Theorizing on learning in renewable energy finance
Investment in utility-scale solar PV and wind turbines
- *Working Paper* -

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Abstract

The availability and scaling-up of financing sources for green technologies are crucial for accelerating sustainability transitions, and especially the energy transition. One key element previously identified as being effective in lowering the cost of capital (CoC) for Renewable Energy Technologies (RET) is the learning process across different financiers. This paper is the first to develop a theory of financial learning for energy transition using the Multi-Level Perspective (MLP) framework. It explains how learning channels are formed and diffuse specific knowledge across the networks within and across the regime and niche in project finance for RET and which are the main actors shaping these channels. Prior research has investigated the role of different sources of finance, as well as the drivers of changes in financing conditions for green technologies, separately. To accelerate the green finance allocation from incumbent technologies to new innovative and emerging ones, it is of utmost importance to understand how knowledge on technologies intertwine with learning and experience within financial sector.

1. Introduction

Empirical evidence highlights the crucial role of finance as an enabler to socio-technical transitions (Hall et al., 2017; Best et. al., 2017), however there is scarce academic discussion about finance within the Sustainability Transitions field (Steffen & Schmidt, 2021; Geddes & Schmidt, 2020; Naidoo, 2020; Köhler et al., 2019; Loorbach & Lijnis Huffenreuter, 2013; Truffer et al., 2022). Scholars in the sustainability transitions field identified some systems that are 'path dependent' (Aghion et al., 2015; Geels, 2014; Geels & Schot, 2007), recently emphasizing the evolutionary aspect of the financial sector (Barazza & Strachan, 2021; Loorbach & Lijnis Huffenreuter, 2013; Naidoo, 2020). Geddes and Schmidt (2020) indicated that the financial sector, which is characterized as a regime[1], is path dependent particularly through its interaction with the technological sectors, considered to be niches[2]. Similarly, behavioral finance scholars (Hall et al., 2017; Lo, 2004) recognize that financial markets are constantly adapting to changes in economic conditions and the behavior of market participants (Adaptive Market Hypothesis). Both literature streams emphasize that the financial sector is dynamic, and its actors acquire knowledge and learn from past experiences, which could accelerate the energy transition (Egli et al., 2019; Geddes & Schmidt, 2020).

More recent literature suggests that the role of learning is a predominant factor in accelerating the deployment of renewable energy technologies (RET) and facilitates the energy transition. Until now,

[1] A regime is defined as "the existing context conditions", more specifically *"the selection environment, defined as the arrangement of established practices, sets of rules and organizational and cognitive routines that affect incumbent actors' resistance to or compliance with system change."*(Geddes & Schmidt, 2020)

[2] A nice is a *"protective space where path-breaking, radical innovations, such as low-carbon technologies, are produced and developed."*(Geddes & Schmidt, 2020)

the main energy transition challenges presented through the lenses of an efficient market hypothesis[3] (Campbell, 2014; Fama, 1970), might find sharper solutions in mechanisms closer to theoretical sustainability transitions frameworks (Egli et al., 2022). The study highlights that investors benefit from learning and experience spill overs (Adams, 2006), mostly through specific learning mechanisms formed at the regime-niche interaction (Egli et. al., 2018; Sagar & van der Zwaan, 2006). Also, the CoC reduction stems from the reduction of debt margins, due to increased investment experience on RET (Egli et al., 2019). At a systemic level, Trancik et. al. (2015) and Rubin et. al. (2015) showed the existence of a learning rate in information-intensive sectors such as finance and renewable energy production. Egli et. al. (2018) found empirical evidence for a learning curve[4], proving that the financial sector undergoes a learning process, especially learning by doing and using (Thompson, 2010; von Hippel & Tyre, 1995), when faced with investments in new projects and technologies.

While previous research marks the existence of learning rate at the interaction of finance regime with different technology niches (Blanchard et al., 2022; Egli et al., 2018; Huenteler et al., 2016; Lindman & Söderholm, 2012), there is no clear empirical indication on how the acquisition of knowledge occurs and what are the channels of learning and its diffusion in the context of energy transitions. Moreover, there is scarce literature on conceptualizing and analyzing the role of finance elements for sustainability transitions, in detail, using the regime-niche interaction theorized within the Multi-Level Perspective (MLP) framework (Geels, 2013, 2014). Geddes and Schmidt (2020) record the only paper to date which take a first approach in theorizing on finance for energy transition in MLP.

Taking a holistic approach, this paper aims at identifying the mechanisms and process of learning for financial actors within the context of sustainability transitions. Extensive literature review and learning concepts are developed in *Section 2*. We choose the project finance structures for RET, such as solar PVs, offshore and onshore wind technologies, as a representative empirical setting for finance in energy transition and conduct 51 semi-structured interviews with experts in the field of RET project financing. We create a unique methodological structure for analyzing the process of financial learning across the sample of interviewees, by combing the MLP framework (Geels, 2013) with the classical learning literature in intensive knowledge sectors (Blanchard et al., 2022; Corradini & D'Ippolito, 2022; Figueiredo et al., 2020; Fu et al., 2013a; Sweerts et al., 2020; van der Zwaan & Seebregts, 2004). The case selection, methodological approach, and data are described in *Section 3*.

The results are presented in *Section 4* and structured on two pillars - the internal learning effects (learning by doing and by using mechanisms) and coordination effects (learning by interacting) - within three levels: (1) the Finance regime and at the interaction of (2) Finance – Technology regimes, as well as (3) Finance regime – Technology niche. Lastly, the rich and unique dataset and innovative methodology, would facilitate the design of effective policy interventions for less developed low-carbon technologies in various sectors. We discuss the results and make policy recommendations in *Section 5*, and conclude in *Section 6*.

2. Theoretical Channels and Empirical Evidence on Learning and Experience driving Energy Transitions

Our theoretical framework blends elements of the transition Multi-Level Perspective (MLP) with the two primary effects of learning, namely internal learning through learning by doing and using within

[3] EMH states that assets' prices fully reflect all available information, including the real and perceived risks. It assumes that market participants are rational and make decisions based on complete information.

[4] A financial experience effect is proposed by Egli et. al. (2019) based on the Wright's law describing the relationship between the financial learning process and the financing costs of RET.

the regimes, and external coordination effects through learning by interaction between regimes and niches or between regimes.

A regime is defined as "the existing contextual conditions," specifically "the selection environment, characterized by established practices, rules, and organizational and cognitive routines that impact incumbent actors' resistance to or compliance with system change" (Geddes & Schmidt, 2020). Previous literature has considered the finance and energy sectors to be regimes (Geddes & Schmidt, 2020; Geels, 2004; Geels, 2014). A niche is defined as "a protective space where path-breaking, radical innovations, such as low-carbon technologies, are produced and developed" (Geddes & Schmidt, 2020). We mark within the interviews the elements of project finance for RET that are close to the technological niche such as: experience with Original Equipment Manufacturer (OEM), Operation and Maintenance (O&M), better tools for curtailment prediction, track record of RET performance etc. (Figure 4, appendix). Also, according to Geddes & Schmidt (2020), actors such as State Investment Banks can redesign finance as a regime. Through their mandates, with innovative agendas, as well as greater technical knowledge, they can facilitate regime change by acting closer to a niche.

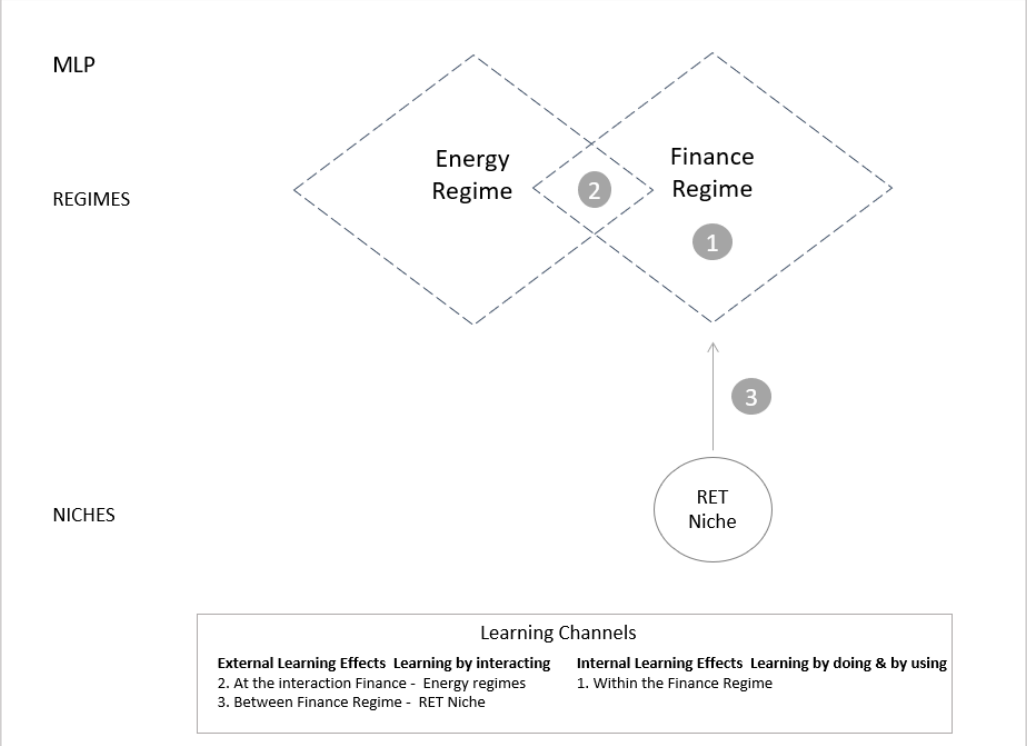


Figure 1. MLP Theory overlapping learning effects and channels

The novel aspect of the framework is classifying some particular types of knowledge observed within the energy finance sector on MLP theory and streamline them on learning channels. Based on these considerations, the analysis of financial learning focuses on three main pillars: (1) within the finance regime, (2) the interaction between the finance and technology regimes, (3) the interaction between the finance regime and technology niche (Figure 1, conceptual framework).

Previous research has identified learning as a vital mechanism in advancing ground-breaking green innovations and exerting pressure for the Energy Regime transformation (Geddes & Schmidt, 2020; Geels, 2014), primarily through its effect of reducing the financing costs of new technologies. Similar impact of learning is observed within the financial sector. According to the Adaptive market Hypothesis (AMH), financial markets are not always efficient, are information intensive, and the behavior and decisions of market participants can change in response to their experiences and learning (Lo, 2004; Campbell, 2014; Epstein & Schneider, 2002). Empirical evidence demonstrates how the process of learning altered the financial sector's perspective on investment in new technologies,

compelling the Finance Regime to "stretch and transform" (Geddes & Schmidt, 2020). Also, the intensity of learning effects has been quantified in "learning curves"(Egli et al., 2019) showing how much they account for CoC reduction.

Therefore, as both RET and financial sectors are information intensive and path-dependent industries, earlier studies observed two main effects: **internal learning effect** (Corradini & D'Ippolito, 2022; Lee & Walsh, 2016; Prencipe & Tell, 2001; Seebregts et al., 2000; Sweerts et al., 2020; van der Zwaan & Seebregts, 2004) and **external coordination effect** (Barlow, 2000; Figueiredo et al., 2020; Fu et al., 2013b; Hewitt-Dundas et al., 2019; Tubiana et al., 2022; van der Wouden & Youn, 2023).

Internal learning usually occurs at the individual, group or organizational level through trial and error and experimentation, during the process of implementation of new technologies. Internal learning effects within organizations refer to the process by which a company learns and improves its operations, products and processes by gaining knowledge and experience through its own activities (Malerba, 1992; Mulder et al., 2003; van der Zwaan & Seebregts, 2004). This is commonly referred to "learning by doing", considered the most effective mechanism for learning when supporting new technologies and business operations (Arrow, 1962). It allows individuals and organisations to gain hands-on experience with the technology and to troubleshoot problems as they arise. This type of learning can be particularly useful for hands-on tasks such as installation, maintenance and repair of new technologies. (Argote & Epple, 1990; Carraro et al., 2003; Dutton & Thomas, 1984).Learning by doing helps streamline and standardize the deployment process, thereby reducing the transaction costs associated with structuring and executing projects (Egli et al., 2019).

The effects of internal learning also manifest through the process of "learning by using", entailing developing knowledge and skills through the use of a product or system. This type of learning is often associated with the use of tools or equipment or more complex procedures, where there are many features or functions to be learned. Knowledge gained in the operation of complex systems also leads to higher returns from continuing use (Fu et al., 2013b; Mulder et al., 2003).

However, to significantly reduce costs and reduce information asymmetries, Jensen et al.'s research on experienced-based mode of learning, based on Doing, Using and Interacting (DUI-mode), determined that the traditional method of learning through experience alone is not sufficient for maintaining a competitive edge in firms. By combining the DUI - mode with the STI (science, technology and innovation) mode, organization could outperform other their competition in terms of costly efficient development of innovation (Jensen et al., 2007).

On the same rationale, there is evidence in the financial sector on banks "learning by lending", by engaging with their clients and "doing" the financial intermediation. Botsch and Vanasco (2019) finds strong evidence that bank learning affects loan prices, with higher quality borrowers receiving lower spreads as relationships progress, while lower quality borrowers see loan prices increase. It is mainly showed that loan contract terms evolve with borrower interactions. Lenders gather information about borrowers through screening and monitoring, as well as by gaining experience from repeated interactions with borrowing firms, peers, and other lenders. However, the impact of this experience on monitoring and screening is complex and varies depending on the type of experience. The study of Degryse et al. (2022) explores exactly the different dimensions of internal learning by experience in credit markets and its implications for lending.

These findings support the second effect of learning in knowledge intensive industries, the external coordination effects occurring through direct interactions and knowledge exchange. Collaboration allows for the reduction of information asymmetries and risks by allowing both sectors to share their knowledge and skills. This can lead to better decision-making and ultimately, a more successful project outcome (Tubiana et al., 2022). Likewise, Jiang and Li (2022) examine how a bank's expertise in a particular industry, developed through its loan portfolio, affects its credit provision to other firms

in the same industry, with evidence of a spill over effect or economies of scale in banks' information production. Looking within teams, Ayoubi et al. (2017) explores how how team members learn from each other and identifies factors that promote individual learning within research teams at the cross-road of collaboration. Acquiring new diverse knowledge is crucial for the effectiveness of scientific teams and team characteristics affect individual learning from teammates; this theory is further applied at the interaction of multiple markets and sectors.

Additionally, cooperation between the technical niches and financial regimes can provide new sources of ideas and knowledge, as well as increase a firm's ability to appropriate returns from innovation and reduce the CoC of the new technology (van der Wouden & Youn, 2023). Especially in immature distributed financial markets, the fragmentation and poor coordination hinder learning, ultimately translated in high transaction costs (Matsuo, 2019). The gaps and weaknesses within the financial regimes appear to be identified and addressed by knowledge intensive actors, such as SIBs that use their position to coordinate the transmission of leaning and best practices(Geddes & Schmidt, 2020). The coordination effect is detected at the interaction of technological niches with the financial regime in the context of financing RET, which makes the case of this paper.

3. Methodology

3.1. Research context

Over the past five years, the renewable energy landscape has undergone significant growth and transformation. There has been an increase in the deployment of renewable energy sources such as wind, solar, and hydropower, driven by declining costs, supportive government policies, and more streamlined investment flows (Egli et al., 2018; Hafner et al., 2020; Polzin et al., 2019; Polzin & Sanders, 2020). Renewable energy capacity has expanded, with wind and solar being the fastest growing sources. Preliminary estimates indicate that the year 2022 set a new record for the annual addition of renewable energy capacity: specifically, the projected annual capacity has been expected to reach approximately 340 GW (International Energy Agency, 2022b).

Despite this progress, putting the world on a a path to net zero until 2050 (Klaaßen & Steffen, 2023), means **tripling decarbonization investment** up to $32 trillion by 2025 out of which more than half is required in the energy transition – notably in electricity sector (International Energy Agency, 2022a). The pace of energy transition remains insufficient and is impeded by several persistent challenges such as a significant perceived risk towards innovative technologies or critical changes in drivers for cost of capital (CoC) reduction (Egli et al., 2018; Hafner et al., 2019; Karltorp, 2016; May & Neuhoff, 2017). At the market level, the sharp and unforeseen hikes in the interest rates might lead to a slowdown or reversal in the trend of decreasing financing costs (Schmidt et al., 2019; Steffen, 2018). This leads to a proportional rise in the cost of borrowing due to an increase in investor risk perception, thereby making it burdensome to secure the substantial amounts of upfront capital required for renewable energy projects. These challenges spark the debate on whether the tightening of current monetary policy may actually encourage reliance of fossil-fuel technologies and eventually hinder the energy transition to net zero (Carbone et al., 2021; Dirk Schoenmaker, 2021).

3.2. Case Selection

We selected through theoretical sampling the project finance for renewable energy technologies as the subject of our research (Eisenhardt & Graebner, 2007) due to its crucial significance in promoting energy transition (Geddes & Schmidt, 2020). To move from a fossil fuel-based energy system to a net positive one, a substantial adoption of renewable energy technologies is necessary. However, RET require significant capital investments (Steffen, 2018). The expansive monetary policies following the 2008-2009 financial crisis led to lower refinancing costs for banks, which in turn decreased the CoC for the RET market (Jimenez et. al., 2012; Dirk Schoenmaker, 2021). As a result, projects with predictable cash flows, off balance sheet, and long-term revenue profile, such as renewable energy

projects in project finance structures, became more attractive investments. For example, over 80% of onshore wind and solar PVs projects in Germany were shaped with project finance (Steffen, 2018).

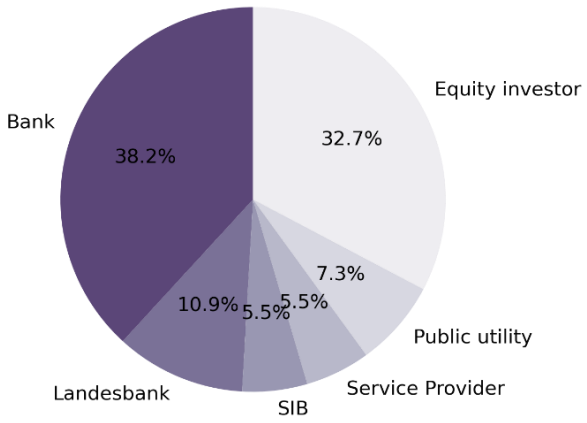
Project finance for RET is asset-specific, non-traded equity and bank debt, the price formation occurs through extensive multi-parties collaboration, especially between financiers and RET developers, perfectly reflecting the interaction between regimes and niche players(Geddes & Schmidt, 2020; Geels, 2013). These interaction processes involve highly-specialized analyses judgments which leads to confidentiality in prices. Arbitreurs cannot instantaneously correct any errors by irrational actors and information asymmetries (Malkiel, 2003). Therefore, project finance in the context of RET constitutes an ideal illustration of the Adaptive Market Hypothesis and path dependent markets.

Furthermore, previous empirical evidence marked the existence of particular learning process in shaping Special Purpose Vehicles (SPVs), which decreases risk perception (Egli et al., 2019). The process of learning and experience accumulation in financing RET facilitates the market to mature, which leads to an increase in competition and the entry of a greater number of institutional investors (Neuhoff et. al, 2005). This results in an improved evaluation of risk and a reduction in the hazards associated with RET projects (Polzin & Sanders, 2020), and consequently increasing their deployment. Geddes and Schmidt (2020) identified that the knowledge diffuses through co-investment schemes and while structuring the SPVs, mostly with the support of some specific actors such as State Investment Banks (Geddes et al., 2018). These empirical findings guide our attention towards the presence of some specific orchestrating actors and channels of knowledge formation marked in the theoretical learning literature, not explored enough.

Considering these distinctive characteristics of project finance and the significant role of learning processes in relation to the new technologies, examining project finance in RET in the context of energy transitions could yield precious data for analysis.

3.3. Data Collection

Primary data was collected by conducting in-depth semi-structured interviews with experts holding high-level, managing position within banks, equity investment structures, state investment banks, Landesbanks (German Regional state Investment Banks), public utilities, and service providers, all involved in shaping project finance for RET (Graph 1). Our sample provides a well-balanced representation of the key actors in the industry: we interviewed 56 participants in total representing 38 unique organisations, in two rounds from late 2017 to beginning of 2019, and from 2019 to early 2020. Given the global nature of renewable energy finance, the financiers included in our sample are part of Germany, Switzerland, the United Kingdom, the Netherlands, and Norway, setting up projects in their countries and in France, Spain and Italy. (listed in Table 1, Appendices).



Graph 1. Interviews sample structure (51 interviews, 56 interviewees, 38 unique organizations)

Part of the data was collected under the INNOPATHS[5] research consortium reaching a rich contact network of relevant private renewable energy financing actors. At the end of each interview session, the interviewees were solicited for their additional unaddressed concerns. This information was systematically integrated into the early stages of subsequent interviews(Eisenhardt, 1989). All interviews were conducted under the "Chatham House Rule". Interviews were conducted until no new information was identified (Eisenhardt & Graebner, 2007).

Data collected under INNOPATHS project brings important insights for the current market situation due to several factors. This includes a period of stability in terms of energy and electricity prices, before the current energy crisis. Furthermore, during this time, the market had started to mature and preceded two critical milestones, the Paris Agreement of 2015 and the Green Deal of 2018, which set the EU and international goals for decarbonizing the energy production sector. As a result, new policies and regulations were implemented to drive the regime change of finance for renewable energy technology and the creation of a specialized finance niche, comprising green mission-oriented banks and state-mandated banks such as Landes Banks and the European Investment Bank.

The main focus of our interviewees is on three RET, solar PVs, onshore wind and offshore wind infrastructure, with the observation that offshore wind, although being technologically close to onshore wind, it seems to differ from on-shore from a financial perspective. Offshore wind did not develop gradually, but instead took off quite suddenly financed on large corporate's balance sheets instead of project finance setups (Higgins & Foley, 2014; Linnerud et al., 2022; Polzin et al., 2019; Voormolen et al., 2016). Previous studies have identified these three technologies as driving the shift in the regime and disrupting the pattern of niche technologies by becoming established closer to incumbent technologies (Geddes & Schmidt, 2020).

One to three researchers either conducted the interviews in person or over the phone and took individual notes during the process (Weston et al., 2001). All the interviews were recorded and the transcriptions were exact verbatim copies. An additional researcher carried out the coding and analysis of the interviews based on the methodology outlined in Section 3.2. The findings were then compared and confirmed with the researchers who gathered the data.

3.4. Data analysis

The study builds on the observation that at the interaction between niches and regimes occurs primarily intensive learning and knowledge diffusion. The coding of the interviews is conducted in two rounds(Deterding & Waters, 2021). The first round uses an inductive approach, following the main elements of project finance and the key drivers of change in the renewable energy technology sector and finance industry, as identified by Egi. el. al. (2018) (Figure 4, appendix). The second round identifies the types of knowledge within project Finance (Figure 2) with the highest recurrence within the interviews which are then matched with the MLP-learning structure and form the primary data analyzed in the results section (Crittenden & Hill, 1971). These knowledge types will be extensively examined within the Results Section, at each level, with a focus on the two learning channels of learning-by-doing and interacting.

The coding elements on the channels of learning are identified on the rationale that knowledge acquisition, diffusion, and improvement were facilitated through internal processes of doing, failing and repeating the process, as well as the use of RET (Hawes, 1972). This led us to categorize such knowledge as closely aligned with the concept of "learning by doing and observing." In contrast, knowledge that was incorporated by financiers through various forms of interaction and

[5] INNOPATHS was a research and innovation programme, project under a European Union's Horizon 2020 grant agreements

communication, as described in the interviews, was classified as closer to the notion of "learning by interacting." (Graph 2).

4. Results

This section reveals that certain types of knowledge (Appendix, Figure 4) are more closely associated with the two specific levels presented by Geels (2007). Figure two presents three distinct flows of knowledge at the regimes interaction level. These includes transferable knowledge from the RET Energy Regime to the Finance Regime such as (10) information about the evolutions of green infrastructure projects and the experience of some technical services providers who successfully transited from the CCGT industry; (11) knowledge on policy and national political dynamics between the 2 sectors; and (13) knowledge on Renewable Energy Technologies (RET) reliability. All three types of knowledge were found to be more relevant at the industry level, particularly with regards to the latest developments in the energy market and the impact on financial markets. For instance, financiers exhibited advanced knowledge about the landscape of technical services providers, which increased their trust and familiarity with RET Project Finance.

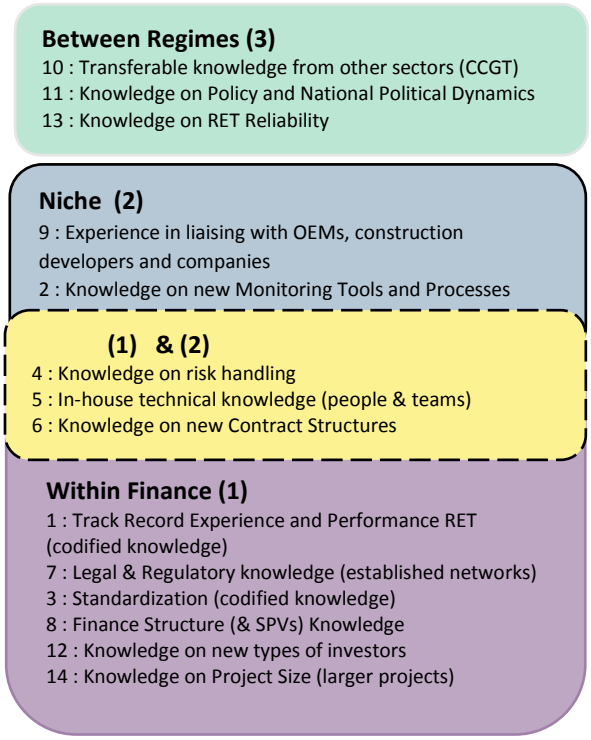


Figure 2. Framework Knowledge and Learning Channels on MLP (boxes numbers 1-3 are linked to the regime - niche interactions mentioned within the conceptual framework, Figure 1; the tickers for each type of knowledge are linked to the bubbles tickers in Graph 2).

Within the niche, this study converges to five knowledge types: two unique to RET developers and three across both levels (Finance regime and RET niche). This includes (9) knowledge gate-kept by Original Equipment Manufacturers (OEMs), construction developers, and companies, and (2) technical information on the use of new software and tools for monitoring and rating the impact of Renewable Energy Technologies. Additionally, there is better curtailment prediction tailored made on each technology (e.g. the ability to calculate Balance of Solar PV system losses (BOS loss) more accurately).

Across both levels we observe (4) knowledge on risk handling, (5) in-house technical knowledge, particularly at the local level, which includes specialized divisions or new hires of engineers or technicians within the finance sector, and (6) knowledge generated through new types of contracting,

particularly multi-party exchanges to set a contract (e.g. Power Purchase Agreements (PPAs), Offtake, Hedge contracts, multi-party or Engineering, Procurement, and Construction (EPC) contracts, Joint Ventures (JV) contracts, and Operation and Maintenance (O&M) contracts etc.)

Finally, this paper points towards six main categories of knowledge within the Finance Regime. These categories refer to the internal capacity of financiers to collect, analyze, and use technical data related to (1) the track record experience and performance of the three RET under analysis, (12) the types of investors involved, and (14) the RET project design and size to make better risk assumptions. Additionally, there is knowledge on *(3) standardization to streamline* the documentation process and create slimmer due diligence.

Furthermore, through intense interaction with (7) legal experts and networks of policy makers, the Finance Regime has created a significant knowledge base on the regulatory framework and the latest policy advancements for the energy finance market. This knowledge could reduce information asymmetries and increase risk prediction before (8) structuring a project finance for specific RET in specific region.

All of the 14 identified knowledge elements will be further discussed in the subsequent sections, where there will be a clear connection s between learning by doing and learning by interacting. The analysis will provide an in-depth exploration of each level of knowledge and present it from the perspective of these two channels of learning (Graph 2).

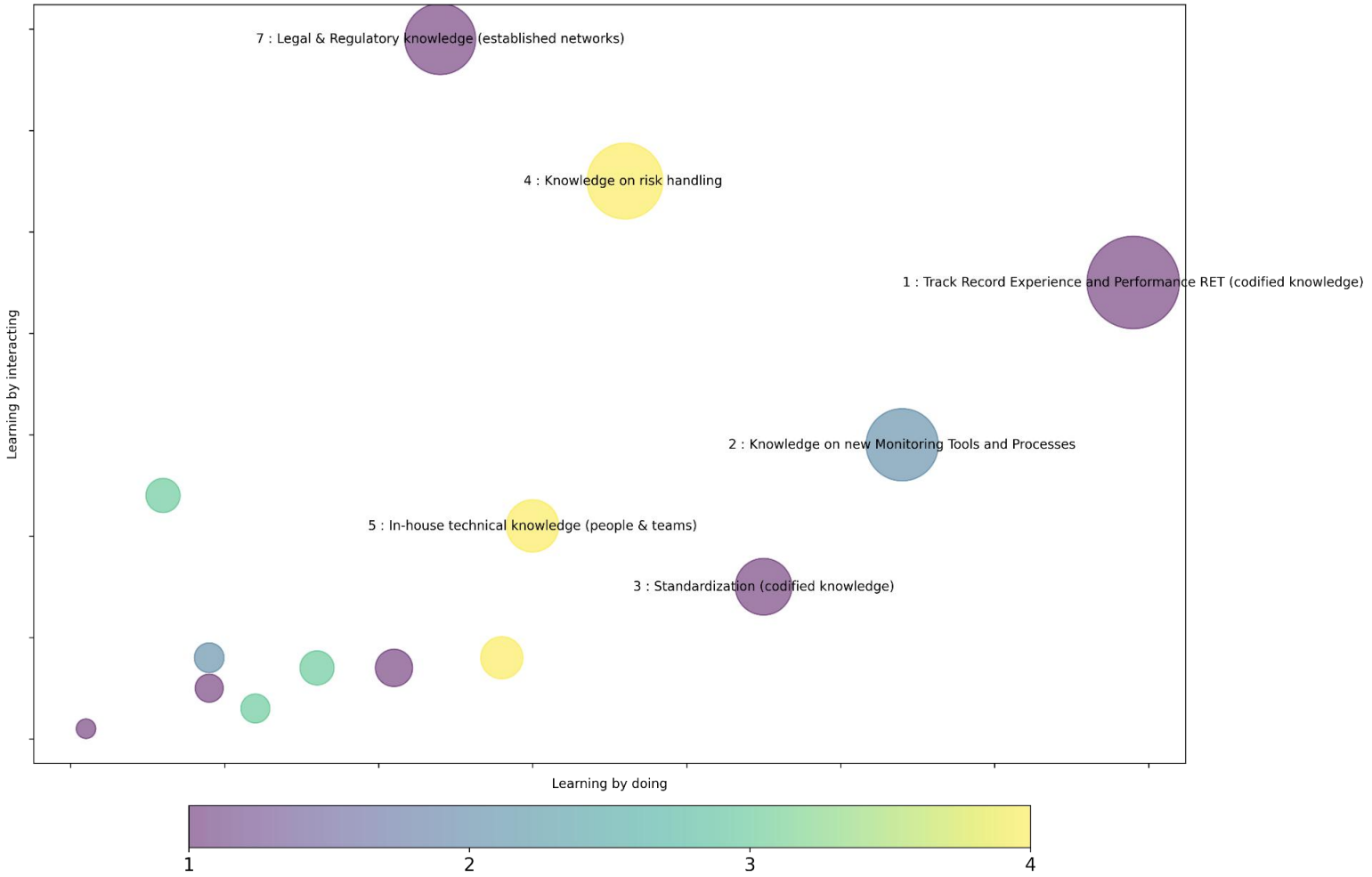
(Below, within each section, to be explained more granular on each type of knowledge – box in Figure 2)

4.1. Learning effects through learning by doing within Finance Regime

Around 80% of the sample discussed the evolution of learning from mistakes in the renewable energy technology (RET) industry, specifically in the context of project financing, with a focus on contract structures, projects' sizes, and projects' lengths. The banking and equity investment sectors have shifted their perspectives on RET project financing due to the technical development of RET asset classes, making it more easier and secured to finance them. One example provided is the offshore wind industry, where general contractors were eventually agreed upon to simplify the financing process after repeating the process with the same pool of finance structurers.

The study identified an intense knowledge development in contract management with multiple parties, reducing time, information asymmetries, and costs of setting them up by designing multiple project finance structures. It was also mentioned that while learning about managing financial flows for RET, the bank's previous requirement for 15-year (financing contract has started to change over time into shorter duration, emphasizing the need of flexibility. The interviewees also mentions that equity investors and banks will be more willing to support bigger and bigger tickets as they 'get comfortable' with, hence learn more on the RET.

Graph 2. Plot Knowledge and Learning Channels on MLP



1. Within Finance Regime; 2. At the Regime - Niche interaction; 3.Between Regimes; 4. Within Finance Regime and at Niche-Regime interaction, as well

One way that financial learning can be facilitated is through large renewable energy funds or new types of finance structures. According to a pension fund investor interviewee, as they are a large investor type they were able to learn about multiple assets through large pure renewable energy funds, particularly those in 2006/2007. By investing in funds, institutional investors have "a way to acquire or to get exposure to smaller assets". This is important as institutional investors generally look to fund large ticket sizes and so these funds enable this investor type to finance these smaller scale technologies without bidding on the individual tickets, the interviewee added. With their large size, this finding shows that institutional investors can access financial learning through multi-asset fund investing. Learning about these assets requires "sitting on the assets", according to the interviewee, which over time allowed the investor to learn "how expensive the vessels are, and what the main causes for the outages" or learn that one "manufacturer is actually worse than the others are". This finding suggests that financial learning was a process that simply required investors to cautiously learn by doing via siting on their investments and processing information in this new market.

Other pool of interviewed institutional investors, from an insurance firm, revealed that partnering with certification companies allowed them to observe and learn about the technologies and their associated potential financial risks without actually investing nor insuring it yet. This insurance investor also revealed that their firm provide risk analysis knowledge from their insurance department to help investors both in and outside their company group to better price the risk of renewable energy assets they've insured in the past, suggesting that insurance companies may have potentially had a role in accelerating the financial learning curve of the current mature technologies of wind and solar.

It is noted that the critical shift was due to the inclusion of experts in RET construction, maintenance, or project design, and the subsequent development of in-house technical capacity in the finance sector. Initially, external teams and technical consultants were hired for risk analysis of the project and RET performance scenario, but later they started building their in-house technical capacity. This interaction is explored further in the next section of results.

The learning by doing effects were strongly visible while using the software provided by their technical peers, for data analysis and RET risk measurement, especially curtailment prediction. It was observed a more pragmatic approach in handling risk. After building technical capacity, financiers acquired knowledge on technical analysis and created codified knowledge (within documents or standardized processes) about RET day-to-day performance (in terms of their reliability, efficiency, and cost-effectiveness over time). From the same sample of interviews, especially with utility companies that recently took the role of financiers, one can distinguish between learning in components versus learning in overall systems. Learning by doing may take place through clusters comprising technologies that have a certain component (for example, batteries attached to onshore windmills or solar PVs) in common, where the learning in one component may affect multiple technology systems

The standardization process was facilitated by the active involvement of a network of legal professionals, including lawyers, legal experts, and policy advisors, as it is furtherly discussed in Section 4.2. However, Finance regime managed to efficiently refine contracting procedures, engaging in a cyclical process of contracting and legal consultation with this network, until an optimal process was achieved.

4.2. Coordination effects through learning by interacting between Finance regime and RET Niche

Within the interview analysis, the coordination effects are examined, showing that this has mitigated the risk of failure within the renewable energy technology (RET) sector, thereby contributing to its transition towards a more stabilized asset class. These effects have been facilitated by means of a learning-by-interaction approach, wherein various stakeholders from the RET niche and finance regime have engaged in the sharing of specific knowledge.

One key channel of interaction is the exchange of knowledge on risk handling. Through interactions between finance stakeholders and RET experts, finance players can gain a better understanding of the risks associated with RET investments and how to manage them effectively. Another important channel is the development of in-house technical knowledge, both at the individual and team levels. RET experts can share their expertise with finance stakeholders, who can in turn use this knowledge to inform their investment decisions. This collaboration led in all interviewed sample to more informed and effective decision-making.

The coordination effects between the finance regime and RET niche also extend to knowledge on new contract structures. By engaging in learning by interacting, finance stakeholders gain insights and knowledge on how to engage with technical experts and into the most effective contract structures for RET investments, contract that are strongly tights to the network involved in the specific RET. In order to avoid this risk, this bank learned to narrow down the amount of contractors that they use by no longer doing "one (contractor) for the foundations and one (contractor) for the turbines, but maybe one of them will do (all of) it (instead)" 5, and then if they are "somehow too late (in delivering their tasks), then I'll just go to them and they'll give me money", and hence responsibility can be allocated better to less contractors. Although "multi-contracting has not been completely abandoned in the offshore wind sector" , this bank has narrowed the amount of contractors from twenty to five. By realizing the problems and costs associated with a very large number of contractors and thereafter learning to solve this issue by reallocating the project task to a smaller number of contractors, the bank was able to decrease the risk of their offshore projects and decrease the financial requirements for their investments.

Experience in liaising with original equipment manufacturers (OEMs), construction developers, and other companies is another knowledge channel through which coordination effects occurred. RET experts shared their experiences with finance stakeholders, helping them to navigate the complex web of relationships that exists within the RET sector, understanding not only the technological characteristics, but also the market.

4.3. Coordination effects through learning by interacting between Finance and RET regimes

The finance sector can learn from technical sectors such as RET, but also through the previous experience that OEMs and O&M companies had with infrastructure from the CCGT(combined cycle gas turbines) sector. The CCGT sector has been successful in using project finance to fund large-scale projects, and the RET finance sector marked knowledge transfers from their experience in structuring deals that provide long-term and low-cost financing similar for RET projects. Additionally, CCGT projects provide valuable insights into project development, construction, and operation of large-scale infrastructure projects that can be applied to RET projects. Nevertheless, the interviews brought no strong evidence in the transfer of knowledge in structuring projects across RET: out of 54 professionals, only 6 mentioned about knowledge spillovers between solar PVs and onshore wind farms, and rejected the hypothesis of shared financial learning on offshore and onshore wind farms, finding more differences in structuring the projects than similarities.

Previous findings are directly linked to the increased knowledge and comprehension of the reliability of renewable energy technology (RET) projects within the market and the systemic potential risks associated with renewable energy production. By having this knowledge, the finance sector can make more informed assessments of the macro risks related to RET financing and create strategies to minimize those risks. It is highlighted the importance of local knowledge and experience in navigating regulations and building markets in new areas, and the need to find win-win situations with national companies.

5. Conclusions

In summary, the study identifies specific types of knowledge that were closely associated with the two levels presented by Geels (2007), namely the Finance Regime and the RET Niche. At the interaction level between these two levels, there are three distinct flows of knowledge, including transferable knowledge from the RET Energy Regime to the Finance Regime such as policy and national political dynamics, knowledge on renewable energy technologies reliability, and information about the evolution of green infrastructure projects. At the industry level, financiers exhibited advanced knowledge about the landscape of technical services providers, which increased their trust and familiarity with RET project finance.

The paper also explains the five types of knowledge that were unique to RET developers and three that were shared across both the Finance Regime and RET Niche levels. These includes knowledge gate-kept by OEMs, construction developers, and companies, technical information on the use of new software and tools for monitoring and rating the impact of Renewable Energy Technologies, better curtailment prediction tailored made on each technology, knowledge on risk handling, in-house technical knowledge, particularly at the local level, and knowledge generated through new types of contracting.

In terms of learning effects, there is observed an evolution of 'learning from mistakes' in the RET industry, specifically in the context of project financing. The study presents an intense knowledge development in contract management with multiple parties, reducing time, information asymmetries, and costs of setting them up by designing multiple project finance structures. Financial learning can be facilitated through large renewable energy funds or new types of finance structures. Institutional investors can access financial learning through multi-asset fund investing. This is a process that simply required investors to cautiously learn by doing via siting on their investments and processing information in this new market.

The aforementioned empirical observations hold significant implications for the theoretical underpinnings of learning in the renewable energy sector. In particular, they highlight the potential for cost reductions associated with learning-by-doing and the spillover effects of knowledge diffusion through learning by collaboration in the industry. The identification of these effects provides a compelling rationale for the deployment of funding aimed at further accelerating the pace of technological progress in the renewable energy industry.

Moreover, the findings offer a promising avenue for reducing the CoC associated with renewable energy projects. As investors become more confident in the long-term prospects of the industry, they are likely to demand a lower risk premium, resulting in a corresponding decrease in CoC. This, in turn, would increase the attractiveness of renewable energy projects, leading to greater deployment and a more rapid transition away from fossil fuels.

Overall, the empirical evidence presented in this study underscores the importance of policy measures aimed at facilitating knowledge diffusion and supporting the growth of the renewable energy industry. By providing a theoretical framework for understanding the mechanisms by which learning and knowledge spillovers operate, policymakers can devise targeted interventions to promote the deployment of renewable energy technologies and accelerate the transition to a low-carbon economy.

References

Adams, J. D. (2006). Learning, internal research, and spillovers. *Economics of Innovation and New Technology*, *15*(1), 5–36. https://doi.org/10.1080/1043859042000332178

Aghion, P., Van Reenen, J., Martin, R., Hémous, D., & Dechezleprêtre, A. (2015). Carbon Taxes, Path Dependency, and DirectedTechnical Change: Evidence from the Auto Industry. *University of Chicago Press*. https://www.tandfonline.com/doi/epdf/10.1080/14693062.2020.1868392?needAccess=true&role=button

Argote, L., & Epple, D. (1990). Learning Curves in Manufacturing. *Science*, *247*(4945), 920–924. https://doi.org/10.1126/science.247.4945.920

Arrow, K. J. (1962). The Economic Implications of Learning by Doing. *The Review of Economic Studies*, *29*(3), 155–173. https://doi.org/10.2307/2295952

Ayoubi, C., Pezzoni, M., & Visentin, F. (2017). At the origins of learning: Absorbing knowledge flows from within the team. *Journal of Economic Behavior & Organization*, *134*, 374–387. https://doi.org/10.1016/j.jebo.2016.12.020

Barazza, E., & Strachan, N. (2021). The key role of historic path-dependency and competitor imitation on the electricity sector low-carbon transition. *Energy Strategy Reviews*, *33*, 100588. https://doi.org/10.1016/j.esr.2020.100588

Barlow, J. (2000). Innovation and learning in complex offshore construction projects. *Research Policy*, *29*(7), 973–989. https://doi.org/10.1016/S0048-7333(00)00115-3

Blanchard, O. J., Gollier, C., & Tirole, J. (2022). *The Portfolio of Economic Policies Needed to Fight Climate Change* (SSRN Scholarly Paper No. 4276886). https://doi.org/10.2139/ssrn.4276886

Botsch, M., & Vanasco, V. (2019). Learning by lending. *Journal of Financial Intermediation*, *37*, 1–14. https://doi.org/10.1016/j.jfi.2018.03.002

Campbell, J. Y. (2014). *Empirical Asset Pricing: Eugene Fama, Lars Peter Hansen, and Robert Shiller*.

Carbone, S., Giuzio, M., Kapadia, S., Krämer, J. S., Nyholm, K., & Vozian, K. (2021). The Low-Carbon Transition, Climate Commitments and Firm Credit Risk. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3991358

Carraro, C., Gerlagh, R., & Zwaan, B. van der. (2003). Endogenous technical change in environmental macroeconomics. *Resource and Energy Economics*, *25*(1), 1–10. https://doi.org/10.1016/S0928-7655(02)00016-7

Corradini, C., & D'Ippolito, B. (2022). Persistence and learning effects in design innovation: Evidence from panel data. *Research Policy*, *51*(2), 104452. https://doi.org/10.1016/j.respol.2021.104452

Crittenden, K. S., & Hill, R. J. (1971). Coding Reliability and Validity of Interview Data. *American Sociological Review*, *36*(6), 1073–1080. https://doi.org/10.2307/2093766

Degryse, H., Kokas, S., & Minetti, R. (2022). *Banking on Experience* (SSRN Scholarly Paper No. 4224476). https://doi.org/10.2139/ssrn.4224476

Deterding, N. M., & Waters, M. C. (2021). Flexible Coding of In-depth Interviews: A Twenty-first-century Approach. *Sociological Methods & Research*, *50*(2), 708–739. https://doi.org/10.1177/0049124118799377

Dirk Schoenmaker. (2021). Greening monetary policy. *Climate Policy*, *21*(4), 581–592.

Dutton, J. M., & Thomas, A. (1984). Treating Progress Functions as a Managerial Opportunity. *The Academy of Management Review*, *9*(2), 235–247. https://doi.org/10.2307/258437

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. https://doi.org/10.1088/1748-9326/ac6ada

Egli, F., Steffen, B., & Schmidt, T. S. (2018). A dynamic analysis of financing conditions for renewable energy technologies. *Nature Energy*, *3*(12), Article 12. https://doi.org/10.1038/s41560-018-0277-y

Egli, F., Steffen, B., & Schmidt, T. S. (2019). Learning in the financial sector is essential for reducing renewable energy costs. *Nature Energy*, *4*(10), Article 10. https://doi.org/10.1038/s41560-019-0482-3

Eisenhardt, K. M. (1989). Building Theories from Case Study Research. *Academy of Management Review*, *14*(4), 532–550. https://doi.org/10.5465/amr.1989.4308385

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory Building from Cases: Opportunities and Challenges. *The Academy of Management Journal*, *50*(1), 25–32.

Figueiredo, P. N., Larsen, H., & Hansen, U. E. (2020). The role of interactive learning in innovation capability building in multinational subsidiaries: A micro-level study of biotechnology in Brazil. *Research Policy*, *49*(6), 103995. https://doi.org/10.1016/j.respol.2020.103995

Fu, W., Revilla Diez, J., & Schiller, D. (2013a). Interactive learning, informal networks and innovation: Evidence from electronics firm survey in the Pearl River Delta, China. *Research Policy*, *42*(3), 635–646. https://doi.org/10.1016/j.respol.2012.09.006

Fu, W., Revilla Diez, J., & Schiller, D. (2013b). Interactive learning, informal networks and innovation: Evidence from electronics firm survey in the Pearl River Delta, China. *Research Policy*, *42*(3), 635–646. https://doi.org/10.1016/j.respol.2012.09.006

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. https://doi.org/10.1016/j.respol.2020.103985

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. https://doi.org/10.1016/j.enpol.2018.01.009

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. https://doi.org/10.1016/j.eist.2012.11.004

Geels, F. W. (2014). Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective. *Theory, Culture & Society*, *31*(5), 21–40. https://doi.org/10.1177/0263276414531627

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy*, *36*(3), 399–417. https://doi.org/10.1016/j.respol.2007.01.003

Hafner, S., James, O., & Jones, A. (2019). A Scoping Review of Barriers to Investment in Climate Change Solutions. *Sustainability*, *11*(11), 3201. https://doi.org/10.3390/su11113201

Hafner, S., Jones, A., Anger-Kraavi, A., & Pohl, J. (2020). Closing the green finance gap – A systems perspective. *Environmental Innovation and Societal Transitions*, *34*, 26–60. https://doi.org/10.1016/j.eist.2019.11.007

Hall, S., Foxon, T., & Bolton, R. (2017). Investing in low carbon transitions: Energy finance as an adaptive market. *Climate Policy*, *17*(3), 280–298. https://doi.org/10.1080/14693062.2015.1094731

Hawes, L. C. (1972). Development and application of an interview coding system. *Central States Speech Journal*, *23*(2), 92–99. https://doi.org/10.1080/10510977209363101

Hewitt-Dundas, N., Gkypali, A., & Roper, S. (2019). Does learning from prior collaboration help firms to overcome the 'two-worlds' paradox in university-business

collaboration? *Research Policy*, *48*(5), 1310–1322. https://doi.org/10.1016/j.respol.2019.01.016

Higgins, P., & Foley, A. (2014). The evolution of offshore wind power in the United Kingdom. *Renewable and Sustainable Energy Reviews*, *37*, 599–612. https://doi.org/10.1016/j.rser.2014.05.058

Huenteler, J., Niebuhr, C., & Schmidt, T. S. (2016). The effect of local and global learning on the cost of renewable energy in developing countries. *Journal of Cleaner Production*, *128*, 6–21. https://doi.org/10.1016/j.jclepro.2014.06.056

International Energy Agency. (2022a). *World Energy Outlook 2022*. https://iea.blob.core.windows.net/assets/c282400e-00b0-4edf-9a8e-6f2ca6536ec8/WorldEnergyOutlook2022.pdf

International Energy Agency. (2022b). *Renewable Electricity – Analysis*. https://www.iea.org/reports/renewable-electricity

Jensen, M. B., Johnson, B., Lorenz, E., & Lundvall, B. Å. (2007). Forms of knowledge and modes of innovation. *Research Policy*, *36*(5), 680–693. https://doi.org/10.1016/j.respol.2007.01.006

Jiang, S., & Li, J. Y. (2022). He who lends knows. *Journal of Banking & Finance*, *138*, 106412. https://doi.org/10.1016/j.jbankfin.2022.106412

Karltorp, K. (2016). Challenges in mobilising financial resources for renewable energy—The cases of biomass gasification and offshore wind power. *Environmental Innovation and Societal Transitions*, *19*, 96–110. https://doi.org/10.1016/j.eist.2015.10.002

Klaaßen, L., & Steffen, B. (2023). Meta-analysis on necessary investment shifts to reach net zero pathways in Europe. *Nature Climate Change*, *13*(1), Article 1. https://doi.org/10.1038/s41558-022-01549-5

Knuth, S. (2018). “Breakthroughs” for a green economy? Financialization and clean energy transition. *Energy Research & Social Science*, *41*, 220–229. https://doi.org/10.1016/j.erss.2018.04.024

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., … Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation and Societal Transitions*, *31*, 1–32. https://doi.org/10.1016/j.eist.2019.01.004

Lee, Y.-N., & Walsh, J. P. (2016). Inventing while you work: Knowledge, non-R&D learning and innovation. *Research Policy*, *45*(1), 345–359. https://doi.org/10.1016/j.respol.2015.09.009

Lindman, Å., & Söderholm, P. (2012). Wind power learning rates: A conceptual review and meta-analysis. *Energy Economics*, *34*(3), 754–761. https://doi.org/10.1016/j.eneco.2011.05.007

Linnerud, K., Dugstad, A., & Rygg, B. J. (2022). Do people prefer offshore to onshore wind energy? The role of ownership and intended use. *Renewable and Sustainable Energy Reviews*, *168*, 112732. https://doi.org/10.1016/j.rser.2022.112732

Lo, A. (2004). *The Adaptive Markets Hypothesis: Market Efficiency from an Evolutionary Perspective*.

Loorbach, D. A., & Lijnis Huffenreuter, R. (2013). Exploring the economic crisis from a transition management perspective. *Environmental Innovation and Societal Transitions*, *6*, 35–46. https://doi.org/10.1016/j.eist.2013.01.003

Malerba, F. (1992). Learning by Firms and Incremental Technical Change. *The Economic Journal*, *102*(413), 845–859. https://doi.org/10.2307/2234581

Matsuo, T. (2019). Fostering grid-connected solar energy in emerging markets: The role of learning spillovers. *Energy Research & Social Science*, *57*, 101227. https://doi.org/10.1016/j.erss.2019.101227

May, N., & Neuhoff, K. (2017). *Financing Power: Impacts of Energy Policies in Changing Regulatory Environments* (SSRN Scholarly Paper No. 3046516). https://doi.org/10.2139/ssrn.3046516

Mulder, P., de Groot, H. L. F., & Hofkes, M. W. (2003). Explaining slow diffusion of energy-saving technologies; a vintage model with returns to diversity and learning-by-using. *Resource and Energy Economics*, *25*(1), 105–126. https://doi.org/10.1016/S0928-7655(02)00019-2

Naidoo, C. P. (2020). Relating financial systems to sustainability transitions: Challenges, demands and design features. *Environmental Innovation and Societal Transitions*, *36*, 270–290. https://doi.org/10.1016/j.eist.2019.10.004

Owen, R., Brennan, G., & Lyon, F. (2018). Enabling investment for the transition to a low carbon economy: Government policy to finance early stage green innovation. *Current Opinion in Environmental Sustainability*, *31*, 137–145. https://doi.org/10.1016/j.cosust.2018.03.004

Polzin, F., Egli, F., Steffen, B., & Schmidt, T. S. (2019). How do policies mobilize private finance for renewable energy?—A systematic review with an investor perspective. *Applied Energy*, *236*, 1249–1268. https://doi.org/10.1016/j.apenergy.2018.11.098

Polzin, F., & Sanders, M. (2020). How to finance the transition to low-carbon energy in Europe? *Energy Policy*, *147*, 111863. https://doi.org/10.1016/j.enpol.2020.111863

Prencipe, A., & Tell, F. (2001). Inter-project learning: Processes and outcomes of knowledge codification in project-based firms. *Research Policy*, *30*(9), 1373–1394. https://doi.org/10.1016/S0048-7333(01)00157-3

Schmidt, T. S., Steffen, B., Egli, F., Pahle, M., Tietjen, O., & Edenhofer, O. (2019). Adverse effects of rising interest rates on sustainable energy transitions. *Nature Sustainability*, *2*(9), Article 9. https://doi.org/10.1038/s41893-019-0375-2

Seebregts, A., Kram, T., Schaeffer, G. J., & Bos, A. (2000). Endogenous learning and technology clustering: Analysis with MARKAL model of the Western European energy system. *International Journal of Global Energy Issues*, *14*(1–4), 289–319. https://doi.org/10.1504/IJGEI.2000.004430

Steffen, B. (2018). The importance of project finance for renewable energy projects. *Energy Economics*, *69*, 280–294. https://doi.org/10.1016/j.eneco.2017.11.006

Steffen, B., & Schmidt, T. S. (2021). Strengthen finance in sustainability transitions research. *Environmental Innovation and Societal Transitions*, *41*, 77–80. https://doi.org/10.1016/j.eist.2021.10.018

Sweerts, B., Detz, R. J., & van der Zwaan, B. (2020). Evaluating the Role of Unit Size in Learning-by-Doing of Energy Technologies. *Joule*, *4*(5), 967–970. https://doi.org/10.1016/j.joule.2020.03.010

Thompson, P. (2010). Chapter 10—Learning by Doing. In B. H. Hall & N. Rosenberg (Eds.), *Handbook of the Economics of Innovation* (Vol. 1, pp. 429–476). North-Holland. https://doi.org/10.1016/S0169-7218(10)01010-5

Truffer, B., Rohracher, H., Kivimaa, P., Raven, R., Alkemade, F., Carvalho, L., & Feola, G. (2022). A perspective on the future of sustainability transitions research. *Environmental Innovation and Societal Transitions*, *42*, 331–339. https://doi.org/10.1016/j.eist.2022.01.006

Tubiana, M., Miguelez, E., & Moreno, R. (2022). In knowledge we trust: Learning-by-interacting and the productivity of inventors. *Research Policy*, *51*(1), 104388. https://doi.org/10.1016/j.respol.2021.104388

van der Wouden, F., & Youn, H. (2023). The impact of geographical distance on learning through collaboration. *Research Policy*, *52*(2), 104698. https://doi.org/10.1016/j.respol.2022.104698

van der Zwaan, B., & Seebregts, A. (2004). Endogenous learning in climate-energy-economic models – an inventory of key uncertainties. *International Journal of Energy Technology and Policy*, *2*(1–2), 130–141. https://doi.org/10.1504/IJETP.2004.004591

von Hippel, E., & Tyre, M. J. (1995). How learning by doing is done: Problem identification in novel process equipment. *Research Policy*, *24*(1), 1–12. https://doi.org/10.1016/0048-7333(93)00747-H

Voormolen, J. A., Junginger, H. M., & van Sark, W. G. J. H. M. (2016). Unravelling historical cost developments of offshore wind energy in Europe. *Energy Policy*, *88*, 435–444. https://doi.org/10.1016/j.enpol.2015.10.047

Weston, C., Gandell, T., Beauchamp, J., McAlpine, L., Wiseman, C., & Beauchamp, C. (2001). Analyzing Interview Data: The Development and Evolution of a Coding System. *Qualitative Sociology*.

Neuhoff, K. Large-scale deployment of renewables for electricity generation. Oxford Rev. Econ. Policy 21, 88–110 (2005)

Hall, S., Foxon, T. J. & Bolton, R. Investing in low-carbon transitions: energy finance as an adaptive market. Clim. Policy 17, 280–298 (2017).

Best, R. Switching towards coal or renewable energy? The effects of financial capital on energy transitions. Energy Econ. 63, 75–83 (2017).

Esty, B. C. (2004). Why Study Large Projects? An Introduction to Research on Project Finance. European Financial Management, 10(2), 213–224. https://doi.org/10.1111/j.1354-7798.2004.00247.x

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. https://doi.org/10.1016/j.respol.2020.103985

Ellsberg, D. (1961). Risk, ambiguity, and the Savage axioms. The Quarterly Journal of Economics, 75(4), 643-669. https://doi.org/10.2307/1884324

Jiménez, G., Ongena, S., Peydró, J. L. & Saurina, J. Credit supply and monetary policy: Identifying the bank balance-sheet channel with loan applications. Am. Econ. Rev. 102, 2301–2326 (2012)

Sagar, A. D., & van der Zwaan, B. (2006). Technological innovation in the energy sector: R&D, deployment, and learning-by-doing. Energy Policy, 34(17), 2601–2608. https://doi.org/10.1016/j.enpol.2005.04.012

Rubin, E. S., Azevedo, I. M. L., Jaramillo, P. & Yeh, S. A review of learning rates for electricity supply technologies. Energy Policy 86, 198–218 (2015).

Trancik, J. et. al. Technology Improvement and Emissions Reductions as Mutually Reinforcing Efforts: Observations from the Global Development of Solar and Wind Energy (MIT, 2015).

Krupa, J., Poudineh, R., Harvey, L.D.D., 2019. Renewable electricity finance in the resource-rich countries of the Middle East and North Africa: A case study on the Gulf Cooperation Council. Energy 166, 1047–1062. http://dx.doi.org/ 10.1016/j.energy.2018.10.106.

Fama, E. F. (1970). Efficient capital markets: A review of theory and empirical work. The journal of Finance, 25(2), 383-417.

Appendices

Table 1. Overview interviewees Project Finance for RET

Position	Eperience RET Finance	Type of Organisation	Country of origin	Country of operantions in RET Finance
Associate Director Global Infrastructure Debt	2013	Bank	UK	UK
Head of Project Finance Origination Renewable Energies	2010	Bank	DE	DE, IT, UK, ES
Vice President	1990	Bank	DE	DE, IT, UK
Vice President	2004	Bank	DE	DE, IT, UK
Head of the Renewable Energies department	1995	Bank	DE	DE, UK, DK, ES
Structurer Finance Renewable Energy	1999	Bank	DE	DE, IT, UK
Director Structured Finance Power & Renewables	2007	Bank	NL	NL, IT, UK
Director Structured Finance Utilities, Power & Renewables	2007	Bank	NL	NL, DE, IT, UK
Director Project & Structured Finance Utilities, Power and Renewables	2007	Bank	IT	IT
Director Project & Structured Finance Utilities, Power and Renewables	2007	Bank	NL	NL, DE, IT, UK
N/A	1996	Bank	NL	NL, DE, UK, FR, FI, SE, NO
Project & Acquisition Finance	2006	Bank	UK	DE, IT, UK
Director Corporate Strategy	1999	Bank	NL	NL, DE, UK
N/A	1989	Bank	NL	NL, DE, UK,ES, BE, non-EU
Head of Sustainable Energy and Green Infrastructure	1995	Bank	UK	UK, NL
Bank Director		Bank	UK	UK,NL
Project Financing Lead	2007	Bank	DE	DE
Associate Director Project Finance & Capital Advisory	2011	Bank	DE	DE, IT, UK
Associate Director	2009	Bank	DE	DE, IT, UK
Head of Finance (CEE Region)	2010	Bank	DE	DE, IT, UK
Head of Finance	1990	Bank	DE	DE, IT, UK
N/A	2005	Equity advisor	DE	DE, IT, UK
Head Risk Advisory	2005	Equity advisor	DE	DE, IT, UK
Investments Director	2006	Equity investor	UK	UK
Director	2006	Equity investor	DE	DE, IT, UK
Investment Partner	2003	Equity investor	UK	CH, FR, SE, UK, FI, ES
Founding Partner	2000	Equity investor	CH	CH
Associate	2000	Equity investor	UK	DE, IT, UK
Associate Director	2006	Equity	FR	DE, ES, UK

		investor		
Senior Investment Manager		Equity investor	NOR	NOR, DE, CEE
N/A	2005	Equity investor	DK	DK, UK, DE, NL
CEO and Founder	2016	Equity investor	DE	DE, IT
CEO	2016	Equity investor	DE	DE IT
Finance Director	2013	Equity investor	CH	CH, DE, IT, UK,FR
Finance Partner	2009	Equity investor	CH	CH, DE, IT, UK
N/A	2000	Equity investor	CH	CH, non-EU
N/A		Equity investor	NL	NL, FI, ES, UK
N/A		Equity investor	UK	UK
Vice President Renewables	2015	Equity investor	CH	CH, DE, IT, UK, SE, NO
Vice President Corporates & Mittelstand Project Finance	2007	Landesbank	DE	DE, UK, FR, ES
Vice President Corporates & Mittelstand Project Finance	2007	Landesbank	DE	DE, IT, UK
Head of Renewable Energies	1991	Landesbank	DE	DE, IT
Director Energy & Utilities	2006	Landesbank	DE	DE, IT, UK
Director Energy & Utilities	2006	Landesbank	DE	DE
Executive Director	1997	Landesbank	DE	DE, IT
Executive Director	N/A	Landesbank	DE	DE
CEO	2010	Public utility	CH	CH, DE, FR, ES
Head of Energy System	2006	Public utility	CH	CH, DE, IT
Deputy Head of Energy	2015	Public utility	CH	CH,DE,IT
CEO	2011	Public utility	CH	CH, DE, IT
Founder	2013	Service provider	DE	DE
N/A	N/A	Service Provider	DK	NO, UK, NL, BE
CEO	2008	Service provider	DE	DE, UK
Economist	2003	SIB	LUX	DE, IT, FR, UK, CEE
Economist	1989	SIB	LUX	DE, IT, FR, UK, CEE
Vice President	2012	SIB	DE	DE, IT, FR, UK, CEE

Appendix

Graph 2. Plot of Knowledge and Learning Channels [Dynamic version here](scatter_plot2.html)

Figure 3. Heat map Inductive coding - all coded tags over their own based on codes recurrency in the interviews text [Dynamic version here](CodesOverCodes.html),

Figure 4. Coding Book (attached) coding book_definitions.xlsx

Figure 5. Knowledge on Technologies (based on code recurrence within interviews)