial system who actively engage with niche innovations to facilitate their development and create new market opportunities (Kivimaa et al. 2019). This perspective aligns with recent critiques of sustainability transition research that challenge the binary assumption of niches as disruptors and regimes as resistant actors (Erbe 2021). Instead, some regime actors, including investors, may actively support, facilitate, or even accelerate transitions by investing in emerging technologies and promoting their integration into mainstream markets (ibid.). These intermediaries not only facilitate knowledge transfer but also play a role in influencing system-level change by advocating for regime shifts and shaping market conditions (Kivimaa et al. 2019).

Expectations Management

Expectations play a crucial role in transition processes, particularly in financial markets, where investment decisions are made based on anticipated future developments rather than on present conditions (Assenza et al. 2014). Since transitions involve uncertainty and long-term commitments, expectation dynamics can create both momentum and instability in clean technology investments (Wüstenhagen et al. 2009). Investors and innovators construct narratives about the potential of new technologies, using these stories to attract capital, talent, and policy support. In this way, expectations become self-fulfilling, as widespread optimism about a technology can increase funding and accelerate its development, while pessimism can restrict capital flows and hinder progress (Persad 2024). Technologies that are perceived as promising and aligned with the direction of the energy transition are more likely to attract funding, while those that face scepticism may struggle to secure investment. However, these dynamics are not always rational as investments often follow a hype cycle, characterized by periods of excessive optimism followed by rapid withdrawal of funds (Wüstenhagen et al. 2009). This boom-and-bust pattern is particularly relevant in cleantech, where past failures (e.g., early fuel cell investments) have led to risk aversion among VC investors (ibid.).

Venture capitalists do not passively respond to industry expectations; they actively shape them. As early-stage investors, they are deeply embedded in the innovation and entrepreneurship process, and their investment choices signal to the wider financial community which technologies are worth backing (Wüstenhagen et al., 2009). In this sense, they act as expectation managers, using strategic narratives to attract further investment and influence industry perceptions (Birch 2023). By strategically positioning technologies within the investment universe, venture capitalists could shift industry beliefs and alter investment trends. This is particularly relevant in the geothermal sector, where dominant investment logics – such as preference for short- to mid-term returns and established asset classes – have historically limited private-sector engagement (Persad 2024). If high-profile venture capitalists successfully promote geothermal cleantech as an attractive and necessary investment, they could help break the cycle of financial path dependence and encourage wider capital inflows. This ability to reshape investment expectations is critical in overcoming financial inertia. Studies show that when investors perceive a sector as growing and well-supported, they are more likely to reallocate funds toward it, creating a feedback loop that accelerates investment flows (ibid.). Conversely, negative expectations can lead to capital withdrawal and stagnation (Persad 2024). However, this role is not without risks. If financial actors overinflate expectations and create unsustainable hype cycles, the industry may experience rapid capital withdrawal, leading to investment volatility and setbacks in technological development (Wüstenhagen et al. 2009).

Institutional Entrepreneurship

Institutional entrepreneurship refers to the process by which actors work to disrupt existing institutional structures and establish new ones, often by mobilizing resources, influencing stakeholders, and challenging entrenched norms (Weik 2011). This concept is particularly relevant in financial markets, where dominant investment logics create path dependencies that make it difficult for emerging technologies to secure funding.

Institutional entrepreneurs are characterized as agents who pursue specific interests and act strategically to reshape existing structures (DiMaggio 1988). Unlike passive market participants, they actively mobilize resources and build alliances to create institutional change. Schumpeter (1934) describes entrepreneurs as "creative destroyers", emphasizing their role in challenging the status quo and introducing new economic possibilities. Rather than merely inventing new ideas, entrepreneurs are responsible for translating innovation into practical reality, often facing resistance from incumbents who benefit from maintaining the existing system. Crucially, Schumpeter emphasizes that entrepreneurship is not confined to individuals holding formal business titles – it is a behavioural pattern characterized by recognizing new possibilities, mobilizing resources, and overcoming resistance from entrenched interests. In this sense, entrepreneurship can emerge in various forms, not only through new ventures but also within existing institutions, where actors work to restructure financial norms, investment logics, and industry expectations.

In this sense, venture capitalists can perform entrepreneurial functions by actively working to reshape institutions in the context of financing clean energy transitions. Like Schumpeter's entrepreneur, venture capitalists are not just financiers but active architects of market transformation. They identify and capitalize on investment opportunities that challenge existing structures, using their influence to alter perceptions of risk and value in the financial sector. This behavioural perspective is particularly relevant in financial markets, where venture capitalists exhibit entrepreneurial agency by identifying and investing in high-risk, disruptive innovations that challenge dominant investment logics. Instead of passively allocating capital based on existing market conditions, they engage in strategic action to create new market opportunities, influence financial norms, and legitimize emerging technologies. By backing capital-intensive clean energy solutions like geothermal, VC firms help introduce new valuation methods and financing models, which, if successful, can become new institutional norms. This aligns with DiMaggio's (1988) view that institutional entrepreneurs leverage resources to create new opportunities that align with their interests.

Schumpeter's (1934) view of entrepreneurs highlights their ability to recognize and act on new opportunities despite resistance from incumbents. Venture capitalists often face pushback from traditional financial actors who remain sceptical of high-risk, long-payback technologies like geothermal energy. However, by demonstrating successful investment cases, they can create momentum for broader financial system change. If venture capitalists manage to reshape financial norms to make geothermal and other clean technologies investable, they will have acted not just as investors but as agents of institutional change – paving the way for a more sustainable and risk-tolerant financial regime.

2.3.3 Synthesis

Figure 5 represents the conceptual framework that reflects the MLP and illustrates venture capitalists as actors situated within the financial regime Positioned at the centre, venture capitalists are shown as engaging in two interrelated activities – expectation management and institutional entrepreneurship – which help explore how they may influence the regime's stability. These roles are placed within the regime level to highlight that they are embedded in and directed toward regime transformation. The intermediary position connecting the niche and regime levels signifies the potential of venture capitalists to support the scaling of geothermal innovations by aligning financial practices with emerging sustainability goals.

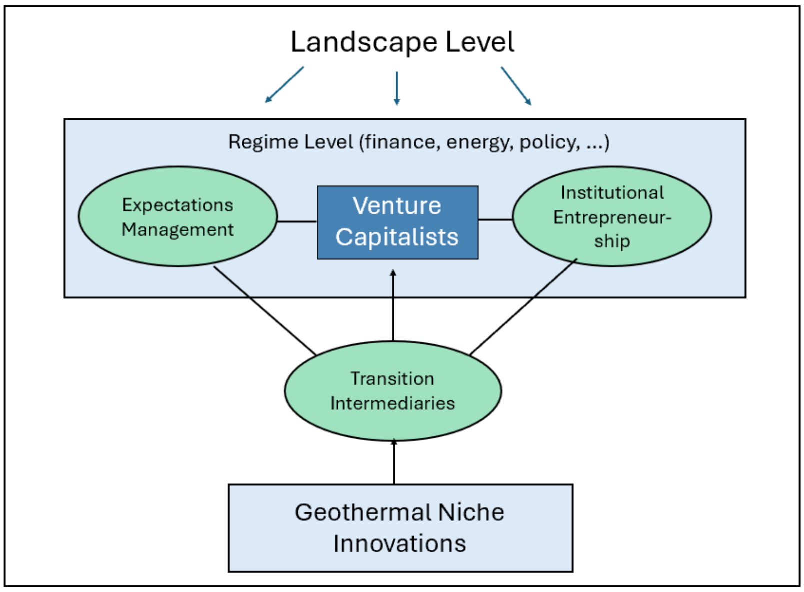


Figure 5: Conceptual framework developed for this thesis (own illustration)

3. Methodology

This chapter outlines the research design, data collection and analysis methods used in this study. It also discusses the ethical considerations and measures taken to ensure the quality and trustworthiness of the research.

3.1 Research Design

This study adopts a qualitative case study research design to explore how VC contributes to the development and uptake of geothermal energy technologies. A case study is suitable when the aim is to gain an in-depth understanding of a contemporary, complex phenomenon within its real-life context (Creswell 2013; Bell et al. 2019). Here, the case is the uptake of geothermal technologies, while the phenomenon of interest is the role of venture capitalists as transition intermediaries. This distinction between case and phenomenon allows for analytical clarity and helps position the empirical investigation within the broader literature on sustainability transitions.

Epistemologically, the study is grounded in interpretivism, acknowledging that the social world is constructed through sense-making and subjective interpretation (Mackenzie & Knipe 2006). The ontological stance follows constructivism, which assumes that reality is multiple and co-constructed by individuals (Creswell 2013). This orientation informs the methodological choices made throughout the thesis, including semi-structured interviews, thematic analysis, and a focus on subjective meanings and experiences of respondents. Moreover, the research takes an inductive approach to theory-building, where it seeks to develop conceptual insights from the empirical data rather than testing pre-existing hypotheses (Bell et al. 2019). This approach aligns with the exploratory nature of the study and its contribution to the transition literature.

3.2 Case Selection

The case was selected using purposive sampling, based on its relevance to the research aim of understanding how venture capitalists influence the development and uptake of geothermal energy technologies. Following Stake (1995), the case is instrumental, chosen for its capacity to understand a broader phenomenon – in this instance, how venture capitalists function as transition intermediaries within the wider energy transition process.

Case selection followed criteria of theoretical relevance and information richness (Flyvbjerg 2006). The chosen case focuses on the geothermal innovations in European context, which are embedded in dynamic interactions with venture capitalists and offer insight into how niche innovations are shaped and financed.

The European context is also significant due to increasing policy momentum for both decarbonization and geothermal energy, which creates a favourable environment for studying finance-innovation interactions in the energy transition.

3.3 Units of Analysis

This research identifies venture capitalists as the primary units of analysis to examine how private finance actors shape the development of geothermal energy technologies. Within the overarching case of geothermal innovation uptake in Europe, the study focuses on how these actors interpret their role, assess risks and opportunities, and influence the formation and scaling of technological niches. Their investment rationales and expectations are explored to understand how they act as transition intermediaries, linking emerging technologies to broader regime and landscape dynamics. This actor-centred focus aligns with the study's constructivist ontology and interpretivist epistemology, which prioritise meaning-making and subjective experience in social inquiry (Creswell 2013; Stake 1995).

3.4 Data Collection

Data were collected through semi-structured interviews with venture capitalists and energy experts active in the geothermal energy sector. The interviews followed a semi-structured guide, which is detailed in Appendix 1. *Table 1* below provides an overview of the interviewees, including their role, organizational context, and geographic location. Out of twenty individuals contacted for interviews, all of whom were relevant to the study – i.e., based in the EU and closely connected to venture capital, geothermal energy, or policy – four agreed to participate. This small sample of interviews places limitations to the study. A larger number of interviews would have allowed for a broader range of perspectives and a more robust validation of the emerging themes. With a limited sample, there is also a greater risk that the findings may reflect the specific experiences or viewpoints of individual participants rather than broader trends. Nevertheless, based on this limitation, the findings of this study should be taken as exploratory rather than conclusive. Future research with a larger and more diverse group of participants would be essential to test the validity of these insights and build a more comprehensive understanding of the topic.

Interviews are particularly well-suited to qualitative case study research, as they allow for an intensive and detailed exploration of how actors perceive and interpret their roles within a specific context (Bell et al. 2019). This method enables to focus on participants' subjective experiences and interpretations, which is essential when studying the meanings actors attach to investment decisions and transition processes. The interviews were guided by a list of key topics, but the format allowed for flexibility in question order and follow-up questions. This approach supports a balance between thematic consistency across participants and openness to unexpected insights (Bell et al. 2019). As Whyte (1953, as cited in Bell et al. 2019) noted, no single interview stands alone – meaning emerges from comparing multiple perspectives. Therefore, several interviews were conducted to gather a diverse range of views. The semi-structured format was chosen over unstructured interviewing because the research began with a clear focus on specific issues and because the data were intended for thematic analysis, which benefits from some degree of comparability across responses (Bell et al. 2019).

To complement the interview data and strengthen the study, additional data sources were used. These include industry reports, policy documents, and literature review. The literature review focused on key themes such as the *energy transition*, *venture capital*, *energy innovation*, *geothermal energy*, and the *multi-level perspective*.

Table 1: Overview of interview respondents, including their professional roles and geographic locations

Respondent Code	Role and organisation type	Country
Respondent A	Venture capitalist – generalist VC firm	Slovakia
Respondent B	Geothermal expert	Slovakia
Respondent C	Venture capitalist – specialised VC firm	Denmark
Respondent D	Geothermal project investor	Sweden

3.5 Data Analysis

The data were analysed using thematic analysis, which is suited to identifying patterns of meaning across qualitative data from interviews (Bell et al. 2019). Coding formed the foundation of the analysis, where each interview transcript was reviewed and coded manually. Codes were defined as short phrases or words that captured the essence of a segment of the data (ibid.).

Themes were then identified by grouping codes that reflected repeated patterns, similarities, or contrasts in how participants described their views on the role of VC in geothermal energy innovations. This process followed established strategies for theme identification, such as looking for repetitions, similarities, and differences (Ryan & Bernard 2003). Each theme was developed in relation to the overarching research focus and questions, with the aim to contribute to the theoretical understanding of how financial actors influence niche development and regime interaction in the context of geothermal innovation.

Table 2 below presents an overview of the themes alongside representative codes that illustrate how the data were organized and interpreted.

Table 2: Codes and Themes from Interview Data Analysis

Code	Theme
Short-termism Risk aversion Investor knowledge gap	Systemic barriers to financing geothermal innovation
Early signals Legitimacy Risk sharing	VC's role in early-stage geothermal innovation
Market readiness Expertise Scaling potential	Importance of scale, experience, and market maturity
Policy clarity Public support Risk mitigation	Regulatory support and policy clarity as investment enablers
Strategic framing Public awareness Storytelling	Importance of narratives and expectations

3.6 Quality and Ethics

To ensure quality of this qualitative research, the study draws on the four widely recognized criteria proposed by Lincoln and Guba (1985): credibility, transferability, dependability, and confirmability (see *Table 3*).

Table 3: Quality Criteria for Qualitative Research (Lincoln & Guba 1985)

Criterion	Meaning
Credibility	Confidence in the truth of the findings; ensuring accurate representation of participants' perspectives
Transferability	The extent to which findings can be applied or generalized to other contexts
Dependability	Consistency and reliability of the research process and findings over time
Confirmability	Degree to which findings are shaped by participants and not researcher bias

Credibility was supported through the use of semi-structured interviews that allowed participants to express their views in their own terms, and by engaging with multiple respondents across the VC and geothermal innovation landscape. This diversity of perspectives strengthened the depth and trustworthiness of the findings. Transferability was addressed by providing contextual detail about the respondents, the focus on geothermal sector, and the regional setting in the EU, allowing readers to assess the applicability of findings in other contexts. To ensure dependability, the same coding process was applied across all transcripts, and notes were kept to track how themes developed during the analysis. Lastly, confirmability was supported through reflexive memo-writing during analysis and the use of direct quotes to ground interpretations in participants' own words, helping to reduce researcher bias and enhance the transparency of the analytical process.

Ethical considerations were carefully followed throughout the research. All participants were provided with clear information about the research purpose, their rights, and the voluntary nature of participation. Prior to each interview, informed consent was obtained, either in writing or verbally, depending on the mode of communication. To protect participant privacy, all responses were anonymised using respondent codes, and no identifiable information is reported in the findings. Audio recordings and transcripts were securely stored on password-protected devices, and only the researcher had access to the raw data. These procedures ensured that confidentiality was maintained throughout the research process.

4. Empirical Data and Analysis

This chapter presents the empirical findings of the study and outlines the key themes that emerged from the interview data. It begins with a case background and continues with the summary of the empirical data collected through semi-structured interviews. The last part of the chapter is devoted to the thematic analysis, which identifies recurring patterns and categories across interviews. These findings lay the foundation for the discussion and conclusions that follow.

4.1 Case background

Geothermal energy holds significant underutilized potential within the EU, with estimates suggesting it could meet up to 25 % of heating and cooling demand and 10 % of electricity generation using existing technologies (European Parliament 2023). Currently, direct-use applications, such as district heating and industrial processes, dominate the geothermal landscape, while electricity production remains limited to a few regions with suitable geological conditions. Although innovative technologies, including advanced drilling methods and systems, are beginning to emerge, they remain in early stages of commercialization. Policy momentum is building at the EU level, with initiatives such as the European Green Deal, REPowerEU, the Net-Zero Industry Act, and the recent EU Council call for a dedicated geothermal energy strategy all signalling an increasing political support for scaling geothermal (European Council 2024). Public funding instruments like Horizon Europe and the Innovation Fund are actively supporting geothermal R&D, however, private investment remains relatively scarce, which highlights a persistent funding gap that hinders broader market uptake and technological development.

4.2 Empirical data

To support the thematic analysis and illustrate the diversity of perspectives among interviewees, the following section provides a summary of each interview. These summaries highlight the main points raised by each respondent regarding venture capital’s role in geothermal innovation, the specific challenges they identified, and the unique positions they occupy within the broader innovation ecosystem.

4.2.1 Respondent A – Generalist VC Investor

Respondent A, a generalist venture capital investor, emphasized the challenges of aligning geothermal technologies with the typical structure of VC funds. They highlighted the incompatibility between standard 10-year fund lifecycles and the long R&D cycles of geothermal innovation. While recognizing the potential of the sector, Respondent A pointed out that high capital intensity, long timelines, and technical complexity make geothermal ventures less attractive within traditional VC models. Nevertheless, they acknowledged that extended duration or evergreen funds could offer better alignment. Importantly, Respondent A discussed the financial logic of sequential risk removal, noting that each investment round serves to reduce specific types of risk (technological, regulatory, market), thereby raising a firm's valuation and appeal to later-stage investors. Their perspective provided key insights into how generalist investors conceptualize risk, value, and timing in clean energy innovation.

4.2.2 Respondent B – Energy Sector Expert

Respondent B, an energy sector expert with experience in geothermal, emphasized systemic barriers in the field, especially the lack of skilled professionals, insufficient public awareness, and limited technical understanding among decision-makers. They highlighted how geothermal remains undervalued in broader cleantech discourse, despite its long-term energy potential. Furthermore, they described the prevailing financial system as poorly suited to high-risk, capital-intensive projects, citing the lack of functional risk mitigation instruments and limited access to grants or loans in many EU countries. Respondent B noted that most investors lack sufficient understanding of geothermal's specific risks and timeframes, leading to little interest in investing in the sector. Venture capital was seen as playing a potentially important role, but only when it comes from strong and reputable investors who can help create an environment of greater certainty and legitimacy. Finally, Respondent B stressed the importance of presenting the societal value of geothermal energy more clearly, not only to attract investors, but also to build a future workforce and broaden public and political support for the sector.

4.2.3 Respondent C – Specialized Geothermal VC Investor

Respondent C, an investor at a specialized venture capital firm focused on geothermal technologies, offered a proactive and strategic view of early-stage investment. They described their firm's role as an intentional first mover, entering before other investors to absorb risk, conduct technical due diligence, and build legitimacy around emerging geothermal startups. By doing so, they aim to "make geothermal venture more accessible for general investors." Respondent C also discussed the importance of narratives and expectation-building, such as framing geothermal as a solution for AI data centres or industrial heat demand. They shared examples like Fervo Energy to demonstrate how early VC involvement can shift market perception. Their perspective highlighted venture capital's function not just as capital provider, but as market shaper, expectation coordinator, and de-risking intermediary across the innovation ecosystem.

4.2.4 Respondent D – Geothermal Project Investor

Respondent D, active in geothermal project development and investment, focused on the importance of ecosystem maturity, policy clarity, and public visibility in enabling geothermal innovation. They contrasted mature regional hubs like Munich with countries lacking basic geological data or institutional support. Respondent D stressed that investor interest follows project availability, and that the absence of infrastructure hinders innovation. They also addressed the undervaluation of geothermal's stability and baseload capabilities in electricity markets, arguing that pricing models fail to reflect its true system value. Moreover, they emphasized the need for targeted policy engagement, noting that policymakers must be educated and influenced by sector actors if geothermal is to gain traction. Their insights tied the success of geothermal innovation to broader narratives, institutional frameworks, and political signalling.

4.3 Analysis

This section presents the insights from the thematic analysis of interviews with venture capitalists and geothermal experts. The analysis revealed five central themes that capture the key dynamics shaping VC engagement with geothermal energy innovations. These themes reflect systemic barriers, strategic investment roles, the influence of market maturity, the importance of supportive policy, and the role of narratives and expectations. *Table 2* below provides an overview of these themes and their corresponding insights, which are discussed in detail in the sections that follow.

Table 4: Summary of key themes and insights from the thematic analysis of interview data

Theme	**Key Insights**
1. Systemic Barriers to Financing Geothermal Innovation	Conventional VC models are poorly aligned with the nature of geothermal technologies. Specialized VC funds can help to resolve this problem.
2. VC´s Role in Early-Stage Geothermal Innovation	VC can serve as a catalyst by investing early, sending legitimacy signals, reducing perceived risk, and helping attracting follow-on investment.
3. Importance of Scale, Experience, and Market Maturity	Mature geothermal markets reduce risk through experience and enable innovation to move from research to application. Ecosystem readiness is essential for capital deployment.

4. Regulatory Support and Policy Clarity as Investment Enablers	Clear and coordinated regulatory frameworks, along with risk-sharing mechanisms are crucial. Strong policy signals influence investor confidence and enable sector growth.
5. Importance of Narratives and Expectations	How geothermal is framed can shape its legitimacy and appeal. Effective but realistic narratives are needed to attract capital, talent, and policy attention.

4.3.1 Theme 1: Systemic Barriers to Financing Geothermal Innovation

All four interviews revealed a significant mismatch between the structure of conventional VC funds and the unique characteristics of geothermal technology innovations. The reason for this is its technological development pathway, which differs from other asset-light and fast-scaling models dominating the portfolios of these funds, such as software companies.

One of the most significant issues is the time horizon of VC compared to the length of the innovation cycle of geothermal technologies. The majority of VC funds are designed for a ten-year term, with an optional two-year extension. This is generally sufficient for digital technologies or the biotech sector, but new geothermal technologies – especially those focused on advanced drilling systems, subsurface screening or novel reservoir enhancement methods – often require a much longer R&D and validation process. Respondent A, a generalist venture capitalist, noted:

> "In this context, the main issue is the typical structure of VC funds, which means a relatively short investment horizon for projects in the energy sector. The solution could be evergreen funds or funds with an extended duration."

The physical nature of geothermal technologies is another investment barrier. Unlike software, testing new tools or drilling techniques often requires hardware prototyping, field deployment, and access to testbeds, each of which is expensive and time-consuming. This slow and capital-intensive innovation process means that VC funds – especially generalist ones – have difficulty aligning investments in geothermal technologies with their portfolio strategies. Respondents highlighted that this results in systematic underinvestment in geothermal innovation, despite the long-term potential. Respondent B, an energy expert, pointed out:

> "Research and development in the field of geothermal energy – especially in drilling implementation – is crucial for the advancement of this energy source. If there is a significant breakthrough in drilling technologies (which, fundamentally, haven't

changed much in the past 100 years), it could have a major impact. However, the required investments in R&D in this area are high, and the return is very distant in time. Therefore, investments in such projects mainly come from large multinational corporations (recently increasingly from oil companies) or through various support programs. Ordinary investors are not interested in this area."

Respondent C acknowledged that some oil and gas companies have begun investing in geothermal technologies, but emphasized that their involvement remains limited:

> "In fact, we have seen a number of the larger energy companies having made venture capital investments into geothermal tech companies. But what is often missed is that the amount of their investments, while they sound really big – $10,000,000 or $20,000,000 – compared to the size of their normal operating business they are tiny. What we really would like to see is that they move in with proper operational funding because they want to exploit the resource of geothermal energy. But I think they are, for now, missing a big opportunity."

These problems are being further compounded by a broader misunderstanding and undervaluation of geothermal technologies. Respondents noted that even investors active in the cleantech sector lack familiarity with geothermal energy, let alone the general public or policymakers. This consequently contributes to the limited broader interest and low capital in this clean energy sector. As Respondent D, a geothermal project investor, put it:

> "We believe in geothermal, but there is such a lack of understanding of [it]. There are so many people that have visited hot springs, but they do not understand that you can actually take the same water and heat your house, your greenhouse, your industry. In Europe, we are currently on the level of just informing people. Everyone knows what solar and wind is and that is where we can really help and make a difference by talking about it."

Respondent B similarly highlighted the lack of understanding encountered in their professional experience with geothermal energy:

> "From my own experience, even major players in the energy market do not adequately understand the challenges of developing geothermal energy. Not to mention government officials who are supposed to make decisions in these matters. Awareness and knowledge levels are very low, and unless that changes, the development of geothermal projects will remain a niche compared to other renewables."

Beyond just awareness, investors' decision-making logic also tends to favour familiarity and integration into existing markets, which puts geothermal at a disadvantage. Respondent C emphasized that investors are more likely to fund innovations that align with known business models:

> "I think, if you integrate into an existing industry, it is a lower risk business case. So, investors are more not only willing to take that risk, but they also understand it more.

> The risk is lower in itself but it is also about the investors' understanding of that risk. And I think geothermal energy is such an unknown industry for most investors that the latter part is also important. You need to find investors that understand the risk, and you lower the risk as much as you can."

Additionally, the broader financial system tends to favour short-term gains over long-term value creation, creating a structural disincentive for patient capital. Respondent C reflected on this systemic short-termism:

> "There are very few investors that are in it for the long run. And, unfortunately, I think the system itself does not incentivize us to be in the long run either because you can make a quick buck [...] But the thing is, if you buy stock today and you sell it tomorrow and you made a profit, you did nothing for that company. Or for the planet or for technology or anything like that. [...] I think government is the key to fix that."

The decision-making environment among investors itself often discourages risk-taking. Respondents highlighted that many investors are not proactive in seeking out transformative opportunities but instead respond cautiously to prevailing market signals. This reactivity is intensified by the need to justify investment decisions which further reduces willingness to engage with unfamiliar or long-term technologies like geothermal. As Respondent C explained:

> "Unfortunately, [investors] are very much reactive, and that goes back to my earlier point about not being risk takers. They need to justify every choice they make because they know the people investing in them also need to justify it. And in times of crisis, we have a European tendency to go towards what is safe."

These insights suggest an incompatibility between the financial architecture of conventional VC and the characteristics of geothermal innovation. The high upfront costs, long development timelines and high demands for field testing place these technologies outside the standard investment logic of most funds, as they focus primarily on rapidly scalable and high-yielding innovations such as software or biotech. However, the emergence of specialised investors suggests that a shift within the financial system is possible, especially when driven by expertise and long-term strategic vision. The following sections explore how these dynamics interact with broader shifts in financial narratives, expectations, and institutional roles.

4.3.2 Theme 2: Venture Capital's Role in Early-Stage Geothermal Innovation

While respondents acknowledged the limitations of conventional VC in fostering geothermal innovation, they also emphasized its strategic role as a catalyst and market enabler when deployed with the right expertise, timing, and realistic expectations. In particular, venture capitalists were seen as important actors in reducing the risk associated with early-stage technologies – whether by enhancing visibility, sending legitimacy signals, acting as intermediaries, or lowering perceived uncertainty and financial risk. This section explores these roles in more detail.

One of the key roles of venture capital, as highlighted by respondents, was its ability to engage with new innovative companies at an early stage. Beyond providing much-needed capital, this early involvement also helps promising technologies gain visibility and credibility in the broader environment. VC firms position themselves at the forefront of emerging opportunities, well before market enthusiasm is present, because this is where they can exert the most strategic influence. This way, they help shape the trajectory of innovations. As Respondent C explained:

> "We have an amazing opportunity and an important role in going in and being the first that are willing to commit to a company to invest. That is where we make a difference. [...] If we have another ten venture capitalists that are interested in the company, we often do not give an offer. We force ourselves out of those deals because we believe our role is to be investing in companies before they reach that stage."

This approach of entering early is especially important in a sector like geothermal, where technologies face limited market understanding. When well-known VC firms invest early, they can send strong legitimacy signals. A concrete example of this was provided by Respondent C, who referred to the case of Fervo Energy, a geothermal startup that attracted investment from leading VC firms such as Breakthrough Energy Ventures. This early interest by renowned investor reportedly shifted the perception of geothermal technologies among more risk-averse and generalist venture capitalists:

> "There are a few cases like Fervo where having good investors in place made a huge difference in how people perceived geothermal. Suddenly generalists became interested. It created a sense of: "maybe this is not as niche and obscure as we thought"."

In addition to VC as credibility builder, respondents emphasized that these investors play an essential role in handling early-stage risk, particularly technology risk, which is often the most difficult for traditional investors to evaluate. As Respondent C elaborated:

> "I think the venture capital model, as developed in the US fifty years ago, is very much there to invest in risk and to handle risk. And I think over time, that has shown itself as very powerful, and in fact, has led to the creation of amazing companies like Google, NVIDIA and others. So that definitely has a strong record of being able to handle risk, especially the technology risk. And probably the best way the market can manage risk right now is through the venture capital structure."

A recurring insight across the interviews was how early-stage capital is difficult to secure in geothermal due to high uncertainty — from unproven technologies and unclear market pathways to regulatory or infrastructural hurdles. However, a willingness to commit from a credible investor to take the first step serves as a signal that can lower perceptions of risk and "creates an environment of greater certainty" (Respondent B). VC investments are made in several rounds - not all capital at once - and each funding round can be understood as removing specific layers of risk. Over time, this risk reduction increases the valuation of the company and improves the likelihood of attracting more capital. As Respondent A put it:

> "Since we are usually the first or one of the first investors in a given project, our primary role is largely to de-risk these companies or projects for later investors. Essentially, each investment round serves to eliminate specific risks – whether technological, market, team-related, regulatory, or traction-based – which then increases the company's valuation."

This process of step-by-step derisking also facilitates the integration of early-stage geothermal companies into the broader energy ecosystem. Several respondents emphasized that geothermal innovators often struggle to connect with established energy firms, utilities, or infrastructure investors. In this matter, venture capitalists can act as intermediaries that help startups navigate the processes to reach the mainstream markets. Respondent B explained:

> "Venture capitalist – if it is a strong investor with references – can bridge the startup with large energy companies."

While venture capitalists have the capacity to foster innovations, it is important to acknowledge that their actions are not purely mission driven. The responses from interviews suggest that financial returns remain a core driver, and that the strategy of early-stage investment is about identifying profitable opportunities. In this sense, financial logic and mission-oriented goals are not mutually exclusive but can coexist. For some investors, supporting sustainable solutions is both a meaningful and financially rational choice, especially when done early, before more of the capital flows in and valuations rise. As Respondent A explained regarding their investment approach:

> "For venture capital, mature sectors are not as attractive. We look for new markets with high growth potential. For example, in 2014 we invested in EV charging networks. At that time, electromobility was in its infancy, almost non-existent in our region. Today, a similar investment would not generate the same returns because there is already broad market consensus that electromobility will be a major part of mobility."

Similarly, Respondent C emphasized that waiting for others to act would undermine both their impact and returns:

> "If we just waited for other people to be interested and then potentially join other rounds, not only would we not make enough difference on the geothermal market, but, frankly, I believe we would make less profitable decisions."

This strategy of entering early is particularly effective when executed by sector-specific expertise. Respondent C highlighted the value of VC specialization, particularly in complex and underexplored domains like geothermal. In contrast to generalist funds, specialized investors can build deep technical and market knowledge, which enables them to evaluate risks more effectively, support startups more strategically, and send stronger signals to follow-on investors:

> "We are so far the only specialized [venture capital] firm for geothermal energy technology. The purpose of why we exist is to invest in what the other venture capital firms are not ready for. Doing that work, we allow other investors to enter in the next rounds [...] without having to do that initial risk assessment and technical due diligence. I do believe that we have an effect [...] in making geothermal tech venture more accessible for general investors."

However, this focused approach also comes with trade-offs. While specialization offers depth, it also concentrates financial exposure in a single sector, which is something most traditional investors are trained to avoid. From a conventional portfolio management perspective, such concentration increases vulnerability to sector-specific shocks or delays. As Respondent C noted:

> "It is enormously helpful. But the problem is that the minute you are as specialized as we are, you are concentrating your risk in one market. And that, from a traditional investment point of view, is not a very good idea. But is it easier for me to do my job well when I only have to be an expert at one thing? Absolutely."

Taken together, the interview data highlight several ways in which VC can contribute to the early development of geothermal technologies. When applied early and by credible investors, its support was described as helping technologies attract additional funding and recognition. These functions were seen as particularly relevant in the context of a sector like geothermal, where early-stage challenges are prominent.

4.3.3 Theme 3: Importance of Scale, Experience, and Market Maturity

Respondents in their answers emphasized the role of mature geothermal markets with rich experience and localized scale effects that result in de-risking geothermal technologies and accelerating innovation.

Unlike modular technologies such as PV, geothermal innovation is highly contextual as its development and adoption depends on local geological conditions and infrastructure availability. As a result, the maturity and density of geothermal markets were described as a crucial enabler for both technology validation and capital mobilization. In particular, respondents mentioned countries such as Iceland, Turkey, and regional hubs like Munich as successful examples where scale and repetition have led to significant cost reductions and risk mitigation. Respondent D, explained:

> "In the Munich area, I think they have drilled almost hundred wells. So, their success rate is so high that actually private insurance companies can insure the risk of it. I have not seen that elsewhere."

Respondent D continued by explaining how scaling not only reduces risk but also creates the market conditions necessary for innovation to move beyond the research phase and into application. As they put it:

> "If the tech companies continue without scaling, I'm afraid they will get stuck in a research phase. But if the sector scales and proves itself as a real energy solution, that will benefit the next generation of technologies when they are ready. Those innovations will then have customers – established projects that will demand and apply them. We need to create that demand."

Such developments of geothermal markets create a desirable chain of events: the availability of tested wells and subsurface data lowers the barrier to entry for technology developers; repeated drilling efforts provide learning-by-doing opportunities; and increased investor familiarity builds confidence. This context allows innovators to test their solutions under real conditions and demonstrate scalability. Within such an environment, VC can be more effectively deployed, as innovations have better chances of reaching the market.

Conversely, in less mature geothermal markets, the absence of experience and scale serves as a compounding barrier. When testing opportunities are limited and data is scarce, even high-potential technologies can struggle to move beyond the laboratory testing phases. Respondent D commented on the situation in some early-stage countries, where the lack of foundational knowledge hinders technological and commercial progress:

> "Spain is one of the countries where they do not have any subsurface data. There is simply nothing in the database – it is just white. So, in that case, either they can do a lot, or they can do nothing. But that is the point – with the current situation, they need to start from scratch."

The uneven development of geothermal technologies across different regions also affects investors' decisions. They are more likely to back geothermal startups operating in mature regions, where the pathway from research to commercialisation is clearer and infrastructure already exists. Respondent D emphasized that regional context plays an important role in investment decisions, noting that opportunities are limited when the necessary ecosystem is absent. As a result, promising technologies may remain unsupported, not due to their technical shortcomings, but because of their geographic context. This can result in a paradox where technologies are available, but there is nowhere to implement them:

> "Go and invest in Europe – they said. But there are no projects. So, you need to have projects to invest in. [...] It is not only about venture capital. You actually need to make sure there is something to invest in. It is like the chicken and the hen. [...] There are large parts of the world that do not have a background in geothermal. [...] So, you need to build the capability and the ecosystem before real investment can follow."

This lack of ecosystem maturity also constrains collaboration between startups and established energy firms, which is critical for commercializing innovations. As Respondent B explained, gaining access to meaningful partnerships with large players requires not just innovation, but credibility, resources, and strategic networks – all of which are hard for startups to acquire in underdeveloped markets:

> "Getting into serious discussions with major players is a challenge that requires excellent contacts and references. To attract the interest of such companies, a project must show seriousness, have credible investors, and a clear vision of mutual benefit. Many established firms conduct their own R&D, and a technological startup in this field would need very strong financial and scientific backing – something that is obviously hard for a startup to achieve."

This highlights how ecosystem maturity can shape investment dynamics as it reduces the perceived risk and makes financing more viable. While VC can supply early-stage financing, it is the ecosystem that enables that capital to be effectively deployed and de-risked over time.

4.3.4 Theme 4: Regulatory Support and Policy Clarity as Investment Enablers

A consistent topic across interviews was the recognition that regulatory frameworks and public policy signals play a central role in shaping the trajectories of geothermal innovation. Although VC was acknowledged as essential for early-stage technological development, respondents emphasized that it alone is insufficient to drive innovation to scale without clear, coordinated, and supportive regulatory environments.

Respondents highlighted that geothermal innovation often involves navigating complex, fragmented, and jurisdiction-specific permitting regimes. This increases the cost and duration of field testing, creates regulatory uncertainty, and discourages follow-on investment. Respondent C commented:

> "If we introduced an EU-wide regulatory simplification for geothermal energy – essentially how to explore, how to build, how to sell the energy – at the same time as

> we started to provide guaranteed offtake or price mechanisms for the energy produced, we could move much faster."

This regulatory fragmentation was contrasted with the more unified and supportive institutional landscape in the United States. While the EU has ambitious climate goals, respondents argued that the absence of a consistent geothermal strategy across member states limits the sector's ability to scale. In contrast, the U.S. federal government was described as offering clearer innovation pathways. As Respondent C explained:

> "Let me take the U.S. federal government as a counterexample. The federal government has already acted towards lowering the regulatory burden of setting up new geothermal systems. And even just doing that is a benefit to the industry and moving technology forward everywhere. The U.S. federal system can take federal lands – without local, state, or other influence – and essentially decide that it is now easier to drill."

This more centralized approach to land access and permitting was viewed as an enabler of faster deployment and private investment. As Respondent C further observed, institutional setups are already reflected in investment patterns:

> "I am seeing a lot of interest. I am not quite seeing it yet in deals, but I will say that overall, globally, we have seen over the past six years venture capital going into geothermal technology go from almost nothing to almost a billion dollars last year. So, there has been an enormous growth in venture capital globally going into this, but most of that has been in the U.S."

However, respondents emphasized that regulation alone is not enough. They highlighted the importance of risk mitigation instruments – especially in early markets – as key to enabling early-stage geothermal technologies to move beyond the prototype phase. Risk mitigation instruments such as insurance, loan guarantees, or early-stage public funding were seen as essential complements to venture capital. In this sense, respondents viewed governments as essential partners in risk-sharing and market formation. While VC plays the leading role in managing technological risk, government support was repeatedly described as "number two" in importance (Respondent C). As respondent D noted:

> "It is not only about bridging the financing gap, but also about covering the cost of the risk – that is where the public can really help, particularly before private insurers are willing to get involved."

Moreover, policy clarity was described not just in terms of technical rules, but also in relation to strategic political signalling. Respondents pointed to the importance of long-term visibility and prioritization of geothermal within broader energy transition agendas. Respondent D, for example, described how political attention can serve as a soft enabler for innovation:

> "I set a dream for von der Leyen to say 'geothermal' – and she did. That kind of visibility matters. It tells innovators and investors that this is on the radar."

This underscores the idea that expectation management that happens through clear public discourse and policy alignment is not only symbolic but materially affects how capital and talent flow into geothermal companies. The absence of such signals contributes to geothermal's historical underrepresentation in clean tech portfolios. Respondent D pointed out that because geothermal remains a young and underrecognized industry, targeted efforts to inform and influence policymakers are essential:

> "We try to impact policymakers in all markets where we are present. Right now, in Europe, the market is so young that policy needs to push for geothermal. It is just market and policy that is needed [...] It is super important what the politicians say, but we need to impact them, because they will not come up with this. They are nor sitting on the answers, we need to educate them."

Respondents also emphasized that direct financial mechanisms can play a decisive role in lowering the risk of geothermal markets and attracting long-term private investment. These instruments were viewed not only as financial incentives but as clear institutional signals that geothermal is recognized and prioritized. As Respondent D explained:

> "You can also have feed-in premiums or contracts for difference – that also will ensure that geothermal is being recognized. [...] Currently, the markets we are present in are those where the state has a feed-in tariff, feed-in premium, contract for difference, something like that. That really makes a difference if we are interested in going to that market. [...] Such ambition sends a signal."

Building on this, Respondent C reflected on how the uptake of solar energy technologies illustrates the powerful interplay between policy and private investment when both are aligned:

> "Solar is probably the easiest to understand because you have had a dramatic decrease of the base cost of photovoltaic cells. And that has come for two reasons. One is that venture capital firms were willing to invest in technologies that could bring that cost down years before they were ready. But what was just as important – and possibly more important – was that government provided incentives for people to buy those solar cells when they got cheap enough. [...] I think geothermal does not quite have a clear picture of a government-supported demand future. [...] There is this amazing technology that may be able to power the planet for much cheaper than anything else [and] had the government acted equivalently to wind and solar on geothermal, we would be getting there much faster."

At the same time, not all respondents believed that policy was the most critical factor for geothermal development. Respondent A noted that while EU policy can play an important role, the primary force driving impact lies in the successful application of geothermal technologies in the energy sector itself:

> "The practical deployment of geothermal in this sector has a significantly greater impact than EU policy – although policy can still play an important supporting role."

This view brings more depth to the conversation, suggesting that while policy is necessary, it is not sufficient on its own. For geothermal innovation to thrive, public support must be matched by real market demand and successful deployment. Respondent C suggested that stronger and more unified EU strategy could really push progress forward:

> "EU is still struggling a bit from that mix of country national and EU government, and we kind of need all of it. But I think if we had a combination of lowering regulation on a European level and ensuring that there are purchases of the power or heat that is being produced, we could probably do ten to hundred times as much. [...] You can do initiatives that are for the whole market instead of project by project – that is what I am missing."

These insights illustrate how policy clarity, communication, and government support are viewed by practitioners as important components of market formation for geothermal technologies. While financial support is essential, respondents emphasized that ambition-setting and direct engagement with policymakers are also necessary to position geothermal energy more prominently within the clean tech landscape.

4.3.5 Theme 5: Importance of Narratives and Expectations

Beyond technical and financial considerations, respondents emphasized the growing importance of expectations and narratives in shaping the legitimacy and investability of geothermal technologies. In a competitive clean technology landscape, where public and private actors must allocate capital under uncertainty, how geothermal is framed matters as much as what it technically offers.

Several respondents mentioned that geothermal sector has long suffered from a lack of compelling, accessible narratives – especially when compared to solar, wind, or even hydrogen. Because it is a technically complex and geologically grounded energy source, geothermal energy has often been perceived as inaccessible or overly location-dependent, which has limited its visibility in international policy agendas and clean tech discourses. As Respondent B emphasized, clear communication of the value and long-term potential of geothermal energy is critical to its future:

> "It is essential to present the potential that geothermal energy can bring to humanity as it can be a key energy source capable of powering our civilization for thousands of years. Presenting quantified values that geothermal energy can offer will be crucial for the

> development of this sector – not only to increase investor interest, but more importantly to attract students and workers. One of the key barriers driving up project costs today is the lack of skilled professionals. Framing expectations in the right way will have a major impact on the future development and use of geothermal energy in all its aspects."

In this context, recent shifts in narratives – particularly around geothermal's relevance to AI-driven data centres and base-load stability – were seen as critical to reshaping the perceptions. Respondent C described how framing geothermal as a solution to emerging energy needs helped position it as a strategic source:

> "I think AI is a very important driving force because it means that geothermal energy all of a sudden is understood by a non-specialist. [...] It is easy to explain that a data centre needs power all the time. It cannot live with a wind turbine or a solar panel that only works at certain times. Instead, you can drill a couple of wells in the ground. And I think in that context, geothermal has appeared as, interestingly, a surprise to many people."

This narrative not only helps make geothermal more relatable to broader audiences but also aligns with system-level concerns such as grid stability and industrial energy demand. Respondent D emphasized that geothermal's stable electrical output offers significant advantages in an energy system that is increasingly dominated by intermittent renewables:

> "Geothermal is a base load, providing stable production, which makes it much easier for the grid owner. [...] If you have intermittent power production, like from solar and wind, the grid owner has to take a cost to stabilize the grid."

However, despite this value, Respondent D noted that geothermal remains undervalued in electricity markets and overlooked in policymaking. Current market structures often fail to reflect the unique benefits of geothermal, such as reliability, predictability, and constant availability:

> "I think there is a misbalance in the remuneration and the pricing on the general market. The advantage of geothermal is not taken into account in the average trade, because you just look at the megawatt-hour price. Some contracts show that grid owners pay three to four times more for a contract with geothermal versus solar. [...] When politicians talk about it, they have not fully grasped it either."

At the same time, respondents warned that narratives must be grounded in technological reality to avoid backlash or overstating the readiness of technologies, as this may damage credibility if their performance falls short. This underscores the importance of setting expectations that are ambitious enough to attract capital and policy attention yet grounded enough to maintain credibility and trust.

This tension is especially relevant given the history of boom-and-bust cycles[1] in clean energy finance. Respondents acknowledged that venture capitalists are acutely aware of previous waves of overhyped technologies that ultimately underperformed and left a trail of disappointed investors. These experiences contribute to a heightened sense of caution when considering investments in emerging sectors like geothermal. As Respondent C noted:

> "I think investors have [these cycles] very much in mind, and that is why it is very hard right now to raise funding. It is because they are all worried that they are investing in that boom-and-bust cycle. [...] Carbon markets were seen as a huge opportunity, ten years ago, five years ago. And today, most of those companies have really suffered because the carbon markets have not really materialized. [...] When you as a venture capital investor have this experience of choosing the wrong new thing, you become less risk willing."

These insights highlight that the success of geothermal innovation is shaped not only by technical feasibility or financial logic, but also by how the technology is perceived and situated within broader societal narratives. Effective storytelling can help position geothermal as a strategic solution rather than a niche technology. However, this requires careful balance as the narratives must be grounded in technological and market realities to maintain trust of investors and the public.

[1] The boom-and-bust cycle describes a pattern in financial markets where a rapid investment flows and enthusiasm for a particular sector or technology is followed by a sharp decline when expectations are not fulfilled. In the clean energy space, these cycles are often driven by a combination of technological hype and unrealistic timelines for returns (Gaddy et al. 2017).

5. Discussion

This chapter interprets the empirical findings in light of the conceptual framework and existing literature on sustainability transitions, venture capital, and geothermal innovation. The discussion is structured around the two research questions and aims to reflect on how dominant financial logics and VC practices influence the development and scaling of geothermal technologies within the broader context of clean energy transitions.

5.1 What shapes the interest of investing in geothermal energy technologies in the EU?

The findings of this study shed light on the factors shaping investor interest in geothermal energy technologies within the EU and reveal how dominant investment logics – defined as short-termism, risk aversion, reliance on historical data and predictability, the assumption of price efficiency, and the emphasis on risk-adjusted returns (Louche et al. 2019) – act as structural filters that influence which technologies are perceived as attractive and viable investment opportunities. These logics have become deeply embedded in how investment funds are structured, how risk is assessed, and how investors behave. This is particularly visible in the early stages of geothermal innovation, where conventional investment criteria fail to align with the technical and infrastructural characteristics of the sector.

Investor interest is particularly constrained at the early stages of innovation, where respondents stressed how conventional VC is often incompatible with geothermal technologies. The capital intensity, slow development timelines, and high upfront uncertainty that are associated with these innovations do not align with the "quick-scaling, high-exit" logic that dominates investments in, e.g., IT sector. This observation supports findings by Gaddy et al. (2017), who argued that venture capital's preference for low-cost entry, short-term returns has systematically disadvantaged energy innovation. Similarly, Geddes et al. (2018) show how preferences on capital markets for predictable and modular technologies tend to steer investment away from infrastructure-heavy cleantech solutions. The short-term investment horizons highlighted by Louche et al. (2019) become particularly problematic when intersecting with geothermal's complexity and uncertainty. Such conditions dampen investor enthusiasm and willingness to commit capital thus reducing the attractiveness of geothermal innovations relative to other renewables.

This dynamic can be interpreted through the lens of the MLP framework on socio-technical transitions (Geels 2002). Within this framework, dominant investment logics can be understood as stabilized patterns of practices, rules, and institutions that reinforce existing trajectories and limit alternative pathways within the socio-technical regime (Geels 2004; 2011). These logics tend to reproduce the status quo rather than support radical innovation. In the case of geothermal technologies, regime-level financial norms – such as standard VC fund cycles, return expectations, and assessment methods –act as selection environments that inhibit the scaling of niche technologies (Geels 2002). Building on this perspective, work by Geddes and Schmidt (2020) also emphasizes the financial regime's role as a powerful selector in sustainability transitions. This study contributes to that view by providing empirical evidence of how these selection mechanisms operate in practice. Geothermal's slow development timelines and high upfront capital requirements make it vulnerable to exclusion, despite offering long-term benefits such as baseload stability and energy security. From a path dependency perspective within the MLP framework, the dominance of these investment logics constitutes a form of institutional lock-in, where institutions "may be defined as any form of constraint that human beings devise to shape human interaction" (Foxon 2002, p. 2). This lock-in is driven not only by past investment preferences but by the broader institutional environment – such as regulatory norms, standardized risk assessment tools, and fund performance metrics – that reward short-term and lower-risk solutions compared to the geothermal. These mechanisms constrain experimentation and make it difficult for capital-intensive, long-horizon innovations to compete. As a result, incumbent financial practices persist, while alternative value metrics in form of climate resilience, systemic integration, or long-term societal benefits remain largely unaccounted for.

The influence of dominant investment logics appears to be geographically uneven. Respondents contrasted Europe's more conservative investment culture with the more risk-tolerant, opportunity-driven one in the U.S., where venture capitalists are more willing to engage early with new technologies, even in the absence of full validation. As Respondent C observed, "there is a pattern of European venture capitalists making low risk bets [and] having tendency to go towards what is safe in times of crisis", highlighting a pattern in which funding flows pull back from emerging technologies and concentrate around already validated models. This geographical difference is further reinforced by institutional factors, such as the presence of targeted public support in the U.S., where agencies like the Department of Energy actively back geothermal innovations and provide more predictable and centralized access to funding (U.S. Department of Energy 2025). In contrast, geothermal energy in EU remains underdeveloped due to limited coordination and fragmentation among member states and insufficient progress in recent years (EESC 2024), which can make it harder for innovators to navigate and align with investment needs. This highlights the contextual nature of financial regimes, where the political economy of finance shapes which technologies get funded, and under what conditions (Bridge et al. 2013). By demonstrating that financial norms are institutionally embedded and spatially differentiated, this study reinforces arguments by Ambrois et al. (2025) on the significance of national frameworks and policy alignment for scaling low-carbon innovation.

Taken together, these findings address the research question by demonstrating that investor interest in geothermal energy technologies in the EU is shaped by dominant financial logics and institutional frameworks that act as selective filters, privileging short-term, predictable investments and marginalizing capital-intensive, long-horizon innovations. This systemic misalignment leads to underinvestment in geothermal energy (IRENA 2023a), reinforcing the stabilization of incumbent pathways and limiting niche emergence (Geels, 2004).

Shifting investor interest to better support geothermal innovation thus requires structural transformation within the financial regime. Some scholars (e.g. Louche et al. 2019) propose rethinking how innovation is valued, not only in terms of return on investment but through broader metrics such as climate resilience, societal benefit, and systemic integration. In this context, tools and mechanisms like mission-oriented finance, blended capital or active ownership (Louche et al. 2019; Nedayvoda et al. 2021) may offer alternative pathways that better align with the long-term and infrastructure-heavy nature of geothermal innovation. These shifts would not only diversify investment logics but could also open space for niche technologies that are currently excluded by dominant selection environments.

5.2 How do European venture capitalists understand their role in supporting clean energy innovations like geothermal?

This study reveals how European venture capitalists perceive their roles as strategic actors within the geothermal energy innovation landscape. While much of the VC industry follows a traditional investment model – typically established for ten years and focused on sectors like IT, biotech, or fintech that offer low capital intensity and faster paths to market – specialized venture capitalists in clean or geothermal energy play a more engaged and complex role. These investors understand their function not merely as financiers but as agents of change who shape investment landscapes by building credibility around geothermal niche technologies, aligning market expectations, and signalling emerging opportunities to a broader ecosystem.

This is particularly evident in the capacity of VC as a signal amplifier and legitimacy builder within the cleantech space. Respondents highlighted that when a reputable VC firm backs an early-stage geothermal startup, the act itself sends strong legitimacy signals that can reduce perceived risk, attract follow-on investors, and generate interest from political and industrial actors. Respondent C, for instance, referred to the case of Fervo Energy, noting that the presence of high-profile investors fundamentally shifted how generalist venture capitalists viewed geothermal – no longer as a niche field, but as a viable energy domain. This illustrates how VC serves a legitimating function, particularly when exercised by influential or specialized actors. They help legitimize the geothermal solutions not only by validating a firm's business case, but also by changing how an entire technology domain is perceived. This aligns with the literature in sustainability transitions, which emphasizes the importance of institutional entrepreneurs – actors who intentionally work to reshape dominant rules and norms in support of sustainability-oriented innovation (Jolly & Raven 2016).

Moreover, this form of entrepreneurial action by venture capitalists contributes to what Wüstenhagen et al. (2009) call "expectation dynamics" within socio-technical systems. By crafting compelling visions about relevance of geothermal solutions – such as its potential to power AI data centres or deliver constant base-load energy – venture capitalists help coordinate narratives about future that attract attention, capital, and complementary innovation. These expectations, while partly speculative, play a real role in shifting market priorities toward emerging energy technologies by reshaping what is imagined as economically and technologically viable.

One of the most consistent insights from this study was the role of venture capitalists as de-risking agents in emerging clean energy technologies. Respondents emphasized that early-stage VC does not simply finance innovation but also helps reduce uncertainty across multiple dimensions – whether technical, market, regulatory, or organizational. By investing in unproven technologies at a point when other financial actors remain hesitant, these actors effectively absorb and manage early-stage risk. This in turn makes follow-on investment rounds more acceptable to generalist venture capitalists, infrastructure funds, or corporate partners, thereby facilitating the broader scaling process. This role closely aligns with insights from work by Jacobsson and Bergek (2011), where the provision of risk capital is identified as a critical enabling function for innovation. The findings of this study extend that insight by showing how VC firms not only provide financial resources but also perform a systemic de-risking function thus helping to remove one of the most persistent obstacles in scaling deep-tech climate innovations such as geothermal.

At the same time, this de-risking function also resonates with the concept of transition intermediaries in sustainability transitions research. By lowering both perceived and real risks surrounding novel geothermal technologies, venture capitalists effectively act as bridging agents that enable connections between niche innovations and regime actors such as utilities, policymakers, and industrial investors (Kivimaa et al. 2019). In this sense, their role is not limited to capital provision but includes facilitating alignment, building credibility, and helping emerging technologies navigate complex and risk-averse regimes. This intermediary role is especially crucial in sectors like geothermal, where long development cycles and high upfront uncertainty often deter early mainstream engagement. Through selective and early-stage risk absorption, venture capitalists help make niche innovations visible and investable within the wider socio-technical system.

Nonetheless, the transformative potential of VC has important limitations. While respondents acknowledged that VC can accelerate early-stage innovation and increase visibility for emerging technologies like geothermal, they also emphasized that this momentum is often difficult to sustain. As a result, even when venture capitalists initially engage with clean energy technologies, their support can be vulnerable to shifts in market sentiment or delayed returns which leads to patterns of boom-and-bust investment (Gaddy et al. 2017). These cycles are often triggered by overhyped expectations or external shocks and can undermine long-term development trajectories.

These insights address the second research question by showing that European venture capitalists – especially specialized investors – understand their role as multifaceted in supporting geothermal innovations. Specifically, they enact this role through four interrelated functions – acting as a legitimizing force, coordinating expectations, serving as a de-risking mechanism, and operating as strategic first movers. By entering early and absorbing technical and financial uncertainty, venture capitalists help signal credibility, attract follow-on capital, and position emerging technologies as viable investment opportunities. In doing so, they influence which technologies financial markets begin to recognize thus contributing to a reorientation – however partial – of investment priorities. Through these functions, VC can help build new markets, mobilize generalist investors, and embed geothermal within broader clean energy transition narratives. However, this influence remains constrained by the structural characteristics of the VC model itself – such as fund timelines and return expectations – but also by the broader investment landscape and institutional context within the EU. VC can open critical doors for niche innovations, but durable shifts in financial priorities require complementary action from public institutions, regulatory frameworks, industry actors and other investors to overcome systemic barriers and sustain momentum (Gaddy et al. 2017).

6. Conclusion

The transition to a low-carbon energy system is not only a technical or political challenge – it is also a financial one, shaped by how capital is allocated, risks are assessed, and innovation is valued. In this context, this thesis set out to explore two interconnected questions: what shapes the interest in investing in geothermal energy technologies in the EU, and how European venture capitalists understand their role in supporting clean energy innovations like geothermal. Drawing on the multi-level perspective, dominant investment logics, and the conceptualisation of venture capitalists as transition intermediaries, this thesis contributes with an integration of financial systems into the MLP framework. It demonstrates that financial markets, in particular, are embedded within institutional path-dependencies and lock-in mechanisms that influence which technologies receive investment and under what conditions. This embedding of finance into the MLP framework reveals how financial systems act as powerful selectors that stabilize incumbent trajectories and shape the prospects for niche innovations.

The analysis revealed that dominant investment logics – characterized by short-termism, risk aversion, assumption of price efficiency, and risk-return trade-off – function as structural filters that limit investment interest in capital-intensive, long-horizon technologies like geothermal energy. These logics manifest as regime-level selection environments, reinforcing established financial practices and creating institutional lock-ins that disadvantage geothermal technologies with their infrastructural complexity and slow development timelines. This mismatch leads to systemic underinvestment in geothermal innovation within the European context, compounded by fragmented policy coordination and a more risk-averse investment culture compared to other regions.

At the same time, the findings demonstrated that venture capitalists contribute in meaningful but often constrained ways to changing how the system works. When deployed with expertise and strategic intent, venture capitalists can help derisk early-stage innovations, signal legitimacy to other investors, and reshape expectations about the viability of geothermal technologies. However, the transformative potential of venture capital remains constrained by broader institutional and geographic factors, as well as by its relatively small scale compared to major institutional investors such as pension funds or sovereign wealth funds, which command significantly larger pools of capital and longer investment horizons.

This thesis contributes to the theoretical development of the MLP by emphasizing the role of financial norms and actors as key components of the socio-technical regime. It shows how investment logics act as filters through which niche technologies must pass, and how these filters are shaped by historical patterns and institutional routines. By integrating perspectives from finance and investments with transition studies, the thesis helps bridge the gap between socio-technical and financial perspectives on innovation.

Empirically, the thesis provides original insights into the investment logics for geothermal energy technologies in the EU, an underexplored but strategically important area in the clean energy transition. It highlights both the barriers and enabling conditions faced by innovators and investors and underscores the importance of aligning financial mechanisms with the unique characteristics of infrastructure-heavy energy technologies. These financial mechanisms may include patient capital (e.g., evergreen funds), blended finance, and risk-sharing instruments. In addition, the findings point to the importance of stronger policy coordination across the EU to improve the investability of geothermal innovation.

This study focused on a specific subset of actors within the geothermal innovation space. While this focus allowed for in-depth insights, future research could expand the scope by examining other investor types (e.g., institutional or state-backed investors) or by conducting comparative studies across different renewable sectors. Additionally, more quantitative analysis of funding flows and project success rates could help extend the findings.

References

Adalı, Z., Dinçer, H., Eti, S., Mikhaylov, A., & Yüksel, S. (2022). Identifying new perspectives on geothermal energy investments. In *Multidimensional strategic outlook on global competitive energy economics and finance* (pp. 1-11). Emerald Publishing Limited.

Ambrois, M., Croce, A., & Ughetto, E. (2025). Greening the future: how venture capital nurtures cleantech companies' growth in Europe. *Small Business Economics*, 1-39.

Assenza, T., Bao, T., Hommes, C., & Massaro, D. (2014). Experiments on expectations in macroeconomics and finance. In Experiments in macroeconomics (Vol. 17, pp. 11-70). Emerald Group Publishing Limited.

Beiter, P., Cooperman, A., Lantz, E., Stehly, T., Shields, M., Wiser, R., ... & Kikuchi, Y. (2021). Wind power costs driven by innovation and experience with further reductions on the horizon. *Wiley Interdisciplinary Reviews: Energy and Environment*, 10(5), e398.

Bell, E., Harley, B., & Bryman, A. (2019). *Business research methods*. Oxford university press.

Birch, K. (2023). Reflexive expectations in innovation financing: An analysis of venture capital as a mode of valuation. Social Studies of Science, 53(1), 29-48.

Bocken, N. M. (2015). Sustainable venture capital–catalyst for sustainable start-up success?. *Journal of cleaner production*, *108*, 647-658.

Bridge, G., Bouzarovski, S., Bradshaw, M., & Eyre, N. (2013). Geographies of energy transition: Space, place and the low-carbon economy. *Energy policy*, *53*, 331-340.

Célia, C., & Marie-Benoît, M. (2023). Knowledge and network resources in innovation system: How production contracts support strategic system building. *Environmental Innovation and Societal Transitions*, *47*, 100712.

CFI (n.d.). Financial System. Retrieved from: https://corporatefinanceinstitute.com/resources/wealth-management/financial-system/. Accessed [24.04.2025]

Council of the EU (2024). Geothermal energy: Council calls for faster deployment. Retrieved from: https://www.consilium.europa.eu/en/press/press-releases/2024/12/16/geothermal-energy-council-calls-for-faster-deployment/. Accessed [24.04.2025]

Cresswell, J. (2013). Qualitative inquiry & research design: Choosing among five approaches.

DiMaggio, P. J. (1988). Interest and agency in institutional theory. *Institutional patterns and organizations*, 3-21.

Dordi, T., Gehricke, S. A., Naef, A., & Weber, O. (2022). Ten financial actors can accelerate a transition away from fossil fuels. *Environmental Innovation and Societal Transitions*, *44*, 60-78.

Dosi, G. (1990). Finance, innovation and industrial change. *Journal of Economic Behavior & Organization*, *13*(3), 299-319.

Dumas, C., & Louche, C. (2016). Collective beliefs on responsible investment. *Business & Society*, *55*(3), 427-457.

Egli, F., Polzin, F., Sanders, M., Schmidt, T., Serebriakova, A., & Steffen, B. (2022). Financing the energy transition: four insights and avenues for future research. *Environmental Research Letters*, *17*(5), 051003.

Erbe, F. C. (2021). *Exploring the role of investors in the alternative 'meat'transition* (Master's thesis).

European Commission (n.d.). 2050 long-term strategy. Retrieved from: https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en. Accessed [20.04.2025]

European Council (2024). Geothermal Energy: Council calls for faster deployment. Retrieved from: https://www.consilium.europa.eu/en/press/press-releases/2024/12/16/geothermal-energy-council-calls-for-faster-deployment/. Accessed [20.04.2025]

European Economic and Social Committee (EESC). (2024). *Geothermal energy can make the green transition happen*. Retrieved from: https://www.eesc.europa.eu/en/news-media/news/geothermal-energy-can-make-green-transition-happen. Accessed [20.04.2025]

European Parliament (2023). Geothermal energy in the EU. Retrieved from: https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/754566/EPRS_BRI(2023)754566_EN.pdf. Accessed [24.04.2025]

Fama, E. F. (1970). Efficient capital markets. *Journal of finance*, *25*(2), 383-417.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative inquiry*, *12*(2), 219-245.

Foxon, T. J. (2002). Technological and institutional 'lock-in'as a barrier to sustainable innovation. *Imperial College Centre for Policy and Technology Working Paper*, 1-9.

Gaddy, B. E., Sivaram, V., Jones, T. B., & Wayman, L. (2017). Venture capital and cleantech: The wrong model for energy innovation. Energy Policy, 102, 385-395.

Geddes, A., & Schmidt, T. S. (2020). Integrating finance into the multi-level perspective: Technology niche-finance regime interactions and financial policy interventions. *Research Policy*, *49*(6), 103985.

Geddes, A., Schmidt, T. S., & Steffen, B. (2018). The multiple roles of state investment banks in low-carbon energy finance: An analysis of Australia, the UK and Germany. *Energy policy*, *115*, 158-170.

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research policy*, *31*(8-9), 1257-1274.

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research policy*, *33*(6-7), 897-920.

Geels, F. W. (2013). The impact of the financial–economic crisis on sustainability transitions: Financial investment, governance and public discourse. *Environmental Innovation and Societal Transitions*, *6*, 67-95.

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research policy*, *36*(3), 399-417.

Geels, F. W., Sovacool, B. K., Schwanen, T., & Sorrell, S. (2017). Sociotechnical transitions for deep decarbonization. *Science*, *357*(6357), 1242-1244.

Ghosh, S., & Nanda, R. (2010). Venture capital investment in the clean energy sector. *Harvard Business School Entrepreneurial Management Working Paper*, (11-020).

Gompers, P., & Lerner, J. (2001). The venture capital revolution. *Journal of economic perspectives*, *15*(2), 145-168.

Gornall, W., & Strebulaev, I. A. (2021). The economic impact of venture capital: Evidence from public companies. *Available at SSRN 2681841*.

IEA (2023). World Energy Investment 2023. Retrieved from: https://iea.blob.core.windows.net/assets/8834d3af-af60-4df0-9643-72e2684f7221/WorldEnergyInvestment2023.pdf. Accessed [17.03.2025]

IRENA (2023a) Global Landscape of Renewable Energy Finance

IRENA (2023b) Boosting the Global Geothermal Market Requires Increased Awareness and Greater Collaboration. Retrieved from: https://www.irena.org/News/articles/2023/May/Boosting-the-Global-Geothermal-Market-Requires-Increased-Awareness-and-Greater-Collaboration. Accessed [18.03.2025]

Jacobsson, S., & Bergek, A. (2011). Innovation system analyses and sustainability transitions: Contributions and suggestions for research. *Environmental Innovation and Societal Transitions*, *1*(1), 41-57.

Jolly, S., & Raven, R. P. J. M. (2016). Field configuring events shaping sustainability transitions? The case of solar PV in India. *Technological Forecasting and Social Change*, *103*, 324-333.

Kanda, W., Kuisma, M., Kivimaa, P., & Hjelm, O. (2020). Conceptualising the systemic activities of intermediaries in sustainability transitions. *Environmental Innovation and Societal Transitions*, *36*, 449-465.

Kanda, W., Magnusson, T., & Hjelm, O. (2024). Intermediaries and Intermediation in Sustainability Transitions. *Cambridge Open Engage*.

Kaplan, S. N., & Lerner, J. (2010). It ain't broke: The past, present, and future of venture capital. *Journal of Applied Corporate Finance*, *22*(2), 36-47.

Kivimaa, P., Boon, W., Hyysalo, S., & Klerkx, L. (2019). Towards a typology of intermediaries in sustainability transitions: A systematic review and a research agenda. *Research policy*, *48*(4), 1062-1075.

Laenen, B., Bogi, A., Manzella, A., & Dumas, P. (2019). Financing deep geothermal demonstration projects. *European Technology & Innovation Platform on Deep Geothermal*.

Leogrande, A., Costantiello, A., & Laureti, L. (2021). The Impact of Venture Capital Expenditures on Innovation in Europe.

Lincoln, Y. S. (1985). *Naturalistic inquiry* (Vol. 75). sage.

Louche, C., Busch, T., Crifo, P., & Marcus, A. (2019). Financial markets and the transition to a low-carbon economy: Challenging the dominant logics. *Organization & Environment*, *32*(1), 3-17.

Mackenzie, N., & Knipe, S. (2006). Research dilemmas: Paradigms, methods and methodology. *Issues in educational research*, *16*(2), 193-205.

Metrick, A., & Yasuda, A. (2021). *Venture capital and the finance of innovation*. John Wiley & Sons.

Michelfelder, I., Kant, M., Gonzalez, S., & Jay, J. (2022). Attracting venture capital to help early-stage, radical cleantech ventures bridge the valley of death: 27 levers to influence the investor perceived risk-return ratio. *Journal of Cleaner Production*, *376*, 133983.

Migendt, M., Polzin, F., Schock, F., Täube, F. A., & Von Flotow, P. (2017). Beyond venture capital: an exploratory study of the finance-innovation-policy nexus in cleantech. *Industrial and corporate change*, *26*(6), 973-996.

Muscio, A., Simonelli, F., & Vu, H. (2023). Bridging the valley of death in the EU renewable energy sector: Toward a new energy policy. *Business Strategy and the Environment*, *32*(7), 4620-4635.

Nedayvoda, A., Delavelle, F., So, H. Y., Graf, L., & Taupin, L. (2021). Financing deep tech. *International Finance Corporation.*

Peng, M. W., Lee, S. H., & Hong, S. J. (2014). Entrepreneurs as intermediaries. *Journal of World Business*, *49*(1), 21-31.

Persad, K. A. (2024). Why institutional investor expectations on the speed of the energy transition matter: a complex systems perspective on sustainable investment behaviour (Doctoral dissertation, Heriot-Watt University).

Polzin, F. (2024). Venture Capital Investments in Cleantech Startups. In *The Palgrave Encyclopedia of Private Equity* (pp. 1-6). Cham: Springer International Publishing.

Polzin, F., & Sanders, M. (2020). How to finance the transition to low-carbon energy in Europe?. *Energy Policy*, *147*, 111863.

Polzin, F., Sanders, M., & Täube, F. (2017). A diverse and resilient financial system for investments in the energy transition. *Current Opinion in Environmental Sustainability*, *28*, 24-32.

Pratty, F. (2022). What opportunities could geothermal energy offer?. Retrieved from: https://sifted.eu/articles/geothermal-energy. Accessed [24.04.2025]

Ryan, G. W., & Bernard, H. R. (2003). Techniques to identify themes. *Field methods*, *15*(1), 85-109.

Schumpeter, J. (1934) The Theory of Economic Development. Cambridge, Mass.: Harvard University Press

Stake, R. (1995). *Case study research*. Cham: Springer.

Steffen, B., & Schmidt, T. S. (2021). Strengthen finance in sustainability transitions research. *Environmental Innovation and Societal Transitions*, *41*, 77-80.

Stern, N. (2006). What is the economics of climate change? World Economics, 7(2), 1-10.

Tester, J. W., Beckers, K. F., Hawkins, A. J., & Lukawski, M. Z. (2021). The evolving role of geothermal energy for decarbonizing the United States. *Energy & Environmental Science*, 14(12), 6211-6241.

US Department of Energy (n.d.). Geothermal FAQs. Retrieved from: https://www.energy.gov/eere/geothermal/geothermal-faqs. Accessed [03.05.2025]

US Department of Energy (2025). U.S. Department Of Energy Releases New Reports Highlighting Benefits Of Consumer-Centric Solutions For Households, Businesses, And Utilities Retrieved from: https://www.energy.gov/technologytransitions/articles/us-department-energy-releases-new-reports-highlighting-benefits. Accessed [03.05.2025]

Van Driel, H., & Schot, J. (2005). Radical innovation as a multilevel process: introducing floating grain elevators in the port of Rotterdam. *Technology and Culture*, *46*(1), 51-76.

Wang, J. Investigating the Roles, Influencing Mechanisms, and Outcomes of Private Equity and Venture Capital on Companies in High-Tech Renewable Energy Sectors.

Weik, E. (2011). Institutional entrepreneurship and agency. *Journal for the theory of social behaviour*, *41*(4), 466-481.

Weinand, J. M., Vandenberg, G., Risch, S., Behrens, J., Pflugradt, N., Linßen, J., & Stolten, D. (2023). Low-carbon lithium extraction makes deep geothermal plants cost-competitive in future energy systems. *Advances in Applied Energy*, 11, 100148.

Wüstenhagen, R., Wuebker, R., Bürer, M. J., & Goddard, D. (2009). Financing fuel cell market development: Exploring the role of expectation dynamics in venture capital investment. In Innovation, markets and sustainable energy. Edward Elgar Publishing.

Yudha, S. W., Tjahjono, B., & Longhurst, P. (2022). Sustainable transition from fossil fuel to geothermal energy: A multi-level perspective approach. *Energies*, *15*(19), 7435.

Appendix 1

Appendix 1 presents the interview guide that was used to conduct semi-structured interviews with venture capital investors, clean energy experts, and professionals involved in geothermal technology and finance. The interview structure was flexible, allowing for follow-up questions based on the participant's responses.

Section 1: Investment Environment and Systemic Narratives

1. How do you perceive the current investment landscape for clean energy technologies? Are certain technologies (e.g., solar, wind) being prioritized over others like geothermal?
2. Does your firm engage with policymakers or regulators to improve the investment environment for geothermal or clean technologies?
3. What influence do EU or national policy developments have on your investment decisions?
4. How well do investors understand the unique challenges of geothermal technologies?
5. What changes in markets, technologies, or policies would most accelerate the scaling of geothermal innovation in the EU?

Section 2: Risk Perception and Financial Models

6. Do current financial structures (e.g., traditional VC models, assessment tools) support or limit investment in long-term, capital-intensive technologies like geothermal?
7. How do you balance the need for financial returns with the uncertainties and long development cycles of geothermal technologies?
8. How does your firm approach risk assessment for investments in emerging energy technologies such as geothermal?

Section 3: VC's Role in the Energy Transition

9. To what extent do you see venture capital as a driver of the clean energy transition, is it reactive to market trends or proactive in shaping them?
10. How do VC firms influence other investors' interest in sectors like geothermal?
11. How much influence do venture capitalists have in reshaping dominant investment logics, such as risk assessment and return expectations?
12. Are there examples where VC investment has reshaped market perceptions or opened doors for geothermal or other clean technologies?

Popular science summary

Geothermal energy offers a promising solution for Europe's clean energy transition. As a stable and low-carbon energy source, it can provide continuous power and support energy security. However, geothermal technologies often face significant obstacles in reaching the market. High upfront costs, long development timelines, and uncertainty around financial returns make it difficult for these innovations to attract private investment. This thesis investigates how venture capital – a form of private equity that funds high-risk, early-stage companies – contributes to the development and scaling of geothermal energy technologies in the European Union.

The research combines insights from transition theory and finance concepts with interviews conducted with venture capitalists, energy experts, and industry stakeholders. It finds that mainstream financial practices, such as the preference for short investment cycles and low-risk profiles, tend to disadvantage capital-intensive technologies like geothermal. These investment norms act as structural barriers that limit the flow of funding to such innovations. At the same time, the study highlights that certain specialized venture capitalists can play an enabling role. These investors help reduce early-stage risks, build credibility around geothermal technologies, and influence the wider investment landscape by signalling the potential of emerging energy solutions. Still, their impact is constrained by the broader financial environment, particularly the limited scale of the venture capital sector and the mismatch between geothermal's characteristics and mainstream investment thinking.

This thesis underscores the importance of aligning financial systems with the needs of complex, long-term clean energy technologies. While venture capital can play a catalytic role in supporting early innovation, achieving meaningful progress in geothermal development will require stronger public support, institutional reforms, and investment mechanisms that are better suited to capital-intensive energy solutions.

Publishing and archiving

Approved students' theses at SLU can be published online. As a student you own the copyright to your work and in such cases, you need to approve the publication. In connection with your approval of publication, SLU will process your personal data (name) to make the work searchable on the internet. You can revoke your consent at any time by contacting the library.

Even if you choose not to publish the work or if you revoke your approval, the thesis will be archived digitally according to archive legislation.

You will find links to SLU's publication agreement and SLU's processing of personal data and your rights on this page:

- https://libanswers.slu.se/en/faq/228318

☒ YES, I, Mariana Cimbalistová, have read and agree to the agreement for publication and the personal data processing that takes place in connection with this

☐ NO, I/we do not give my/our permission to publish the full text of this work. However, the work will be uploaded for archiving and the metadata and summary will be visible and searchable.