Thesis Report

"Addressing complexity in Energy Transition projects"

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“HOW CAN COMPLEXITIES IN ENERGY TRANSITION PROJECTS BE EFFECTIVELY ADDRESSED?”

An Exploratory study

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PREFACE

This thesis marks the culmination of my two-year journey in the Master of Construction Management and Engineering at TU Delft. When I moved to the Netherlands in 2021 to pursue this master's degree, I was just a naïve girl, unaware of the experiences I would have in this place and the person I would become. Much of this development occurred during my thesis journey, and I am thankful for the wonderful people I met during the course of this master's program.

I am beyond grateful to my graduation committee for their constant support and critical feedback that shaped this thesis. To Prof. Marleen Hermans, my chair, I am grateful for setting the initial stage of my thesis. The critical feedback from her during my Kick-off meeting significantly influenced the trajectory of my thesis. To Yirang Lim, my first supervisor, I am thankful for the immense patience and understanding she showed during our meetings while I was finding my true footing in my thesis. To Leonie Koops, my second supervisor, I am immensely grateful for broadening my thinking and making me consider perspectives I never knew were possible. Her guidance helped me understand the value of my work, even when I didn't realize it myself.

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Last but not least, to my *Amma*, without whose unwavering support I would not be here. Her constant display of strength and resilience in the face of adversity taught me to persevere through some of the most challenging times of my life during this thesis. Thus, I owe and dedicate this thesis, a reflection of the person I have become, to her.

EXECUTIVE SUMMARY

INTRODUCTION

The main aim for this thesis stemmed from the global imperative to combat climate change, which necessitates a transformative shift in energy systems, aligning with objectives like the Paris Agreement's 2050 goals (EU-Commission, 2021). This research pivoted on a critical observation: the underperformance of energy transition projects relative to the ambitious targets set for achieving this energy transformation (Jalali Sohi et al., 2021; Kaldellis & Kapsali, 2013; Pegels & Lütkenhorst, 2014; Wassermann et al., 2015). Furthermore, Bosch-Rekveldt (2011) identified a strong negative correlation between project performance and complexity. This raised a fundamental question: Why aren't energy transition projects, which bear similarities to conventional energy projects, effectively managed by existing approaches?

Consequently, Toonen (2022) identified various differences between energy transition projects and conventional energy projects, mainly related to **'Novelty', 'Business Case', 'New and different Relationships', 'Time Pressure',** and **'Subsidy Component'**. These insights shaped the research problem: The slow progress of Energy transition projects could be attributed to the existing management approaches not adequately taking these distinctive features into account when managing their complexity.

In order to address this gap, the following main and sub-research question were formulated:

"How can complexities in energy transition projects be effectively addressed?"

Sub-research questions:

1. What are complexities in the context of energy transition projects?
2. What are the existing project management approaches to address complexity?
3. How is the management of complexities currently practiced in energy transition projects?
4. What are the challenges and opportunities when managing complexities in energy transition
5. projects?
6. What adaptations in project management approaches are needed to address the complexities of energy transition projects?

METHODOLOGY

This thesis was conducted in collaboration with Fluor B.V., a global engineering and construction firm, providing a real-world context to explore and apply these findings. The study was conducted in three phases, the first phase included a literature study to establish the theoretical foundation, then the second phase included an empirical study with semi-structured interviews with practitioners from Fluor B.V. The semi-structured interviews encompassed a total of 18 interviews with 9 project managers who then referred to various other roles such as project controls, contract managers, sales managers, engineering manager, process director and a client (9 interviews in second round). The last phase included thematic analysis of these findings to identify common themes and patterns to effectively answer the research questions.

RESULTS

COMPLEXITIES IN ENERGY TRANSITION PROJECTS

The literature study, led by insights from Kian Manesh Rad et al. (2017), established a foundational understanding of complexities in energy-related projects. These complexities encompass various aspects related to both the internal and external environments of projects. Internally, these complexities include **objectives**, **technical** aspects, **capital resources**, **disciplines**, **people**, **physical resources**, **information**, **time**, **tasks**, and **tools & methods**. Externally, they extend to the **economy**, **environment**, **legal & regulations**, **politics**, and **social** aspects. This theoretical background provided a comprehensive view of the typical complexities encountered in energy projects, laying the groundwork for further exploration and analysis.

In contrast, the empirical study, which involved semi-structured interviews with 18 practitioners, delved deeper into the specific complexities inherent to energy transition projects. It identified six major themes: **people**, **technology**, **financial**, **resources**, **legal & regulations**, and **project management & execution methods**. This empirical approach not only validated some of the complexities highlighted in the literature but also uncovered complexities specific to energy transition projects.

When comparing the findings from the literature with the empirical study, several key distinctions and similarities emerged:

People: The literature on energy projects typically covers general complexities related to stakeholder management and team dynamics. In contrast, the empirical study sheds light on specific complexities in energy transition projects. These include the **diversity of client types**, each with **distinct drivers** for investing in these projects, the **novelty of participants** which leads to **unclear project objectives**, and a prevalent **deficiency in experience and trust** between the various parties involved (such as client and contractor). These findings pointed towards the need for a more proactive and adaptive approach in managing stakeholders in the context of energy transition projects.

Technology: When examining the technological complexities within energy transition projects, the findings from the literature review and empirical studies show that both conventional and energy transition projects share certain complexities, such as dealing with a wide variety of technologies which leads to a broader scope. Additionally, both types of projects must contend with the ongoing evolution of technology, necessitating that project managers and technical teams remain up-to-date and prepared to implement changes. However, energy transition projects present unique complexities not typically encountered in conventional energy projects, as identified from the empirical study. These include **lack of ownership of new technologies**, creating a dependency on external parties such as licensors. The technologies themselves are often **novel** to both the market and the implementing organizations, significantly increasing the risk and requiring specialized knowledge. Furthermore, energy transition projects need **to integrate these new technologies into existing facilities**, which might not have been originally designed to accommodate them and manage the **high degree of interconnectedness** between technologies.

Financial: In the domain of financial complexities, both literature and empirical studies have recognized general financial constraints such as a variety of investors, and financial resources as a common complexity between energy transition projects and conventional energy projects. Yet, the empirical study emphasizes a distinct shift in the financial dynamics of energy transition projects. These projects have shown a notable **dependency on external funding** sources, necessitating agile financial planning and a more flexible approach to address **financial uncertainties**. This shift is particularly pronounced in the way energy transition projects are structured financially, with a stronger **reliance on offtake agreements** to ensure the viability of the business case. Practitioners noted that such agreements are crucial as they often determine the project's financial viability by guaranteeing a market for the energy produced, thereby treating these ventures more as marketable products with defined buyers rather than traditional projects.

Resources: The literature on resource complexities in energy projects broadly addresses the availability of human resources, while the empirical study emphasizes the availability of specifically **skilled human resources**, underlining the critical need for expertise in energy transition projects. Moreover, the empirical study brings to light additional complexities, such as matching **demand with capacity**, meeting **precise technological resource requirements**, and navigating a **dynamic supply chain market**.

Legal & regulations: The empirical study has uncovered a particularly **dynamic and complex legal and regulatory landscape** for energy transition projects, which stands in contrast to the more defined and stable frameworks associated with conventional energy projects. This complexity is compounded when projects span multiple locations, each with its own set of regulations, thereby multiplying the legal considerations that need careful navigation. Furthermore, both the literature and empirical findings converge on the point that local laws and regulations bring about their own set of challenges. Specifically, in the Netherlands, the complexities of the permitting process and stringent environmental regulations are common hurdles for both traditional and energy transition projects. Political influence also emerged as a shared complexity, affecting project outcomes in both contexts.

Project management & execution methods: In the realm of energy projects, the literature acknowledges complexities related to the variety and applicability of project management methods and tools, as well as the unpredictability and dependencies among tasks. However, empirical findings reveal more specific complexities associated with energy transition projects. These include a range of **interdependencies between different business verticals**, driven by the evolving business case that necessitates collaboration across these business lines. The empirical data also underscores the **diversity in work approaches and terminologies**, especially when participants from various industry backgrounds, such as the oil & gas and power sectors, come together. This situation calls for the seamless integration of practices and knowledge from different sectors. In addition, both literature and empirical findings recognize the interdependence between tasks. Yet, empirical insights reveal that the time-sensitive nature of energy transition projects often leads to tasks being carried out concurrently, thereby amplifying their interdependence.

In conclusion, the empirical study provided a deeper understanding of the complexities inherent to energy transition projects when compared to conventional energy projects, revealing aspects that go beyond the general complexities discussed in the literature. This enhanced understanding is crucial for developing more effective strategies and approaches tailored to the specific complexities of energy transition projects to catalyse the progress of these projects.

Management approaches employed in energy transition projects

The literature identifies three primary approaches to managing project complexity: **Control-oriented**, **Hands-off**, and **Combined** (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011). The empirical study observed a significant **shift in management styles** in energy transition projects, compared to conventional energy projects. While the latter tend to favour a Control-oriented approach, attributed to their high level of predictability and thereby aligning with project success, energy transition projects were found to increasingly adopt a Hands-off and Combined approach. This shift includes a specific focus on the front-end development phase to establish clear and achievable objectives. It also emphasizes early and proactive engagement of a wide range of stakeholders, from clients and technology experts to permitting authorities, venture capitalists, key supply chain parties, and management consultants. Such engagement was deemed crucial for ensuring alignment and informed decision-making throughout the project lifecycle. Furthermore, management approaches in energy transition projects were found to incorporate more agile methodologies. This change is driven by the need to accelerate processes due to time pressures and to introduce greater flexibility in project execution. The less predictable and dynamic nature of energy transition projects necessitates this adaptability and flexibility. Therefore, traditional Control-oriented approaches were found to be too rigid for these projects.

CHALLENGES, OPPORTUNITIES & LESSONS LEARNED

This study also identified specific challenges encountered by practitioners when managing the complexities through the empirical study. A prominent challenge was to prevent **micromanagement** by the client, which necessitates maintaining the right level of oversight without hampering the contractor's ability to innovate and remain agile. Another significant challenge faced by both clients and contractors was balancing the need for **control** (over key elements like scope, time, and cost) with the flexibility required in the dynamic setting of energy transition projects. Particularly on the client's side, a hurdle observed was in overcoming the traditional **engineer's mindset**, which often focuses on constant technological optimization, sometimes to the extent of sacrificing the schedule and cost constraints. Additionally, managing **unrealistic expectations** set by clients on contractors regarding timelines and schedules, coupled with an optimism bias, was a notable challenge. This issue was evident both in clients' overestimation of their engineering capabilities and in contractors' eagerness to secure a market share in these projects.

However, the study also sheds light on numerous opportunities amidst these challenges. These include the development of **innovative solutions** and **business models**, fostering **collaboration with new clients** and stakeholders, and **rethinking traditional project management methods** to suit the dynamic nature of energy transition projects more effectively. Additionally, the research highlights a learning curve for practitioners, emphasizing the importance of dedicating **more time and resources to the front-end development phase**. This approach not only strengthens client relationships but also mitigates risks that could cause delays later. Moreover, practitioners have learned the significance of **engaging various stakeholders early** in the project, such as technology experts and supply chain parties, to integrate their expertise during the initial planning phase, thereby accelerating the project's later stages.

A GUIDING CHECKLIST TO ADDRESS AND NAVIGATE THE COMPLEXITIES IN ENERGY TRANSITION PROJECTS

Based on the insights gathered from the empirical study, a seven-step checklist has been developed to effectively address and navigate the complexities in energy transition projects, facilitating their progression toward execution, as shown in Figure 1. This checklist offers a holistic and structured approach, considering the various facets of energy transition projects and their interdependencies. The **first** checkpoint in the checklist involves the assessment of clients and the integration of embedded teams. This step is about understanding client needs and ensuring that project teams are effectively aligned and integrated. The **second** checkpoint focuses on technology assessment and financial feasibility, evaluating the viability of technological solutions in conjunction with their financial implications.

The **third** checkpoint addresses the interface between financial, legal & regulatory, and resource aspects, utilizing data and change management strategies. This checkpoint is critical in ensuring that these interconnected facets are managed effectively. The **fourth** checkpoint includes navigating the financial aspects of the project, managing the dependency on external funding sources, requirements for subsidies, and the estimation process. Legal and regulatory compliance encompasses the **fifth** checkpoint, emphasizing the need to adhere and adapt to current and evolving legal standards and regulations. The **sixth** checkpoint calls for effective and early resource management, ensuring that both human and material resources are aligned with project needs from the outset.

Lastly, the **seventh** and final checkpoint involves tailoring execution methods specifically for energy transition projects. This checkpoint is crucial in ensuring that the execution methods are scaled and suited for each type of energy transition project.

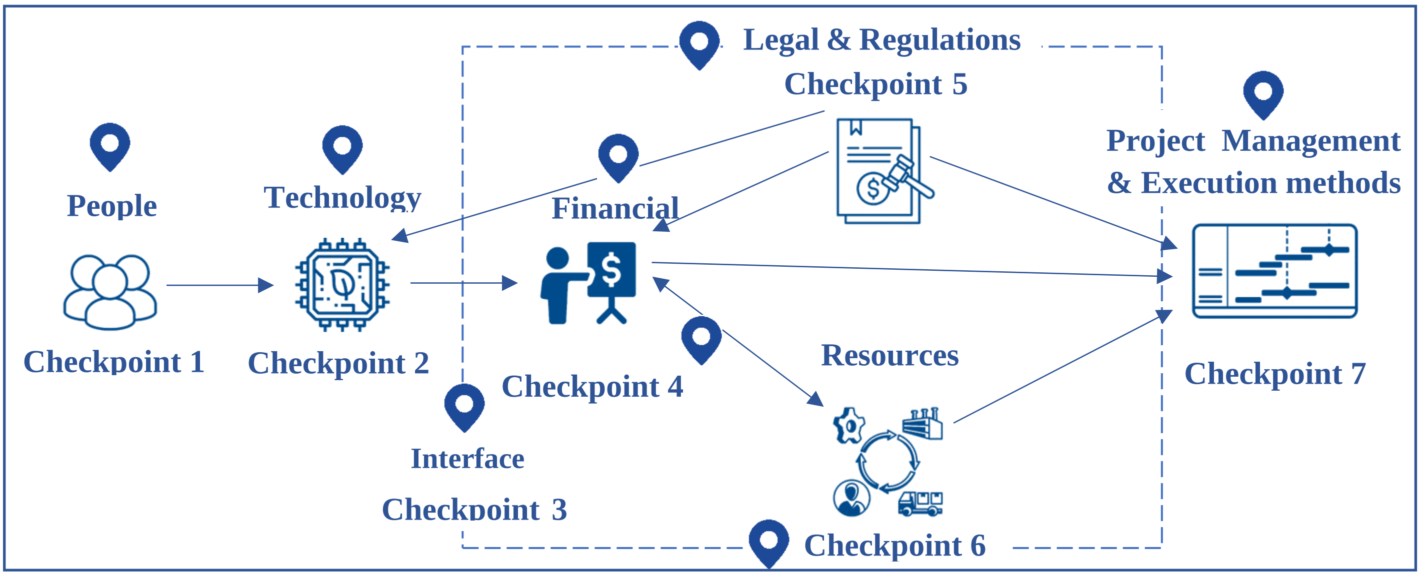

FIGURE 1: SEVEN CHECKPOINTS TO ADDRESS AND NAVIGATE THE COMPLEXITIES IN ENERGY TRANSITION PROJECTS

PRACTICAL RECOMMENDATIONS

To expedite the progress of energy transition projects, it is imperative to implement specific, actionable recommendations. One key recommendation is to transition away from traditional methods by adopting a more **agile and flexible management methodologies**. For instance, shifting from comprehensive minutes of the meeting to concise bullet-point summaries can significantly save time and maintain a focus on critical action items and decisions. Utilizing a shared document for real-time notetaking during meetings ensures quicker dissemination and implementation of decisions. Additionally, **revamping traditional contracting methods** is essential for effective stakeholder engagement. Moving towards alliance-type partnerships with subcontractors and key supply chain parties not only leverages their experience for current projects but also facilitates knowledge transfer to future energy transition projects, thereby enhancing their efficiency and speed. Integral to this approach is **strengthening the front-end development phase**. By investing more time and resources in this initial phase, potential risks can be identified and mitigated early, which is instrumental in avoiding later project changes and delays. This proactive approach in the front-end phase ensures a solid foundation for the project, setting the stage for smoother progression and fewer unexpected challenges.

Implementing **project learning and reflection phases** is another critical recommendation. Regular review sessions, either post each phase or at project completion, should involve the project team and, where possible, all stakeholders, to constructively assess what worked, the challenges encountered, and the lessons learned. This reflective practice fosters a problem-solving mindset and encourages continuous improvement. Moreover, encouraging **cross-project knowledge sharing** through forums or workshops enables project managers and teams to exchange experiences and insights, enriching each project with the collective wisdom from others. This approach aids in bridging knowledge gaps and accelerates the efficiency of subsequent projects, aligning with the dynamic and evolving nature of energy transition projects.

LIMITATIONS AND SIGNIFICANCE OF RESEARCH

The research presented in this thesis, while insightful, has its limitations. Conducted within the context of project-based organizations, it reflects the perspectives of stakeholders from these entities, which may differ from those in other organizations. Efforts to mitigate these limitations included incorporating viewpoints from experts across various organizations, broadening the research's applicability. However, the inherent subjectivity in interpreting findings and the unavoidable presence of individual biases and deviations in semi-structured interviews are noted. The study's limited sample size of 18 interviewees, while providing valuable insights, suggests that a larger participant pool might have yielded a more comprehensive understanding. A trade-off was also evident between offering a holistic overview and delving into detailed case studies in energy transition, with the latter potentially offering more specific insights. Despite these constraints, the research significantly contributes to the field of energy transition project management, elucidating specific complexities and management strategies within project-based settings. This study not only enriches the academic discourse but also serves as a practical guide for practitioners to effectively manage complexities in energy transition projects.

FUTURE WORK

Future work presents substantial opportunities to enhance contracting strategies in energy transition projects, transforming them into proactive tools for fostering collaboration and better risk-sharing. Addressing the knowledge gap is crucial, and future research should focus on effective knowledge capture and reuse across various projects. Broadening the study to include more organizations and diverse case studies would enrich understanding of the complexities at different levels and their interactions. Long-term studies evaluating the performance and outcomes of energy transition projects relative to the management approaches discussed could provide valuable insights into their long-term efficacy. Continued research in these areas will contribute significantly to the growing body of knowledge in energy transition project management.

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1 INTRODUCTION

This chapter sets the scene for this thesis by exploring the research topic's background in section 1.1 and identifying the problem area, subsequently leading to the identification of a research gap in section 1.2. Following this, the main research question and the sub-research questions are formulated in section 1.3. The scope of this research is delineated in section 1.4, which includes an exploration of the study's context in subsection 1.4.1. This leads to the consideration of an organizational perspective in subsection 1.4.2, and the definition of complexity along with its relationship to risk and uncertainty is elucidated in subsection 1.4.3. Finally, this chapter concludes by providing an outline of the thesis, serving as a reading guide in section 1.5.

1.1 SETTING THE SCENE

The global climate change, as highlighted by Rotmans and Loorbach (2009), can be classified as a persistent and complex problem. The growing scarcity and dependency on fossil fuels necessitate a fundamental shift in our energy systems to address this issue. This requires a systemic transition from current supply systems to those based on renewable and sustainable energy sources. This transition, known as the 'Energy Transition,' needs to take place across all levels, from strategic to tactical to operational, within energy systems to effectively address climate change (Loorbach, 2007; Loorbach & van Raak, 2006).

Recognizing the urgency and to facilitate the transition at the strategic level, The European Union formulated the 'Green Deal' as part of global climate action under the Paris agreement as shown in Figure 2. This initiative aims to encourage EU member states, such as The Netherlands, to move towards this transition, thereby reducing the European Union's greenhouse gas emissions by at least 55% by 2030 and reaching climate neutrality by 2050 (EU-Commission, 2021).

FIGURE 2: THE EUROPEAN GREEN DEAL (EU-COMMISSION, 2021)

A part of the Dutch transition management approach, Kemp (2010) introduced seven energy transition platforms, namely, New gas, Green resources, Chain efficiency, Sustainable electricity supply, Sustainable mobility, Built environment, and Energy-producing greenhouse as shown in Figure 3. These platforms focussed on accelerating the shift away from fossil fuels, encompassing a wide range of activities across society and the policy domains. For instance, development of renewable technology, the creation of energy efficient infrastructure, and the establishment of laws to promote clean energy. The primary goal of these platforms is to influence broader societal innovation dynamics and drive changes in the fossil-based energy regime.

Based on these platforms, several energy transition projects were formulated, including, Carbon Capture Utilization and Storage (CCUS), Hydrogen, Renewable Fuels, Asset Decarbonization, Gasification, Nuclear Energy, Green Chemicals and Chemical Recycling, Battery Chemicals, Offshore Wind Energy, and Energy Storage, among others. These projects are essential in driving the energy transition at the operational level (Kemp, 2010).

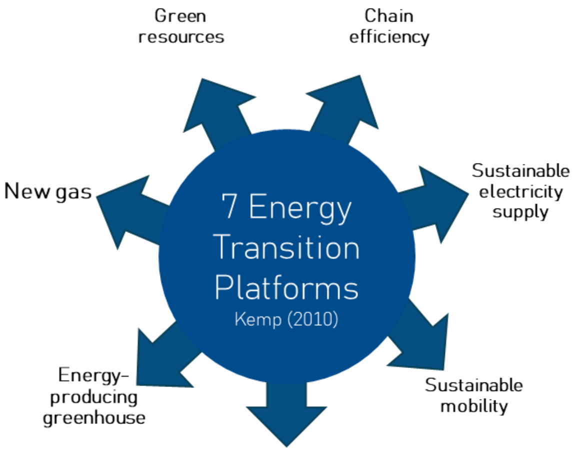


FIGURE 3: ENERGY TRANSITION PLATFORMS (KEMP, 2010; LOORBACH, 2007)

However, a recent study by Yergin (2022) reveals that the coming energy transition is meant to be a profound shift. Instead of just adding to the current energy landscape, it seeks to replace the foundation of today's $86 trillion global economy, which relies on hydrocarbons for 80% of its energy. This transformation aims to create a net-carbon-free energy system, potentially resulting in a $185 trillion economy by 2050. Achieving this within 26 years, with substantial progress in the next six across various domains such as Energy generation, storage, transportation, policy development, Infrastructure development, building supply chain, and at various levels of the energy systems, poses a monumental challenge.

In fact, global organizations like the International Energy Agency, as of 2020, have already noted that the energy transition is progressing too slowly to effectively tackle climate change. Specifically, The Netherlands remains heavily reliant on fossil fuels and fosters a high concentration of ‘energy-intensive’ and ‘emissions-heavy’ industries that pose significant challenges to decarbonization. Moreover, studies by Jalali Sohi et al. (2021), Kaldellis and Kapsali (2013), Pegels and Lütkenhorst (2014), and Wassermann et al. (2015) have highlighted ‘underperformance’ of these energy transition projects in comparison to the goals set for them. They further noted that this underperformance, particularly evident in countries working towards the 2050 climate goals such as the Netherlands and Germany, is one of the major factors for the slow progression of energy transition. This situation underscores the urgent need to focus on and accelerate these projects, as solving the global climate change problem is deemed the most important task for humankind in the 21st century, as noted by Armaroli and Balzani (2007).

1.2 Problem Definition

Bosch-Rekveldt (2011) identified a strong and negative link between complexity and project performance. They found that increasing complexity of projects and mainly the underestimation of the complexities hindered the performance. This posed a significant question as to why these energy transition projects, bearing similarities to traditional energy projects (Kian Manesh Rad et al., 2017), were not being effectively addressed by the existing management approaches. This pondering led to the research conducted by Toonen (2022), which revealed that energy transition projects have different features compared to conventional energy projects, such as, '**novelty**', '**business case'**, '**new and different relationships**', '**subsidy component'**, and '**time pressure'**.

Additionally, research suggests that project management approaches need to be adapted to the specific characteristics and context in which the projects take place when managing the complexity to improve project performance (Bosch-Rekveldt, 2011; Engwall, 2003; Sauser et al., 2009; Shenhar & Dvir, 1996; Smyth & Morris, 2007; Williams, 2005). Gatzert and Kosub (2016) also emphasized the need for a holistic management approach that takes into account the distinctive features of energy transition projects. Failing to do so was suggested as the biggest risk to sustainability and organizations in the study by (Toonen, 2022).

These findings highlight a gap in existing management approaches in adequately considering the distinctive features of energy transition projects when managing complexity (Kermanshachi et al., 2023). Furthermore, (Kian Manesh Rad et al., 2017), identified 51 indicators of complexities for projects in the energy sector, however, in light of these different features, they need to be tested and adapted to energy transition projects as well.

In conclusion, this has led to the problem statement, that the energy transition is progressing slowly, raising concerns about meeting the set goals. This slowness could be attributed to the existing management approaches not adequately taking the distinctive features of energy transition projects into account when managing their complexity. Therefore, highlighting the need to assess where and why these management approaches fall short and explore ways to adapt them to energy transition projects. This adaptation could, in turn, enhance project performance and contribute to achieving the 2050 climate goals.

Therefore, to address this research gap, the following main research question and sub-questions were structured to explore "What" are the complexities in energy transition projects, and "How" these complexities can be effectively addressed. Essentially, adopting a **"What,"** and **"How"** format to delve into the **"Why"** aspect of the research through practical experiences and to explore the challenges and opportunities specific to managing complexity in the energy transition context to adapt the management approaches based on them.

1.3 MAIN RESEARCH QUESTION

"How can complexities in energy transition projects be effectively addressed?"

1.3.1 SUB-RESEARCH QUESTIONS

1. What are complexities in the context of energy transition projects?
2. What are the existing project management approaches to address complexity?
3. How is the management of complexities currently practiced in energy transition projects?
4. What are the challenges and opportunities when managing complexities in energy transition projects?
5. What adaptations in project management approaches are needed to address the complexities of energy transition projects?

1.4 RESEARCH SCOPE

The aim of this section is to outline the boundaries of this research and provide a structured overview of the following sections considering the limited time frame for this research. Beginning with section 1.4.1 where the context for the research is established through the relevance of Fluor Corporation's practical insights into managing complexities in energy transition projects. Moving to section 1.4.2, the scope encompasses an exploration of project complexity, considering its relationship with uncertainty and risk. At section 1.4.3, emphasis is placed on the organizational perspective when understanding the management of complexity in energy transition projects to foster a holistic approach.

1.4.1 SETTING THE CONTEXT

When looking at the context of this research, it is crucial to understand the role of FLUOR B.V in this research, Fluor B.V is a renowned engineering, procurement, and construction firm that also provides project management services. The clients worldwide turn to Fluor for their expertise handling complex projects, especially for energy projects. Like many other companies, Fluor is slowly transitioning their business portfolio and striving to transition and provide services in the energy transition sector and position themselves as strong contenders in this market. Their extensive experience in executing complex projects underscored their practical insight into addressing the challenges posed by energy transition projects. This context emphasizes the significance of Fluor's involvement in this research, as it directly aligns with their commitment to advancing knowledge and innovation in energy transition projects. Collaborating with Fluor reflected the importance of bridging academic research with industry experience to enhance the understanding and effective management of energy transition projects.

1.4.2 COMPLEXITY

The scope of this research encompasses a thorough exploration of project complexity, characterized as multi-dimensional and context-dependent (Bosch-Rekveldt et al., 2011; Geraldi, 2008; Parwani, 2002). While the literature provides various perspectives on defining project complexity, the following definition was assimilated: ***“Complexity is a characteristic of a project, attributed by an intricate arrangement of interrelated parts, encompassing technological, organizational, and environmental elements, all subject to evolution, and impacting one or more project objectives.”***

It is important to note that complexity, uncertainty and risk are often used interchangeably in project management literature. A lack of consensus could be observed regarding the relationship between complexity and risk, as well as between complexity and uncertainty. A major portion of the literature considers complexity as the source of uncertainty, while the other perspectives include uncertainty as a source of complexity or suggest that they are independent concepts. Similarly, many studies regard complexity as a source of risk, while other propose the opposite view. Recently, a new perspective has emerged suggesting a bidirectional relationship between complexity and risk. Consequently, for the purposes of this thesis, uncertainty and risk are considered components of complexity.

1.4.3 ORGANIZATIONAL PERSPECTIVE

An organizational perspective was adopted for this thesis, as this perspective extends the definition of project success beyond just task execution. It encompasses aspects such as effecting necessary organizational changes, aligning these changes with existing processes, and adapting to evolving goals and stakeholder dynamics in the management of complex projects. This perspective facilitates a holistic understanding of the complexity management process. Additionally, it provides a comprehensive framework for exploring tailored management approaches in the context of energy transition projects, which often necessitate transformational leadership and a broader emphasis on value creation.

Moreover, this perspective enhances the applicability of the findings to other organizations facing similar challenges. It adopts an integrative approach by considering various stakeholder perspectives, thereby increasing the relevance and transferability of the insights gained (Andersen, 2014).

1.4.4 ENERGY TRANSITION PROJECTS

Loorbach et al. (2008) defines 'transitions' as a large-scale transformation within society or important subsystems, wherein the structure of the societal system fundamentally changes. This transition involves shifting from a relatively stable system in dynamic equilibrium though a period of rapid change, during which the system undergoes irreversible reorganization into a new stable system. According to Rotmans et al. (2001), transitions are characterized by long processes and significant developments in technology, ecology, economy, socio-culture, and institutions.

Hauff et al. (2014) refer to energy transition as a long-run structural change in the energy systems. It is a multifaceted process that encompasses various aspects of the energy sector such as renewable energy generation, energy storage, smart grids, and many more. Geels (2002) further elaborates that energy transition is a complex process that co-evolves with institutions, societal actors, technologies, individual behaviours, markets, networks, and policies, ultimately forming socio-technical systems as shown in Figure 3.

These factors influence and reinforce interactions between different scale levels such as niche, regime, and landscape. Geels (2002) formulated the multi-level perspective to understand transitions as outcomes of alignments between developments at multiple levels: niche-innovations, sociotechnical regime, and socio-technical landscape. This perspective considers transitions as changes from one socio-technical regime to another.

To manage these transitions, a governance framework had been formulated by Loorbach (2007) and Loorbach and van Raak (2006), with three levels, as shown in figure 4. Firstly, the strategic level involves processes such as vision development, strategic discussions, and long-term goal formulation. This level plays a crucial role in providing direction to social and cultural developments through leadership capacity, long-term orientation, and top-down decision-making.

Secondly, the tactical level encompasses processes like agenda-building, negotiating, networking, and coalition building. At this level, the regime-structures of a societal system are redefined through the design of new structures that facilitate a sustainable system. This often involves co-evolution between actors' interests, agendas, and strategies.

Lastly, the operational level involves processes such as experimenting, project building, implementation, and the adoption of new practices. However, the studies by Jalali Sohi et al. (2021), Kaldellis and Kapsali (2013), Pegels and Lütkenhorst (2014), and Wassermann et al. (2015) highlighted that the energy transition projects were underperforming compared to the goals set for them to combat the climate change such as the 2050 Paris Agreement. Therefore, this thesis focused on the operational level, specifically on energy transition projects, to explore ways for these projects to navigate through complexity and progress in meeting the overarching energy transition goals.

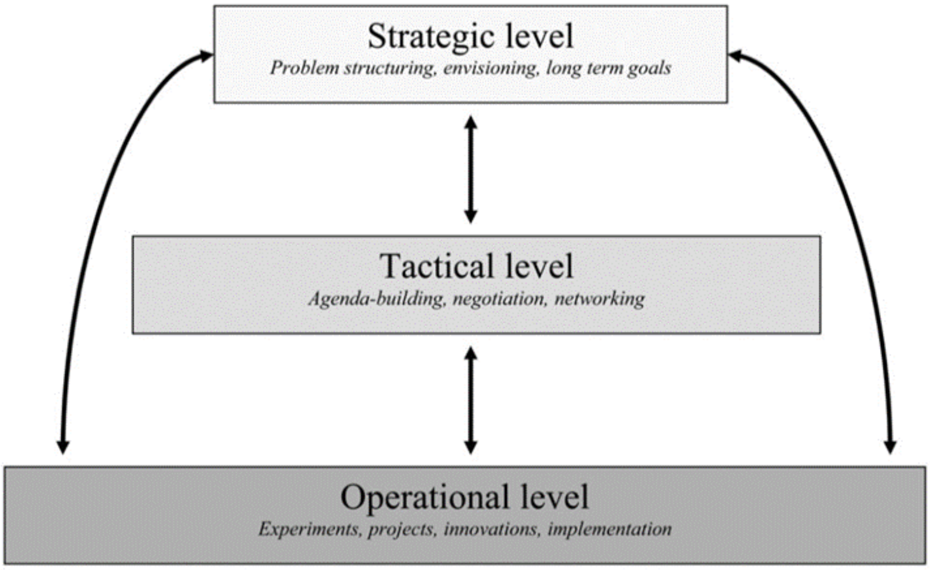


FIGURE 4: ENERGY TRANSITION GOVERNANCE FRAMEWORK BY LOORBACH AND VAN RAAK (2006) AND LOORBACH (2007)

Additionally, to gain a comprehensive understanding of energy transition implementation, it is essential to identify the key actors involved in facilitating this transition. These actors span a wide spectrum, including government officials (Fischer & Newig, 2016), researchers, as well as international environment organizations, commonly referred to as "policy makers" at the strategic level (Bednar & Henstra, 2018). At the tactical level, niche actors such as industry leaders, research institutions, and local municipalities are involved. Furthermore, when mainly looking at the operational level, energy companies (Danielson et al.), service providers, financial institutions (Pathania & Bose, 2014), Utility companies (Frei et al., 2018), grid operators, technology providers, energy consultants (Rohdin et al., 2007), start-ups (Perrot, 2009) were found to contribute to the energy transition process.

1.5 THESIS OUTLINE

This thesis is divided into five phases as shown in figure 4,

Research Phase 1 (Setting the stage): establishes the foundation of the study in Chapter 1 by exploring the background, identifying the problem, and subsequently revealing the research gap. This leads to the formulation of the main question designed to address this gap. Additionally, this stage delineates the boundaries of the study. Following this, Chapter 2 outlines the research methodology, detailing the approaches employed for data collection and analysis.

Research Phase 2 (Zooming Out): This phase involves conducting a comprehensive literature review in chapter 3. During this stage, existing research, theories, and knowledge related to complexities in energy transition projects are examined from a broad perspective. The goal is to establish "What" exists in the current body of knowledge regarding complexity and management approaches. The primary aim is to establish a foundational understanding of the subject matter, consequently answering sub-questions 1 and 2. This phase serves as a critical starting point for the subsequent phases, providing a context for the in-depth exploration and analysis that follows.

Research Phase 3 (Zooming In): This phase centres on conducting semi-structured interviews. Chapter 4 delves into the development of the questionnaire based on the gaps identified from the literature study and identification of interview participants. Following which, chapter 5 delves into the various themes identified from the data analysis. The focus is on "How" it is in practice, uncovering specific challenges, approaches, and experiences related to managing complexities. This phase serves as a deep dive into practical experiences, enriching our understanding of the nuanced aspects within the field, answering sub -question 3 & 4.

Research Phase 4 (Zooming Out Again): Following the detailed insights gathered through interviews, the research transitions to the fourth phase. In this stage, the insights from theory and practice are juxtaposed to form the guiding checklist, thereby answering sub-question 5. These findings are then contextualized within the broader landscape of energy transition projects. This contextualization involves subjecting the checklist formulated to subject matter experts in the field of managing energy transition projects. These experts provide feedback and validation of the research outcomes, ensuring the wider applicability and reliability of the findings.

Research Phase 5 (Closing): This phase explores the implications of the results of this thesis on the wider context, aiming to connect the dots between practical experiences and theoretical knowledge to understand the overarching "Why" aspect, thus addressing the main research question.

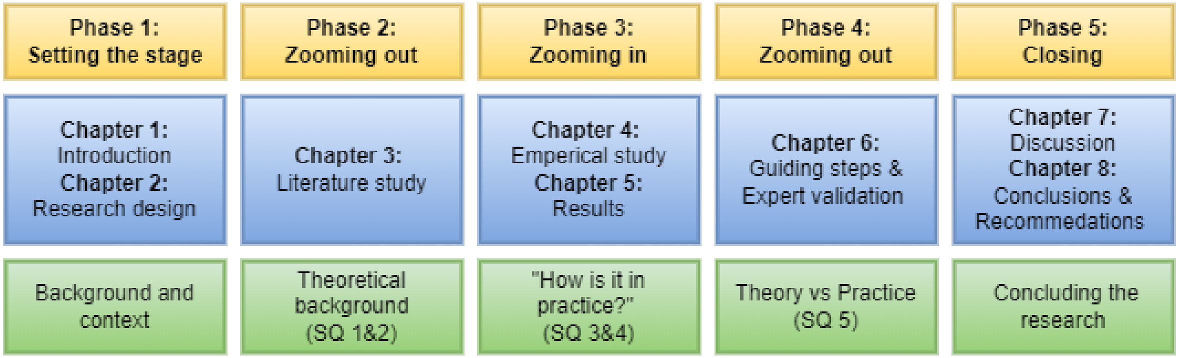


FIGURE 5: RESEARCH OUTLINE

2 RESEARCH DESIGN

This chapter begins by delineating the research objectives in Section 2.1, where the objectives of this study are clearly articulated. Following this, Section 2.2 provides an in-depth exploration of the methodology employed, offering insights into the theoretical underpinnings and the rationale guiding the selection of specific research methods. The chapter then progresses to Section 2.3, which is dedicated to the data collection process. This section is further subdivided into Sub-Section 2.3.1 which delves into the literature study, detailing the sources, and the selection criteria. In Sub-Section 2.3.2, the focus shifts to the empirical aspect of the study, where the process and significance of conducting semi-structured interviews are discussed, highlighting how these interviews aid in addressing the research questions. Sub-Section 2.3.3 outlines the expert validation process, emphasizing the methods used to corroborate the final deliverable of this thesis. Lastly, section 2.4 delves into how the data was analysed to collect the results

2.1 RESEARCH OBJECTIVE

The objective of this research is to understand the complexities in energy transition projects and to identify the adaptations needed in the existing project management approaches for managing these complexities. By doing so, the aim is to enhance the performance of these projects and help them progress in meeting the overarching climate goals.

2.2 RESEARCH METHODOLOGY

A three-fold approach is adopted for answering the research questions, as shown in figure 5.

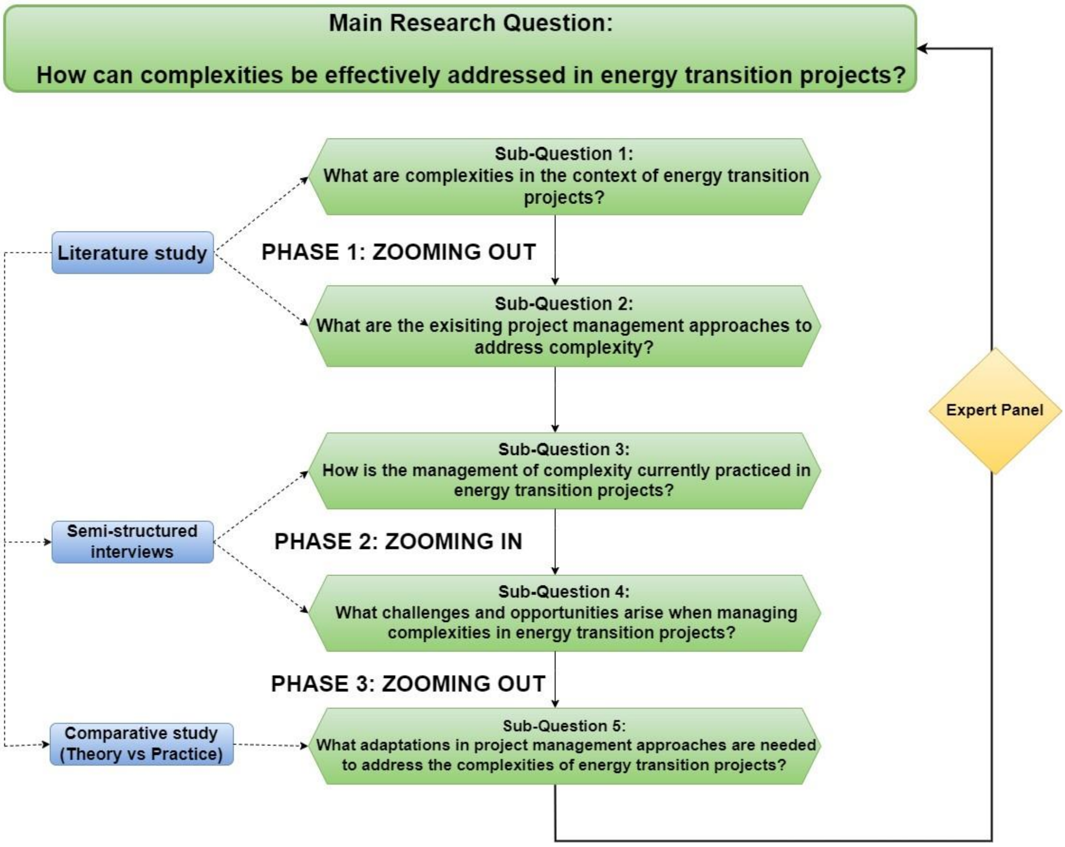


FIGURE 6: SCHEMATIC REPRESENTATION OF RESEARCH METHODOLOGY

Firstly, the theoretical background for this study is established using a literature study to answer sub-questions 1 and 2. Following this, based on the gaps identified in the literature, semi-structured interviews were conducted with practitioners from Fluor B.V to address sub-questions 3 and 4. The theoretical and practical insights are then compared to understand the adaptations needed in the existing project management approaches, thereby answering sub-question 5. Based on this comparison, guiding steps were formulated, which were subsequently subjected to a round of expert validation. This ensures the reliability and wider applicability of the steps, thereby addressing the main research question. This methodology strives to bridge the gap between existing knowledge and the practical realities of managing complexities in energy transition projects, delving into the specific experiences and insights of project stakeholders, and thus enhancing our comprehension of this field.

2.3 DATA COLLECTION

2.3.1 LITERATURE STUDY

In order to carry out the literature review, a methodology was employed, by making use of a diverse range of scholarly resources such as JSTOR, Google Scholar, and Scopus. The search was narrowed down by using specific keywords such as "project complexity," "energy transition projects," “energy projects” "management approaches," "project performance," "risk and uncertainty in projects," and "complexity indicators." The primary emphasis was placed on peer-reviewed scholarly journals in order to assure the credibility and validity of the sources. On the other hand, theoretical frameworks and models have played a crucial role in offering conceptual perspectives on the management of complexity. The method employed in this literature review was devised with the intention of not only identifying established theories, but also identify gaps in the current body of literature. This approach consequently lays the groundwork for the empirical study phase.

2.3.2 EMPIRICAL STUDY

Following the themes identified from literature – Theme 1: Complexities in Energy Transition Projects, Theme 2: Management approaches used in practice for Energy transition projects, Theme 3: Challenges, opportunities, lessons learned, Sub-Theme: Comparison between energy transition projects and conventional energy projects. In order to gain the specific insights into these themes, semi-structured interviews were conducted with nine project managers from Fluor B.V forming the first round of interviews. Following the roles referred by these project managers led to the second round of interviews with Contract Managers, Sales Managers, Clients, Engineering Managers, Project Controls, and Process Directors as shown in Practioner selection . This concluded the total number of semi-structured interviews to 18. Semi-structured interviews were specifically chosen as they are designed around a set of themes and involve open-ended questions. This approach facilitates an understanding of the interviewees' perspectives, which is crucial in gaining insight into the management of complexities in energy transition projects (Soiferman, 2010).

Location of the Interviews: interviews were conducted either in-person or via online platforms like Microsoft Teams. This approach allowed interviewees to choose the mode they are most comfortable with, enhancing the likelihood of their participation and the quality of their responses.

Duration: Each interview lasted for approximately 45-60 minutes. The duration allowed for initial formalities and provided an opportunity to establish a comfortable rapport with the interviewees, facilitating a more candid and insightful responses.

2.3.3 EXPERT VALIDATION

Following the semi-structured interviews, the insights from practice were compared to the insights from literature, from which guiding steps were formulated. These guiding steps were then validated by three experts from other organizations, such as Worley and Technip to widen the applicability of the guiding steps. The questions revolved around four main themes: the validation of the sequencing and bundling done to arrive at these steps, the feasibility and timing of the steps, how the practitioners would like the steps to be visualized, whether the terminology used was general, and finally, what makes the guiding steps particularly relevant to energy transition projects. These interviews were conducted individually for sixty minutes via Microsoft Teams meetings. Following which, based on the insights from the experts, the steps were converted into a checklist for better adaptability and a roadmap for visualization.

2.4 DATA ANALYSIS

Given the qualitative nature of this study, thematic analysis was adopted to analyse the data. Clarke and Braun (2017) define thematic analysis as the process of identifying, analysing, and interpreting patterns of meaning, known as 'themes', within qualitative data. These codes were further interpreted as recognizing an 'important moment' and encoding it prior to interpretation (Fereday & Muir-Cochrane, 2006). Subsequently, deductive coding was undertaken, meaning that the codes were interpreted based on the research questions. Thus, the codes were deductively categorized based on the themes identified from the literature and further interpreted in light of the main research question (Braun & Clarke, 2006).

In alignment with these insights, the interview data was coded using the thematic analysis software Atlas.ti, following a thorough comprehension of the interview transcripts. These codes were then grouped into 'code groups' based on either the frequency of occurrence or the 'co-code occurrence', a feature in the software that analyses which codes were mentioned together, highlighting the interrelations between the codes. Consequently, these code groups became the second-order themes. These second order themes included **'People'**, **'Technical'**, **'Financial'**, **'Resources'**, **'Legal & regulations'**, and **'Project management & Execution methods'**. Finally, these themes were contextualized under the research questions to effectively answer sub-research questions 3 and 4.

3 LITERATURE STUDY

This chapter aims to zoom out and understand the concept of project complexity and its management. Firstly, it delves into the fundamental understanding of the concept of complexity in Section 3.1. This section also explores the definition of complexity (Section 3.1.1), its relationship with risk and uncertainty (3.1.2), as well as with performance, and subsequently the front-end development phase in Section 3.1.2. Following this, a brief understanding of the various complexity models is examined. This section further explores what literature suggests about the complexities in energy transition projects in Section 3.2, followed by the identification of the various approaches to manage project complexity in Section 3.3.

3.1 UNDERSTANDING PROJECT COMPLEXITY

Before delving into identifying what literature suggests about the complexities in energy transition projects and managing complexity, it is crucial to establish a fundamental understanding of the concept of "complexity" within the realm of project management. The concept of complexity in projects encompasses multiple dimensions and is interconnected to several other fundamental factors, such as project performance, risk, and uncertainty. Hence, it is crucial to comprehend this correlation and demarcate the limits that establish the extent and influence of complexity within the realm of project management.

3.1.1 WHAT IS PROJECT COMPLEXITY?

The concept of project complexity has been widely debated in academic literature, with no universally accepted definition emerging. This lack of consensus is partly due to the subjective nature of complexity, as individuals perceive and experience it differently, and these perceptions can vary depending on the context as well (Dao et al., 2017; Zolin et al., 2009). Therefore, this study aims to contextualize the concept of complexity within the scope of projects.

Various definitions and perspectives on complexity exist in literature. One view posits complexity as comprising numerous interrelated components, such as tasks, stakeholders, or technologies. These components are characterised by their differentiation (diversity in types of activities or stakeholders) and interdependency, where changes in one component can necessitate adjustments in others (Baccarini, 1996). Another perspective describes complexity as a characteristic that makes a project difficult to understand, predict, and control, even with sufficient information (Vidal & Marle, 2008). This idea was expanded by Zolin et al. (2009), who argue that 'complex projects' exhibit various characteristics to a degree and severity that reduce predictability and management ease.

The literature identifies three perspectives of complexity. First is **Structural complexity**, this concept is rooted in the idea of “emergence”, where higher level systems have certain qualities that are unique and cannot be predicted just based on the properties of their constituent parts. For example, the behaviour of a project organization cannot be explained just by the characteristics of the individuals in it. Consequently, Structural complexity arises from often unpredictable interaction between various elements such as tasks, people, technologies and organizational structures. These interactions can in turn lead to outcomes that are more than just the sum of these elements, making the outcome of the project unpredictable. Furthermore, structural complexity also includes the concept of “downward conditioning” where the higher-level systems influence the behaviour of the components within them. For instance, attributes of the project organization can influence the characteristics of the individuals in it at various levels of the organization. Therefore, Structural complexity could be understood as the interplay of various elements within a project, leading to “emergent” behaviours and outcomes that are challenging to predict or control solely by looking at the elements individually (Benbya & McKelvey, 2006; Floricel et al., 2016; Whitty & Maylor, 2009).

Dynamic complexity represents the second perspective of complexity, characterized by the ever evolving and often unpredictable nature of systems. This complexity emerges from processes and interactions within a system that can lead to sudden, radical, and unforeseen changes. For example, a large infrastructure project could have a variety of stakeholders, whose interests and objectives could evolve over time, influencing project decision (Benbya & McKelvey, 2006; Floricel et al., 2016; Whitty & Maylor, 2009). The third perspective, **Representational complexity**, pertains to the challenges in accurately representing and comprehending the reality of complex systems. This type of complexity underscores the difficulty in fully grasping and depicting the intricate and multifaceted nature of complexities in a holistic manner. (Benbya & McKelvey, 2006; Floricel et al., 2016; Whitty & Maylor, 2009).

When zooming in at the project level, the concept of complexity takes on three different forms (Bosch-Rekveldt et al., 2011). **'Technological'** complexity is concerned with the characteristics of a project, such as its objectives and the technical aspects involved. On the other hand, **'Organizational'** complexity relates to the people and organizations involved in the project, encompassing their interactions and interdependencies. This form of complexity includes both structural and dynamic elements, and it expands to consider softer aspects like organizational culture and interpersonal interactions. As a result, there emerges the notion of **'Environmental'** complexity, which is associated with external factors that impact the project environment.(Bosch-Rekveldt et al., 2011; Cicmil & Marshall, 2005; Geraldi, 2009; Jaafari, 2003; Williams, 1999; Xia & Lee, 2004).

Bakhshi et al. (2016) attempted to synthesize these views into a unified definition of project complexity, defining it as "**an intricate arrangement of interrelated parts that can change and evolve, impacting project objectives"** (p.5). This definition acknowledges the structural, dynamic, representational, and softer aspects of complexity and emphasizes the impact of complexity on achieving project objectives.

Therefore, the literature suggests defining project complexity as ***“A characteristic of a project, attributed by an intricate arrangement of interrelated parts, encompassing technological, organizational, and environmental elements, all subject to evolution, and impacting one or more project objectives.”***

3.1.2 Relationship between Complexity, Uncertainty and Risk

Examining the various definitions of complexity revealed a consistent focus on 'unpredictability' and the 'unforeseen' nature of projects, influenced by complexity. These notions of ‘unpredictability’ and ‘unforeseen’ are closely linked to the concept of uncertainty and its implications to ‘risk’. This observation prompts an exploration into the relationship and distinction between complexity and uncertainty, as well as between complexity and risk. Given the latter part of the definitions which suggests the impact on project objectives, it becomes essential to understand how complexity interacts with and differs from these concepts. Clarifying this correlation is vital, especially in the context of project management where the subjective nature of complexity can vary widely. Understanding these relationships will help delineate the scope and effect of complexity in project management.

Complexity and uncertainty

Project management literature often confuses complexity and uncertainty, leading to misunderstandings between the two concepts (Daniel & Daniel, 2018). Firstly, when breaking them into two parts and looking solely at the concept of uncertainty, literature suggests that uncertainty in projects is the lack of predictability or knowledge about various aspects of the project such as requirements, resources and outcomes, essentially referred to as the ‘unknown unknowns’ in a project. This means that the events are not only unpredictable but also unrecognized when they occur (Jaafari, 2001; Taipalus et al., 2020; Wideman, 1992; Winch, 2015). When looking at it phase wise, literature suggest that uncertainty is the lack of ability to define project goals and performance objectives in the early phases, and uncertainty related to project partners and contractual terms in later stages (Kreye & Balangalibun, 2015). Therefore, it could be inferred from literature that **“*Uncertainty is a lack of predictability or knowledge spanning across the various stages of a project”***

In examining the relationship and difference between complexity and uncertainty, a notable viewpoint that emerged is that complexity is often seen as the source of uncertainty. This is particularly evident when considering the perception of complexity (Daniel & Daniel, 2018; Danilovic & Browning, 2007; Dikmen et al., 2021; Williams et al., 1995). For example, in a project deemed complex, the multitude of variables in play can make it difficult to foresee outcomes, thereby introducing uncertainty. Williams (1999) ties this concept to the structural aspect of complexity, noting that the number and interconnections of elements contribute to structural uncertainty, thus positioning **complexity as a source of uncertainty**. Atkinson et al. (2006), while not explicitly stating complexity as the source of uncertainty, suggest that complexity is an element of it, implying that the interrelated components and interactions in a project, which constitute complexity, add to the overall uncertainty of the project. In contrast, Geraldi et al. (2011) and Müller et al. (2007) view **uncertainty as a component of complexity**, emphasizing that uncertainty, particularly regarding goals and methods, contributes to a project's complexity.

Adding to these diverse perspectives, Shenhar (2001) proposes that the relationship between complexity and uncertainty is "orthogonal," meaning they can coexist independently within a project without directly influencing each other. This implies that a project can have varying degrees of complexity and uncertainty independently. Sommer and Loch (2004) align with this view, suggesting that while **complexity and uncertainty are separate constructs**, both are crucial aspects of project management.

Complexity and risk

The PMBOK Guide Institute. (2021) defines risk as ***“an uncertain event or condition that, if occurs, has a positive or negative effect on one or more project objectives”.*** This definition emphasizes that both complexity and uncertainty can impact project objectives. Literature identifies three main themes in the relationship between complexity and risk.

Firstly, **risk is considered an element of complexity**. This perspective suggests that risk contributes to complexity. For instance, an unforeseen weather condition could introduce an additional layer of complexity to a project. Similarly, in projects with a high number of risks, increased interactions or dynamics could add to the complexity (Bosch-Rekveldt et al., 2011; Geraldi et al., 2011; Turner & Cochrane, 1993). Conversely, the second theme presents **complexity as the source of risk**, whether caused directly or indirectly by the project's complexity. For example, a greater number of dynamic elements or interactions may increase the likelihood of risks occurring, thus positioning risk as a consequence of complexity (Kian Manesh Rad et al., 2017; Vidal & Marle, 2008)

More recently, a third perspective had emerged, suggesting that complexity and risk can interact **bidirectionally**, each triggering the other in a cause-effect relationship. This implies that managing complexity can generate new risks, and in response to these risks, the project team's actions could further intensify existing complexities, creating a dynamic interplay between the two (Erol et al., 2020).

In conclusion, the literature review reveals a nuanced and multifaceted interplay between complexity, uncertainty, and risk in project management. There are three distinct perspectives regarding the relationship between complexity and uncertainty: first, complexity as a source of uncertainty; second, uncertainty contributing to complexity; and third, both existing as independent yet significant factors in project management. Similarly, when considering the relationship between complexity and risk, literature presents three primary perspectives: risk as a contributor to complexity, complexity as a source of risk, and a bidirectional relationship where complexity and risk mutually influence each other. This intricate association between complexity, risk, and uncertainty underscores the importance of considering these elements in tandem rather than in isolation when addressing the complexities in a project.

3.1.3 Relationship between Complexity, Front-end development and Performance

Research into the impact of complexity on project objectives, such as the study by Bosch-Rekveldt (2011) revealed a **direct** and **significant** relationship between project complexity and performance, particularly during the front-end development phase. This finding is crucial because project performance is directly linked to the accomplishment of project objectives. In other words, project performance metrics are often used to evaluate the extent to which a project achieves its set objectives. Hence, if the complexity of a project has a substantial impact on its performance, it can be deduced that complexity also has a significant impact on the attainment of project goals, especially in the critical initial development stage, where key objectives are established and refined. This relationship emphasises the importance of grasping and addressing complexity from the beginning of a project to guarantee that goals are not only specified but are also achievable. Other studies have also highlighted a strong relationship between complexity and the front-end development phase, although less emphasis was placed on the performance aspect (Eriksson et al., 2017; Rehman, 2022; Wesz et al., 2018; Yeo & Ning, 2002). Thus, exploring the concept of front-end development and performance in relation to complexity becomes important.

Gibson Jr et al. (2006) and Turner (2008) define the front-end phase (FED) as the process of developing strategic information that allows owners to assess their risks and make informed decisions regarding committing their resources and picking the right project management approach to maximizing the chances of project success. They further elaborate that the front-end phase aims to answer essential questions about the project, including its business needs, objectives, scope, design basis, project planning, required resources and, associated risks to provide a comprehensive understanding of the project to the owner representatives, ultimately helping them in making the Final Investment decision. Therefore, a well-defined project, facilitated by the front-end development phase, can add significant value, potentially offsetting the effects of poor project execution (Hutchinson & Wabeke, 2006).

The front-end development phase is typically divided into several sub-phases, forming a **stage-gate process**. As Turner (2008) notes, data gathering and viability proving at each stage are essential to commit resources to the next stage, with the final gate assimilating all information for the final investment decision. This phase provides a logical, step-by-step process for gathering information, which typically includes three sub-phases: FED1 (defining project objectives, budget, and risk assessment), FED2 (identifying the best approach and selecting an option), and FED3 (detailed definition of the preferred alternative for the final investment decision). Scope development, aimed at finalizing before the final investment decision, is crucial throughout these phases (Bosch-Rekveldt, 2011). Regarding project performance, literature defines it as the extent to which a project achieves its intended objectives (Shelley, 2023). Therefore, project performance can be seen as a measure of the level to which objectives are met, and complexity significantly impacts these objectives.

Bosch-Rekveldt (2011) identified that complexity **negatively impacts** project performance. They found that a lack of thorough front-end development can contribute to the increase in project complexity, subsequently hampering project performance. In contrast, they discovered that integrating **'value-improving practices'** into the front-end development phase, such as active goal setting, alignment, monitoring, timely involvement of project stakeholders, and building a cohesive project team, can significantly aid in dealing with complexity, and thereby improve project performance.

Therefore, Bosch-Rekveldt's findings suggest that complexity acts as a '**moderator'** between the front-end development phase and project performance. In essence, insufficient front-end development may lead to increased complexity, which in turn negatively impacts project performance. Conversely, a well-executed front-end development phase can reduce complexity, ultimately contributing to improved project performance. Building upon these insights, Paraschiv (2023) found that by incorporating complexity management strategies in the front-end development phase, had the potential to transform complexity from a threat to an opportunity.

In summary, the literature underscores the significant relationship between complexity, front-end development, and project performance. It underscores the pivotal role of the front-end development phase in addressing and managing complexity to ensure that projects progress smoothly and achieve their intended objectives.

3.2 COMPLEXITIES IN ENERGY TRANSITION PROJECTS

According to the Commerce (2009), an organization's capacity to recognize, perceive, and navigate complexity plays a pivotal role in determining the success or failure of a project. Consequently, there has been a growing body of literature dedicated to the task of **"recognizing"** complexity through various models, frameworks, tools, and assessments. In the specific context of energy projects, Kian Manesh Rad et al. (2017) found that a lack of effective methods for assessing project complexity frequently led to project failure. This study focused on frameworks due to their capacity to encompass a wide array of elements categorized into appropriate dimensions. These frameworks were specifically developed to assist practitioners, as the name suggests, in "assessing" the level of complexity in their projects. The elements within these frameworks span a broad spectrum of aspects throughout the project lifecycle, offering practitioners a holistic understanding of the complexities they may encounter.

One noteworthy framework in this field is the **TOE framework**, developed by Bosch-Rekveld et al. (2011). This framework offers a comprehensive methodology for characterizing the complexity of large engineering projects. It integrates elements from existing literature and empirical cases and establishes criteria for the inclusion of these elements. This requires corroborative evidence from multiple sources, including literature, independent literary sources, or interviews from various cases. The TOE framework classifies complexity into three categories: **technological**, **organizational**, and **environmental**, comprising a total of **47 complexity elements** distributed within these three categories. These categories are further subdivided into subcategories, providing a detailed perspective on various aspects of project complexity.

The TOE framework encompasses both structural and softer aspects, as well as considerations related to risk. In the technical complexity category, structural elements such as the number of goals, scope, tasks, and dependencies are included, along with the uncertainties associated with goals and methods. The organizational complexity category recognizes structural elements such as the number of project management methods and tools, the involvement of various disciplines, and the multiplicity of stakeholders. Soft aspects, such as trust, resource availability, skills, and experience with involved parties, are considered in both the organizational and environmental categories. The environmental category encompasses elements like political influence, competition level, and weather conditions. Risk is also considered a contributing factor to project complexity in the TOE framework, with a separate risk element incorporated into all three categories. Risk-related aspects are also addressed in various other elements across the framework, particularly those pertaining to uncertainty, weather conditions, and political influence. Furthermore, they identified certain complexity elements, such as the non-alignment of project goals and uncertainties in scope, to have a stronger impact on project performance, as shown in Appendix A.

Other important studies in the field include Vidal et al. (2011), who identified **18 elements** of complexity using a system thinking approach. Under '**technological'** and '**organizational'** complexities, indicators were categorized and subdivided into project system scale, variety, interdependencies, and context dependence. Geraldi et al. (2011) conducted a systematic review and formulated an integrated framework with five categories: '**structural**', '**uncertainty'**, '**dynamics**', **pace**, and **socio-political** complexities. This paper was particularly relevant because it depicted complexity as a lived experience for project managers and provided a common language for interpreting complexities. In the context of construction megaprojects, He et al. (2015) employed a fuzzy analytic network method to identify **28 elements**, further classified as **technological**, **organizational**, **goal-oriented**, **environmental**, **cultural**, and **informational** complexities.

Bakhshi et al. (2016) analysed over 420 different publications and identified seven dominant elements that characterize complex projects, namely, **context**, **autonomy**, **belonging**, **connectivity**, **diversity**, **emergence**, and **size**. Furthermore, they identified 36 elements affecting these characteristics and changing the degree of complexity as shown in Appendix A. Additionally, they found that project context, diversity, size, and autonomy elements had a large number of complexity factors, with **project context** recognized as the most pronounced complexity characteristic in terms of the number of complexity elements.

When examining the complexity elements and frameworks tailored to energy transition projects, and drawing upon renowned frameworks by researchers such as Bosch-Rekveldt et al. (2011), Geraldi et al. (2011), He et al. (2015), and Vidal et al. (2011), as briefly introduced in the previous section, Kian Manesh Rad et al. (2017) integrated and applied their frameworks to **energy megaprojects** through the use of case studies, Delphi- AHP study and expert reviews, leading to the identification of **51 complexity elements** specific to projects in the energy sector. This study indicated that complexities in energy transition projects can be divided based on whether they are related to the internal project environment or external to the project environment, as shown in Table 1. The internal complexities are further divided into the 'what' category, which encompasses complexities related to the characteristics of the projects, namely **'objectives'** and **'technical'** aspects. The 'who' category pertains to the people involved in the project and delves into aspects such as '**capital resources'**, the **'disciplines'** involved, 'the **people**' involved, and the **'physical resources'** needed. Additionally, the 'how' category relates to the process of delivery and includes aspects related to the **'information'** in the project, the **'tasks'** of the project, the **'time'** aspect of the project, and the **'tools & methods'** used. This framework also expands to external factors, encompassing aspects related to the **'economy'** surrounding the project, the project's **'environment'**, adherence to **'legal & regulations'**, the **'political'** scenario around the project, and the **'social'** implications of and around the project. Further explanation of the complexity indicators within these various categories have been provided in Appendix B.

TABLE 1: INTERNAL AND EXTERNAL COMPLEXITIES BY KIAN MANESH RAD ET AL. (2017)

INTERNAL COMPLEXITIES	
WHAT?	
Objectives	Variety in goals and objectives
	Interdependence of objectives
	Transparency of objectives
	Scope Changing
Technical	Level of innovation
	Technological experience and capabilities
	Repetitiveness of process
	Specifications interdependencies
	Technological varieties
	Variety of system components
	Changing technology
WHO?	
Capital resources	Size of Capital investment
	Variety of investors and financial resources
Disciplines	Contract types
	Variety of institutional configurations
	Support from permanent team
	Team cooperation & communication
People	Availability of human resources
	Level of trust (within/between teams)
	Diversity of participants
	Dynamic and evolving team structure
	Experience & Capabilities with teams
	Interest & perspectives among stakeholders
Physical resources	Resource & raw material interdependencies
	Variety of resources
	Availability of Physical resources
HOW?	
Information	Availability of information
	Reliability of information platforms
	Interdependence of information systems
	Level of processing and transferring information
Tasks	Diversity of sites and location

	Process interdependencies
	Dependencies between tasks
	Number of activities
	Unpredictability of tasks
	Diversity of activity elements
Time	Duration of project
	Dependencies between schedules
	Intensity of project schedule
Tools & Methods	Applicability of project management methods & tools
	Variety of project management methods & tools
EXTERNAL COMPLEXITIES	
Economy	Changing economy
	Market competition
	Market unpredictability and uncertainty
Environment	Stability of project environment
	Interaction between technology system and external environment
Legal & Regulations	Local laws and regulations
Politics	Political influence
Social	Cultural configuration and variety
	Cultural differences
	Significance on public agenda

Kian's framework for energy projects considers a multitude of highly relevant factors in the industry. These encompass economic aspects like market competition and unpredictability, environmental factors requiring stability, as well as legal and regulatory considerations. Additionally, political and sociocultural elements significantly influence project decision-making and public perception. The framework also acknowledges the unique characteristics of energy projects, such as their complex objectives, technical aspects related to innovation and technology, and organizational and team aspects.

The review of these frameworks provides a comprehensive lens through which the complexities of energy transition projects can be viewed and analysed. This is crucial for this study, as it forms the foundation for a holistic understanding of the complexities in these projects. The frameworks not only offer a structured approach to identify and categorize complexities but also serve as a guide for developing tailored strategies to manage them effectively. This understanding is instrumental in driving the subsequent analysis in this thesis, particularly in identifying the complexities that are specific to energy transition projects. This would in turn help practitioners become aware of the complexities they could encounter in these projects and adopt management approaches that are tailored to address these specific complexities. Therefore, by integrating insights from these frameworks, this research aims to contribute to the more effective management of energy transition projects, thereby supporting the broader goal of accelerating the transition.

3.3 APPROACHES TO MANAGING PROJECT COMPLEXITY

Before exploring the various management approaches suggested in literature for managing complexity, it is important to establish a foundational understanding of what constitutes a 'management approach'. Literature indicates that, in the context of a project, a management approach refers to the methods, techniques, and strategies used to effectively plan, execute, and control projects. This is done in order to meet the objectives of the project as well as the expectations of the stakeholders. Additionally, It encompasses the project management framework, which includes stakeholders, process groups, knowledge areas, tools, techniques, project success, and the project's contribution to the success of the organization (Al Swaidi, 2023).

Koppenjan et al. (2011) suggest two approaches to managing complexity in the context of large engineering projects: a **predict & control approach**, regarded as **'Type 1'** and a **prepare & commit approach**, regarded as '**Type 2'** as shown in Table 2. The two approaches are formulated based on key features of the project and how the project team manages them (Paraschiv, 2023). The predict & control approach is perceived more as a traditional approach which focuses on meticulous planning and controlling mechanism, whereas the prepare & commit approach embraces a management style that is more organic in nature by considering the inherent complexities and uncertainties that are bound to arise in the context of large projects (Koppenjan et al., 2011).

Therefore, the 'predict & control' and 'prepare & commit' approaches are regarded as **'competing' approaches**. Additionally, the authors advocate for a combination of these two approaches to leverage their strengths and counteract the disadvantages when managing complexity in a project. For instance, the strong focus on front-end development from the Type 1 approach could be combined with the more functional role of the contractor from the Type 2 approach. This would involve the contractor in a more collaborative form, providing key insights to the decision-making process from the outset of the project (Koppenjan et al., 2011). Further information about these two approaches is provided in Appendix B.

TABLE 2: PREDICT & CONTROL AND PREPARE & COMMIT FROM PAGE 743, TABLE 1 OF KOPPENJAN ET AL. (2011)

Key Elements	Predict & Control (Type 1)	Prepare & Commit (Type 2)
Terms of Reference	Terms of Reference Blueprint	Functional
Task definition	Narrow for best control	Broad for best cooperation
Contract	Task execution	Functional realisation
Incentives	Work-task based	System-output based
Change	Limit as much as possible	Facilitate as much as needed
Steer	Hierarchical	Network
Information exchange	Limited, standardised	Open, unstructured
Interface management	Project management task	Shared task

In a similar perspective, Hertogh and Westerveld (2010) propose four approaches based on the level of detail or dynamic complexity as shown in table 3, with the 'systems management' approach paralleling the 'predict & control' strategy in its focus on control and breakdown of complex elements (Control oriented strategies). The 'interactive management' approach, suitable for dynamic complexity, mirrors the 'prepare & commit' approach, emphasizing stakeholder engagement and adaptability (Interaction oriented strategies). Both Hertogh and Westerveld (2010) and Koppenjan et al. (2011) advocate a combination of the competing management approaches to effectively deal with project complexity.

TABLE 3: MANAGEMENT APPROACHES FOR DETAIL & DYNAMIC COMPLEXITY BY HERTOGH AND WESTERVELD (2010)

DETAIL COMPLEXITY			
	HIGH	COMPLICATED	COMPLEX & COMPLICATED
		SYSTEMS MANAGEMENT	DYNAMIC MANAGEMENT
	LOW	SIMPLE	COMPLEX
		INTERNAL & CONTENT MANAGEMENT	INTERACTIVE MANAGEMENT
		LOW	HIGH
		DYNAMIC COMPLEXITY	

Table 4 shows a comparison between the strategies of ‘control’ and ‘interaction’ from page 291, Table 8.3 of Hertogh and Westerveld (2010).

TABLE 4: STRATEGIES OF CONTROL AND INTERACTION FROM PAGE 291, TABLE 8.3 OF HERTOGH AND WESTERVELD (2010)

Strategy	Control	Interaction
Problem	Unambiguous and fixed problem	Ambiguous perceptions of the problem
Goal	Fixed goal, determines direction and course	Goal is related to players and is likely to change. Fixed goals block creativity
Focus of management	Optimizing content (Schedule, cost & quality)	Satisfying needs
Structure	Unravelling makes sub-solutions possible (break down structures). From a selection of alternatives, one best alternative is chosen	Broadening and linking of needs leads to new opportunities. Variation of strategies (e.g. scenarios) leads to the ability to respond adequately to changes
Information	Objective, robust and analysable	Subjective, player related and negotiable
Schedule	Linear. Start with agreements on the content	Iterative. Start with process agreements
Decision making	Decision assures result and determines new phase	Decision is related to a specific moment (in time). Durability depends on forthcoming interactions
Relationship	Hierarchy, formal	Network, informal
Environment	Stable, independent players	Volatile, a network of interdependent players
Complexity perception	Threat	Opportunity

Bram Kool (2013) further combined these approaches into ‘control-oriented’ and ‘hands-off’ categories, advocating for a ‘combined’ or ‘dynamic’ approach that effectively integrates elements of both to manage complexity, as shown in figure 7. However, it's important to note that these approaches, while comprehensive, tend to be more theoretically oriented.

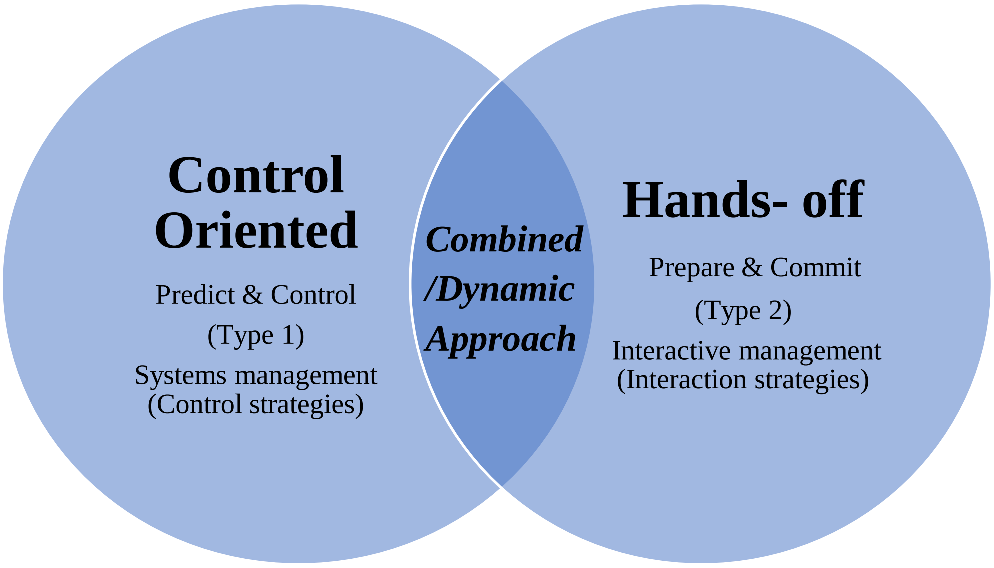


FIGURE 7: CONTROL ORIENTED, HANDS-OFF AND COMBINED MANAGEMENT APPROACHES (BRAM KOOL, 2013)

This recognition of the theoretical nature of previously discussed approaches prompted an exploration into more practically oriented approaches. In this context, a recent study by Kermanshachi et al. (2023) identified a notable gap in the current body of knowledge, specifically in the development of a well-rounded list of practical strategies for managing a wide variety of complexities encountered in construction projects. To address this gap, a two-round Delphi method was conducted to systematically collect expert opinions from practitioners with a cumulative experience of 250 years in construction projects, aiming to handpick the best strategies for managing project complexity. The management strategies were further categorized and combined under various complexity categories such as 'Stakeholder Management', 'Governance', 'Legal Considerations', 'Fiscal Planning', 'Interfaces', 'Scope Definition', 'Design and Technology', 'Project Resources & Quality', and 'Execution Targets', as shown in Table 5.

TABLE 5: MANAGEMENT STRATEGIES FROM KERMANSHACHI ET AL. (2023)

Complexity Categories	Management approaches
Stakeholder management	Governance Team for understanding and relaying stakeholder needs and value propositions
	Portfolio manager or Program manager to ensure consistent objectives
	Stakeholder Management plan for external stakeholders
	Engaging a consultant for liaising with external approving authorities
	Inspection engagement plan to procure the necessary approvals.

	Code compliance plan to make sure the design and all aspects of the project comply with the regulations
Governance	Establish a Joint-Venture Control Board for effective communication and coordination between the JV members and the project team
	Alignment Meetings between the joint venture members
	Formal Delegation of Authority Matrix for the Project manager to demarcate the boundaries for decision making
Legal Considerations	Formal Permitting and Regulatory Engagement Plan
	Benchmarking against similar construction activities
	Alternative locations or modifying the project design for easier permit approval
	Checklist of permit application requirements
	Obtaining preliminary feedback from approving authorities to avoid rework
	Incorporating a legal advisor into the project management team
Fiscal Planning	Developing a detailed funding plan to reduce funding uncertainties
	Clarifying roles and responsibilities for funding
Interface	Standardizing project management team structure for each phase.
	Developing a communication and document control plan for within and between project management teams.
Scope Definition	Utilizing advanced work packaging to develop an earned value deliverable-based measure
	Robust change management process
Design & Technology	Extending the front-end development phase
	Involvement of technology or innovation partners
	Pilot testing for novel technology
	Bringing in external consultants
	Licensing the technology
	Development of customized specifications for integrating new technology into existing operating facilities
	Forming cross-functional teams
	Documenting any differences encountered between old vs new operation systems
Project Resources & Quality	Creating a pool of subcontractors and suppliers that are prequalified
	Establishing strategic alliances with supply chain parties
	Implementing a recruitment plan for skilled resources
Execution targets	Establishing clear constraints for cost and scope

	Early procurement plan

The examination of various management approaches to project complexity, as delineated in this section, culminates in several key insights. The theoretical frameworks proposed by Koppenjan et al. (2011), Hertogh and Westerveld (2010), and Bram Kool (2013) highlight a range of approaches varying from 'predict & control' to 'prepare & commit', each tailored to the different degrees and types of complexities. These approaches, from the rigidly structured to the more fluid and adaptive, underscore the necessity of a combined or dynamic management style that can navigate the complexities in energy transition projects. Furthermore, the shift towards a more practically oriented approach, as evidenced in the study by Kermanshachi et al. (2023), reveals the importance of grounding theoretical management approaches in real-world experiences. Lastly, the understanding of these management approaches acts as a comparative lens which involves assessing how current practices in managing the complexities of energy transition projects align with or diverge from these established approaches. This sort of a comparison helps derive practical and actionable insights for the effective management of energy transition projects.

3.4 KEY TAKEAWAYS

The literature review suggests a lack of a unified definition of complexity. It also highlights that this ambiguity could potentially impact the perception and management of complexities within different contexts (Bosch-Rekveldt et al., 2018). This lack of clarity extends to the relationship between complexity, risk, and uncertainty. A major portion of the literature considers complexity as the source of uncertainty, while some suggest the reverse, and others propose that they are independent concepts (Atkinson et al., 2006; Daniel & Daniel, 2018; Danilovic & Browning, 2007; Dikmen et al., 2021; Geraldi et al., 2011; Müller et al., 2007; Shenhar, 2001; Sommer & Loch, 2004; Williams et al., 1995). Similarly, with risk and complexity, some literature suggests that risk contributes to complexity and vice versa, while some propose a bidirectional relationship (Bosch-Rekveldt, 2011; Erol et al., 2020; Geraldi et al., 2011; Kian Manesh Rad et al., 2017; Turner & Cochrane, 1993; Vidal & Marle, 2008). Therefore, for this thesis, uncertainty and risk will be considered as components of complexity, and the following definitions of complexity, risk, and uncertainty will be adopted:

"Complexity is a characteristic of a project, attributed by an intricate arrangement of interrelated parts, encompassing technological, organizational, and environmental elements, all subject to evolution, and impacting one or more project objectives (Bakhshi et al., 2016; Bosch-Rekveldt et al., 2011; Cicmil & Marshall, 2005; Geraldi, 2009; Jaafari, 2003; Vidal & Marle, 2008; Williams, 1999; Xia & Lee, 2004)."

"Uncertainty is a lack of predictability or knowledge spanning across the various stages of a project(Jaafari, 2001; Taipalus et al., 2020; Wideman, 1992; Winch, 2015)."

"Risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives (Institute., 2021)."

Furthermore, the literature suggests a strong link between complexity, front-end development, and project performance, with a key finding that complexity acts as a moderator between front-end development and performance (Bosch-Rekveldt, 2011). This highlights the need to focus on the front-end development phase in order to manage complexity and thereby improve or ensure project performance.

The study provided valuable insights into various frameworks for identifying project complexity. These include the TOE framework by Bosch-Rekveldt et al. (2011), which encompasses 47 complexity elements, the TO framework by Vidal et al. (2011) with 18 complexity elements, and the integrated framework by Geraldi et al. (2011), which categorizes complexities into five distinct domains: 'structural', 'uncertainty', 'dynamics', 'pace', and 'socio-political'. He et al. (2015) further expanded the complexity understanding with a framework comprising 28 elements under categories such as technological, organizational, goal-oriented, environmental, cultural, and informational complexities. Among these, the framework developed by Kian Manesh Rad et al. (2017) is particularly relevant to this study as they integrate and tailor the various frameworks mentioned above to energy related projects, offering a comprehensive list of 51 complexity elements, making it the most encompassing and recent framework.

However, despite its comprehensiveness and focus on energy projects, this framework presents certain gaps that need addressing. First, it was developed primarily in the context of megaprojects, which may not fully represent the scope and nature of energy transition projects, many of which are in their nascent stages and do not necessarily qualify as megaprojects (Toonen, 2022). Second, the framework is predominantly based on case studies from the oil & gas and renewable energy sectors, but energy transition projects are not limited to renewable energy projects (Kemp, 2010). These gaps highlight the need for a deeper understanding of the specific complexities encountered in practical settings of energy transition projects.

The identification of specific complexities is crucial for practitioners to gain a comprehensive awareness of the complexities to be expected and adopt appropriate management approaches needed to navigate them. This, in turn, will facilitate the progression of energy transition projects. Therefore, further empirical study was needed to test and validate the applicability of the framework of complexities developed by Kian Manesh Rad et al. (2017), as shown in Table 6, to Energy transition projects.

TABLE 6: INTERNAL AND EXTERNAL COMPLEXITIES BY KIAN MANESH RAD ET AL. (2017)

Internal complexities	External Complexities
Objectives	Economy
Technical	Environment
Capital resources	Legal & regulations
Disciplines	Politics
People	Social
Physical resources	
Information	
Tasks	
Time	
Tools & methods	

When examining existing management approaches, literature suggests two main perspectives: one being theoretically oriented and the other practically oriented. Theoretically oriented approaches, namely the control-oriented and hands-off approaches, are often combined into what is known as the Combined or Dynamic approach, as advocated by Bram Kool (2013), Hertogh & Westerveld (2010), and Koppenjan et al. (2011), to effectively deal with project complexities. However, as reiterated, energy transition projects have distinct features compared to conventional energy projects (Toonen, 2022). Consequently, researchers such as Bosch-Rekveldt (2011), Engwall (2003), Sauser et al. (2009), Shenhar & Dvir (1996), Smyth & Morris (2007), and Williams (2005) suggest adapting project management approaches to the specific characteristics and context of each project to improve performance. Additionally, Gatzert and Kosub (2016) emphasized the need for a holistic management approach that considers the distinctive features of energy transition projects, noting that failing to do so poses a significant risk to sustainability and organizational success (Toonen, 2022). This underscores a gap in understanding how existing management approaches can be tailored to the complexities and characteristics specific to energy transition projects.

On the practical side, Kermanshachi et al. (2023) identified various strategies for managing different complexity categories. However, these strategies were developed in the context of large construction projects, leading to a gap in understanding the specific management strategies suitable for energy transition projects in practical settings. Therefore, further empirical study was necessary to fill this knowledge gap, which would, in turn, help guide practitioners with actionable insights for effectively managing the complexities in energy transition projects.

Furthermore, although the overarching differences between energy transition projects and traditional energy projects are evident, there remains a gap in understanding these distinctions, particularly in the context of project complexities and their associated management approaches. Additionally, while existing literature provides a comprehensive overview of complexities and various management approaches, it often lacks specific insights into the real-world challenges and opportunities that practitioners face when managing complexities, especially in the context of energy transition projects. Consequently, there is a need for empirical research to bridge this gap. Such a study would not only shed light on the specific challenges of managing energy transition projects but also enable the adaptation of management approaches based on the practical experiences of practitioners.

4 EMPIRICAL STUDY

This chapter presents the methodology undertaken to conduct the empirical study. The first section, 4.1 Questionnaire Design, delves into what was asked during the semi-structured interviews and, more importantly, why. This is followed by Section 4.2, which details the selection of interviewees. Lastly, Section 4.3 describes the step-by-step approach used to analyse the interview data.

4.1 THEME DEVELOPMENT & QUESTIONNAIRE DESIGN

Based on the literature study, several themes were identified from the gap in the existing literature. Literature highlighted several frameworks for complexities in projects and specifically in energy related projects. However, a gap was identified in understanding the specific or major complexities in energy transition projects, and how these complexities differ from those in conventional energy projects, particularly in the practical setting, leading to the theme of '***Understanding the unique complexities in Energy Transition Projects'***. Secondly, while literature clarified existing management approaches, there was a significant gap in understanding the management approaches that are tailored to the complexities and characteristics of energy transition projects. This led to the second theme, '***Tailored management approaches for energy transition projects***.' Furthermore, although literature provided an overview of managing complexity, it lacked specific insights into the challenges and opportunities practitioners face when managing complexity in the context of energy transition projects, essentially forming the lessons they learned for future projects. This resulted in the third theme of '***Lessons Learned from energy transition projects***.' Lastly, literature highlights the overarching differences between energy transition projects and conventional energy projects. However, a gap is observed in understanding this comparison in the context of complexities and their subsequent management approaches, leading to the subtheme of ***'Comparison with conventional energy projects'***. This empirical approach is meticulously designed to directly address the gaps found in existing literature on energy transition projects. By employing semi-structured interviews, this research aims to enrich the current body of knowledge's understanding of the unique complexities and management approaches within these projects, ensuring that the findings are both academically robust and practically relevant.

Therefore, these themes, along with the research questions, served as a guide for the interview protocol, as shown in Appendix B. The interview protocol was structured to capture the element of *"how is it in practice?"* by asking for specific examples to encourage introspection and context understanding. It began with a brief introduction, followed by questions to understand complexities in energy transition projects. These questions aimed to uncover the practitioners' perceptions of complexity and delve into specific examples. A similar process was used to identify management approaches, comparing them with those in conventional energy projects. The interview protocol then explored the challenges and opportunities faced and prompted reflection on the lessons the practitioners would carry into future energy transition projects. This approach ensured the interviews focused not only on current practices but also provided actionable insights on adapting existing management approaches. These interviews lasted 60 minutes and were held in-person.

4.2 PRACTIONER SELECTION

To obtain a comprehensive understanding of complexity management in energy transition projects, semi-structured Interviews were conducted with nine **project managers (PM)** from Fluor B.V. Their roles and expertise made them ideal candidates to discuss the main themes of the study, as they could offer valuable insights on the practical aspects of complexity, contribute to various perspectives on the management approaches employed, and share firsthand accounts of challenges, opportunities, and lessons learned.

Recognizing the collaborative and multidisciplinary nature of managing complexity in energy transition projects, these project managers directed me to other roles within their teams and organizations as part of their delegation strategy for managing complexity. **Contract Managers (CM)**, **Sales Managers (SM)**, **Clients (CL)**, **Engineering Managers (EM)**, **Project Controls (PC)**, and **Process Directors (PD)** were among these additional roles. This resulted in a second round of interviews, bringing the total to 18 as shown in table 7, thereby enhancing the study with an in-depth understanding of the management of complexities in energy transition projects.

TABLE 7: PRACTITIONER SELECTION

Role	Years of Experience	Description
PM1	26	Started as a lead engineer in the electrical and control systems department at Fluor. Over the last 10 years, has transitioned into a project manager role, overseeing a diverse portfolio of both traditional and energy transition projects.
PM2	35 +	Started as a general manager of operations at Fluor and transitioned through various roles and locations within the company. These roles included serving as deputy general manager for the Spain division, operations manager, general manager for the European headquarters, and he currently holds the position of Executive Project Director at Fluor B.V.
PM3	23+	Started as a project engineer and later transitioned into the role of Civil and Structural Lead with Technip and eventually joined Fluor B.V as a Project Director for 15 years. Until recently, also held the position of Operational Head for Fluor B. V's Energy Transition Business Line.
PM4	30+	Started in various positions and assumed increasing responsibilities in project management and line management across various organizations, including Fluor. Within Fluor B.V, has progressed through different roles, starting as a (Lead) Project Engineer, advancing to Project Engineering Manager, and subsequently to Project Manager. Currently, holds the position of Executive Project Director.
PM5	33	Transitioned into various roles before current role as project director at Fluor B.V.
PM6	32	Started as an engineering manager before transitioning into his current role of Project director. Has worked in various chemicals, oil & gas and energy transition projects.
PM7	12	Started as a mechanical engineer before transitioning into current role as a project manager.
PM8	35+	Started as a production engineer before transitioning various roles and is currently a project director at Fluor B. V
PM9	29	Started as a piping engineer in Fluor B.V before transitioning into current role of project manager.
SM1	20+	Started as a junior organizational change and communication manager at Fluor B.V before transitioning through various roles and is currently the Executive director, Business development & strategy for Energy solutions. Also, the Sales head of the Energy transition strategic group within Fluor.

SM2	20	Started as a structural engineering before transitioning through various roles and is currently the director of sales and business development at Fluor B.V.
CM1	15+	Started as contracts engineer before transitioning into various roles and is currently the Commercial strategies lead at Fluor B. V
CM2	20	Started as a project buyer before transitioning various roles in the procurement department and is currently a contract manager at Fluor B. V
PC1	25+	Started as a lead cost controller before transitioning various roles and is currently the Project controls manager for decarbonization programs at Fluor B. V
PC2	25+	Started as a technical manager before transitioning various roles and is currently the senior project controls specialist at Fluor B. V
PD1	35+	Current senior process director at Fluor B.V and also the technical head of the energy transition strategic group
EM1	15+	Started as a process manager before transitioning into various roles within the engineering department and is currently an Engineering manager at Fluor. Until recently, was also the operational head of the energy transition strategic group
CL1	25+	Current contract manager at Gasunie

4.3 Data Analysis

For the data analysis section of this study, a methodical and multi-step approach was used to assure a solid interpretation of the empirical data gathered from the interviews. Initially, all interviews were transcribed using specialized transcription software to convert the audio recordings into textual data. This offered a dependable and easily accessible format for in-depth analysis.

In order to acquire a nuanced understanding of the interviewees' perspectives, each transcript was read carefully two to three times after transcription. This iterative reading process facilitated an intimate familiarity with the data and help read 'between the lines' which was essential for identifying initial patterns and emerging themes associated with managing complexity in energy transition projects.

The subsequent phase consisted of a structured thematic analysis, which was performed using the software for qualitative data analysis, Atlas.ti. During this stage, codes were assigned to specific sections of the transcripts based on the interpretation of the interviewees' statements. These codes served as initial analytic units that captured the essence of the respondents' statements and helped organize the data for further analysis.

Following the initial understanding of these interrelations between the codes, the codes were organized into second-order themes based on the themes identified from literature and the research questions, a list of which has been provided in Appendix B. This step of the thematic analysis facilitated the categorization of the data into meaningful clusters, thereby facilitating a more in-depth comprehension of the main themes that emerged from the interviews as shown in Figure 8. These second-order themes ultimately served as the basis for this study's empirical findings, providing valuable insights into addressing complexities in energy transition project.

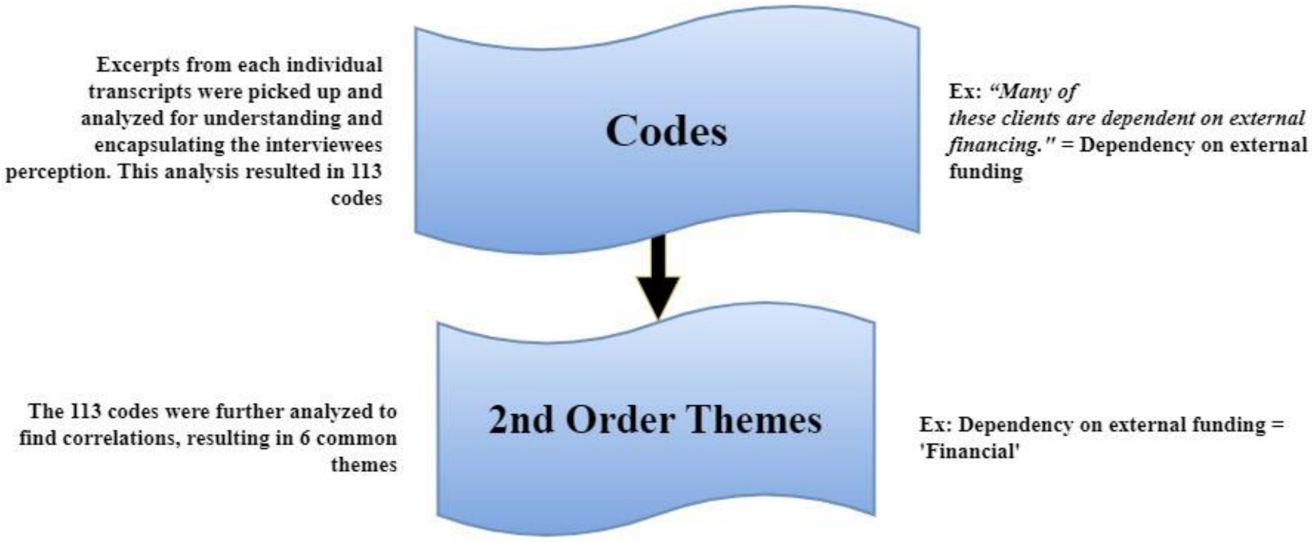


FIGURE 8: SCHEMATIC REPRESENTATION OF THEMATIC ANALYSIS CONDUCTED

When combining the 113 codes identified into second-order themes, six primary themes emerged. These are related to the 'people involved in energy transition projects,' the 'technology involved,' the 'financial' theme, the 'legal & regulatory' theme, the 'resource' theme, and finally, the 'project management and execution methods' theme. Table 8 displays the ranking of each of these themes based on the number of quotations that directly or indirectly addressed the aspect, the number of participants who mentioned this theme, and an excerpt of the type of statements used to arrive at these themes.

TABLE 8: WEIGHTAGE OF SECOND ORDER THEMES BASED ON SEMI-STRUCTURED INTERVIEWS FROM ATLAS.TI

Ranking	Themes	No. of Quotations (/256)	No. of participants (/18)	Example of statements
1	**People**	75	18	*"- According to me, complexity in these projects is where a lot of different parties are getting involved, parties or people, then things become complex."* *"- However, in these energy transition projects, clients like to have a specific way of working, and when we present our work process, they may scrutinize it, question it, express disbelief".* *"- It's what we do for a living. Yeah, that's our job in these projects: making complex matters easy in these projects. However, if you keep it complex, with many people involved, the content becomes more complex, and more people become involved without a clear direction, leading to things going wrong. It's the fundamental principle of project management."* *"- Defending our work process can be quite energy-consuming, and it took about a month to complete. This project is under heavy scrutiny, but it's gradually becoming more stable."* *"- One very important aspect is that it was not a pleasant exercise. Everything in the schedule was challenged, including work processes. the position that clients Typically like to take is "you know how it works, then we tell them how we work".* *"- In my current case, I'm dealing with a mix of clients. Some of them are quite knowledgeable, while others can only read a schedule and may ask, " when is it done?" "Can you give me that now?" No contribution on the content."* *"- In my experience, it takes a while when you work with new clients to establish discipline, build relations, and gain trust. People may naturally question, "Why would I listen to you if I don't know you?" So, there's always this trust factor that has to be built."* *"- There is a complete misunderstanding between these parties on a personal level."* *"- The complexity of misunderstanding and the need to navigate it is something that I encounter frequently. I experience it on an ongoing basis, almost every hour."* *"- projects' engagement with technology providers. These projects need to collaborate with a technology provider".*

2	**Technical**	67	14	*"- Technology requirements are often unclear in these projects"* *"- While technology is the biggest challenge in this project, there is also the issue of a lack of clear regulations to provide a framework for the work. This absence of guidelines makes it difficult to determine the project's strategy* *"- Most of the time that technologies are not mature yet. You don't have that much data."* *"- All right. The pressure was on them to develop the technology that could be scaled up to produce larger quantities of hydrogen. Additionally, they were seeking reassurances that their investment would be recouped by establishing a partnership with the project owners. This would allow them to sell their machines and receive a return on their investment."* *"- Okay, this is what the plant From a technology perspective management, the point is, of course, you can have a technology, you can have to say, "Okay, this is what the plant would look like, which can produce a, b, and c," but ultimately, it's to develop it from an idea to something that you can finance completely."*

3	**Financial**	50	13	*"- I believe the main challenge for these projects is the cost."* "*- the most complex factor that I've encountered in a project falling under the energy transition, I think, is financing requirements. This complexity is new for us."* *"- "When a project is financed, the requirements for delivery predictability become much higher, with a strong emphasis on scope definition, estimating, EPC planning, which all need to go deeper for the financing process. As soon as you involve external financial entities like banks or other lenders, it adds to the complexity."* *"- You can see that clients are struggling to secure Final Investment Decisions (FIDs)"* *"- Some clients have substantial financial resources and a strong desire to invest, while others are waiting for a solid business case to emerge."* *"Many of these clients are dependent on external financing."* *"So, these are finance projects, and finance projects typically have longer approval cycles. The funding is not always readily available upfront. Therefore, they need to start with limited funding."* *"- but in the end, it often comes down to whether it is also financially viable."* *"- I think one complexity is indeed providing sufficient definition in a broad sense to make the project bankable. To allow the client to reach financial close and make a final investment decision."* *"- They're talking about banks or financing institutes, if not even governmental authorities if there is public funding involved in a specific project, they need some requirements. So, in terms of an estimate, in terms of an investment estimate, but also in terms of offtake agreements being in place, in terms of how this project is realistic."* *"- Now, of course, in the case of new products like green steel, the client still wants to be the first of them on the market. But in order to do that, they need to secure funding, so they have to comply with the requirements of the lenders."*
4	**Resources**	44	9	*"- you see nowadays more suppliers the subcontractors are going bankrupt."* *"- Labor accessibility might also pose challenges."* *"- Additionally, for projects involving biofuels, there's the issue of sourcing raw materials, which should not compete with food production. These projects need to secure their feedstock, which can become a strategic concern. Supply chain complexity is definitely a factor, especially when it comes to feedstock security."* *"- market dynamics are affecting the supply chain"* *"- The prices of the steel to build a facility, cables, the equipment – you name it, everything you need it's very volatile. As the trend has been happening, it is also the observation that we had a slow market from 2017 to 2021".*

5	**Legal & Regulations**	20	7	*"- There is considerable uncertainty in the market related to subsidies,"* *"- Another issue I've observed is that subsidies can introduce delays and uncertainties into the project due to their unpredictable nature. This adds another layer of complexity to the management process."* *"- Clients often negotiate to secure as much subsidy as possible. There is an ongoing negotiation, and they may avoid showing too much commitment prematurely, fearing that it might harm their chances of negotiating favorable subsidies."* *"- In some cases, there's a fair amount of subsidizing or new legislation that needs to be adhered to. So, there is a huge amount of focus on this. The interesting thing is that the result of energy transition, or is energy transition taking place in this perfect storm? Right now, it's almost a chicken and egg situation."* *"- Definitely, without subsidies, many of these projects wouldn't move forward."* *"- The complexity of the project requires an in-depth understanding of regulations. Regulations play a pivotal role in shaping the strategy for this new project. Whether you are proposing a new strategy to your client or you are the owner developing the strategy."* *"- While technology is the biggest challenge in this project, there is also the issue of a lack of clear regulations to provide a framework for the work. This absence of guidelines makes it difficult to determine the project's strategy."* *"Absolutely, one example that comes to mind is the permitting stage. When the decision and business case are made to start a project, the first major challenge we encounter is dealing with all the necessary permitting conditions. This involves a significant amount of documentation and studies. Initiating the permitting procedure itself is a challenging step, and if successful, it comes with a multitude of conditions. So, the complexity of the project is greatly influenced by the permitting stage."* *"I would say yes, the permitting stage is a complex and necessary phase for all kinds of infrastructure projects. However, in the context of energy transition, the complexity can be even greater. There's often more at stake."*

6	**Project management & execution methods**	11	7	*"Metals pay less attention to detailed definition in the Front-End Engineering Design (FEED) stage, while they focus more on client management and client relations. In energy solutions, the emphasis is on the accuracy of the FEED package, and we pay less attention to building relationships with clients."* *"- Another challenge could be that a specific project requires a completely different approach than what we've used in our traditional oil and gas projects. Our systems and procedures may not be equipped for these differences. "* *"As I said, I've worked on projects where the pressure was so high that we were convinced that there was a high level of concurrency to reach a certain point in your project, and the level of maturity means that the various disciplines basically work next to each other. Ideally, it is that the first discipline finishes a process, and when the process is at a certain point of maturity, they're given the data to the other discipline. For example, processes and mechanical. But if you don't have the time, you need to do things more in parallel, which requires you to manage the change. So, if a process says, 'I'm not finished, but you can use this data already right now,' then mechanical starts working on that data."* *"There was a misunderstanding and misalignment of the expectations, on the management terminology used where the same words mean different things coming from different businesses. So essentially, using the same words with different meanings."*

5 RESULTS

This chapter presents the results of the empirical study, which explored various themes. It starts with the process of identifying complexity in practice in Section 5.1. This is followed by an examination of the complexities, management approaches, challenges, and opportunities related to people aspect (Section 5.2), technical aspects (Section 5.3), financial aspects (Section 5.4), legal and regulatory aspects (Section 5.5), resource aspect (Section 5.6), and project management and execution methods (Section 5.7) in the context of energy transition projects from practical settings, with the people aspect observed through all the other aspects as well. Each subsection also delves into how it was with conventional energy projects and how it is now with energy transition projects. Additionally, throughout this chapter, the interviewees are referred to as participants or practitioners interchangeably.

5.1 COMPLEXITY IDENTIFICATION

The complexity identification and assessment process by participants plays a pivotal role in managing project risks and steering the project towards success. PM2 emphasized the intertwined nature of complexity and risk assessment: *"Complexity requires management, but what drives that management? It's the identification of potential risks stemming from that complexity."* Essentially adopting a **complexity-based risk assessment**.

PC1 illustrated the methodology of complexity assessment in their organization, highlighting that it is a standard practice during the proposal stage. They described how **specialists** perform a risk assessment for each project, regardless of its nature. This process involves evaluating and classifying the project's risk level based on its inherent complexities.

PM2 further detailed this process, noting that it's designed to identify risks affecting both the project owner and the project itself. This comprehensive assessment directly influences the project's success and bottom line, ensuring that all potential complexities are accounted for and addressed appropriately.

PM8 discussed the approach of going through the entire project chain to identify key parameters that can help fix the revenue stream and minimize risks. This method **involves contract and phase-based assessments**, where project leadership engages in brainstorming sessions to pinpoint complexities. The goal is to not only identify risks emerging from these complexities but also to characterize the complexities to decide on the most appropriate management approach.

5.2 SEQUENCE & INTERPLAY

The results of the empirical study revealed the interconnected and interdependent nature of the various themes as shown in figure 9. The 'people' theme was prevalent across all other aspects. For example, there was a dependency on technology providers in the 'technology' aspect, a reliance on banks, investors, and government officials for funding and subsidies in the 'financial' theme, a dependency on permitting authorities for obtaining necessary permits in the 'legal & regulatory' theme, and finally, the work approaches of different individuals involved in the 'project management and execution' theme.

Firstly, through the interview results it was evident that when clients approach, the initial aspect assessed is the technology, specifically the idea that needs development. This technology then depends on its viability or financial feasibility, which in turn is contingent on the subsidy component linked to the legal & regulatory aspect. This legal aspect is also connected to the technology aspect, as practitioners note a lack of clear regulations to understand which technology will prevail, creating a sense of boundary ambiguity in these projects. Given the time pressure characteristic of these projects, practitioners noted the need to provide estimates much earlier, even before proper design completion, so that clients can present them to their funding institutions for approval. Additionally, practitioners observed that various financial institutions have their own requirements that must be incorporated, typically demanding a high level of project definition to assess and approve funding. This requirement creates a dependency on the resource aspect, as they need to consult key supply chain parties to include their bids in the estimation.

Similarly, the resource aspect depends on the financial aspect, as these key supply chain parties also rely on the availability of project funding and the presence of offtakers for their products. Lastly, once practitioners have successfully navigated these various themes, they must assess their project management and execution methods, as individuals involved in these projects have their own work approaches and terminologies. Therefore, they need to align these and scale down their execution methods for energy transition projects. This highlights the high interdependencies among these themes when managing an energy transition project, underscoring the need to thoroughly understand each theme and its interplay with the others. In essence, understanding figure 9 is a crucial first step for a holistic management approach, based on which the guiding steps were developed for navigating the complexities in energy transition projects. Therefore, the subsequent sections delve into each theme's complexities, management approaches, challenges, opportunities, and lessons learned, providing a comprehensive understanding of their collective impact on energy transition projects.

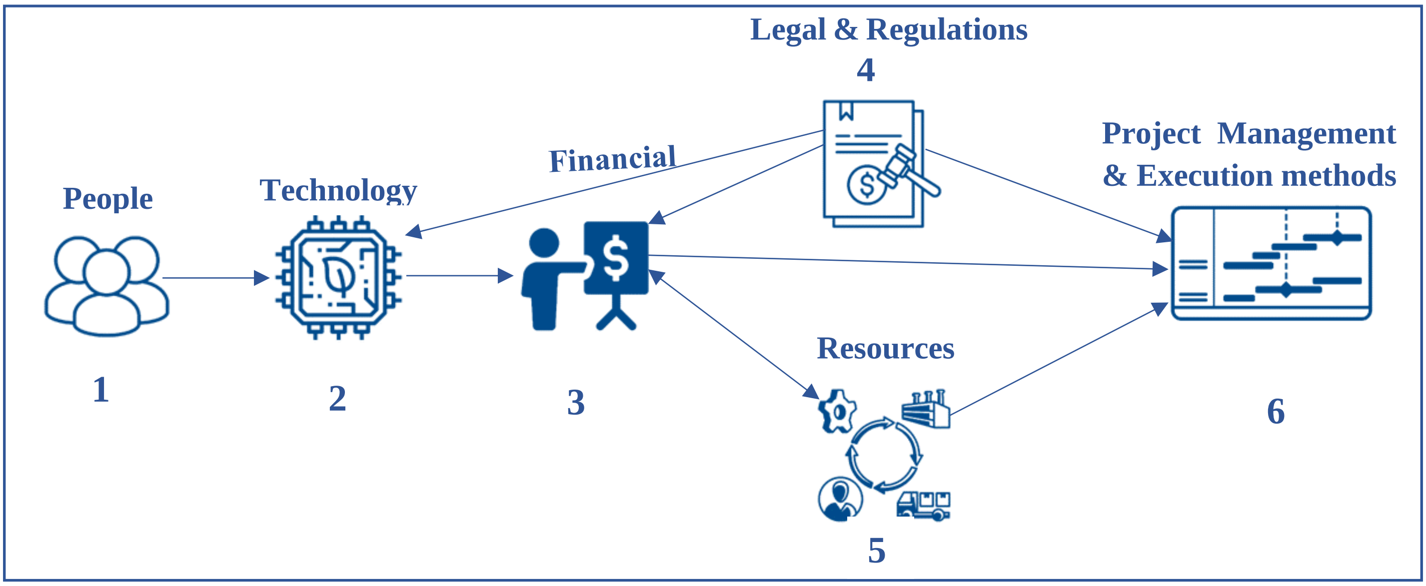


FIGURE 9: SEQUENCE & INTERPLAY BETWEEN THE VARIOUS THEMES

5.3 PEOPLE

5.3.1 COMPLEXITY INDICATORS

In exploring the complexities of energy transition projects, a major and first theme that emerged was the 'people aspect', particularly the diverse nature of clients involved as shown in figure 10. These projects often present a new frontier for many clients, each category bringing its own unique challenges and experiences to these projects.

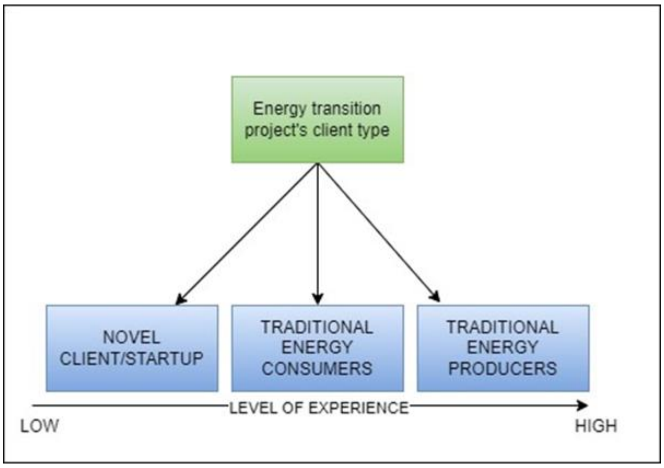


FIGURE 10: DIFFERENT TYPES OF CLIENTS IN ENERGY TRANSITION PROJECTS AND THEIR LEVEL OF EXPERIENCE

The first category, '**new entrants or startups'**, often includes smaller companies looking to scale up their technology or entities that are spin-offs of larger corporations. These clients typically exhibit the least experience in managing energy transition projects. A recurring issue with these clients is their lack of organizational structure, which often results in project delays as project managers scramble to find appropriate counterparts for project initiation as PM1 notes *" They are in the phase of being established, getting the organization set up, and that is a different sort of client compared to the traditional energy sector. That is a key difference that adds to the complexity."* Furthermore, these startups are heavily reliant on external financing, such as venture capital or government subsidies, which come with their own stringent requirements.

The second category comprises '**traditional energy consumers'**, like steel producers transitioning to green energy for their production processes. Despite their established presence in their respective industries, these clients often find themselves navigating unfamiliar territory with energy transition projects. Their experience in their domain doesn't necessarily translate to expertise in energy transition as PM4 states *"When explaining something to someone who has never done it before, it's like teaching them a sport like soccer or hockey. They may understand the basics, but there's a massive gap between that and leading a professional team."*

Then there are the '**traditional energy producers'**, such as Shell or Exxon, who are now pivoting to produce more sustainable forms of energy. These clients usually bring a wealth of experience to their projects, often comprising in-house engineering departments, which reduces their dependence on external stakeholders.

A notable variety was observed not only in the types of clients involved in energy transition projects but also in the factors driving their involvement, marking a stark contrast to traditional energy projects. PM5 insightfully drew an analogy, stating, *"When comparing an EV-car and a diesel car, the primary* *difference lies in what powers them. Once they start moving, their function is the same: to drive."* This comparison underscores that while the key distinction in energy transition projects lies in the varied motivations of the clients, once these projects reach the execution phase, they operate similarly to any other energy project. Four major drivers or motivation to invest and implement energy transition projects were identified. First is **time**, particularly the time to market. This is crucial for clients like startups who are scaling their niche technologies, where being first to market offers a competitive edge. The second driver is **financial incentives**, such as government monetary incentives for emission reduction, subsidies, or basic profitability. The third driver is **regulatory adherence**, especially in light of the 2050 Paris Agreement. Clients need to comply with numerous regulations put in place as part of this commitment. Finally, **public opinion** plays a significant role. With a shifting public mindset towards environmental issues, many companies are keen to enhance their green image. Participants noted the importance of understanding each of these drivers and tailoring their approach accordingly. However, PM6 pointed out a complication: while the overarching drivers might be identifiable, it's challenging to ascertain the underlying factors driving each client, adding another layer of complexity to managing these projects.

A striking observation from 6 out of the 18 interview participants was the common theme of a **lack of trust** in contractors, which permeates across all client types. This lack of trust is especially pronounced with startups or traditional energy consumers who might not have previously engaged with contractors like Fluor. Even with traditional energy producers, each new project type requires building trust from the ground up. This contrasts with traditional energy projects, where clients often come with a clear vision and established trust, making the contractor's role more straightforward.

Interview with a client to understand their perspective for this lack of trust revealed a sense of vulnerability due to their limited knowledge with energy transition projects. Venturing into these uncharted territories often makes clients feel less in control, leading to a reliance on contractors for expertise and guidance. This dynamic makes the clients feel that most of the power is placed on one entity, fearing potential opportunistic behaviour from the contractor's side leading to a lack of trust.

The theme of inexperience was also more pronounced in energy transition projects as observed by 10 out of the 18 interview participants. Inexperience in this context refers to the relative lack of experience among stakeholders involved in energy transition projects compared to traditional energy projects, where decades of experience have been accumulated, resulting in tried-and-tested practices and knowledge. This disparity in experience levels introduces distinctive challenges and complexities, as established practices and knowledge may not readily apply to the novel context of energy transition projects. Lastly, the results of the empirical study also highlighted a **dependency on external stakeholders** such as technology providers for the technology aspect, or investors, government funding authorities, venture capitalists for the financial aspect, permitting officials for the legal & regulations aspect, manufactures, subcontractors, and key supply chain parties for the resource aspect.

Therefore, the complexities identified in energy transition projects related to the people aspect can be summarised as ***'Varying client types', 'Varying client drivers', 'Lack of experience', 'Lack of trust', and 'Unclarity regarding objectives***.

5.3.2 MANAGEMENT APPROACH EMPLOYED IN PRACTICE

The findings regarding the management approaches applied in practice revealed a notable shift in approaches for addressing the people aspect of complexities in energy transition projects. These approaches were seen to differ based on the type of client, their drivers, and the specific stage of the project. The following outlines the management approach adopted across different phases of these projects, spanning from initial client engagement to the various stages of the front-end development.

In the initial proposal phase of energy transition projects, a significant shift was observed in client engagement approaches. Traditionally, clients would approach companies like Fluor with a set project vision, necessitating a reactive response. However, with energy transition projects, the emergence of new clients unfamiliar with engineering and construction companies like Fluor called for a **proactive approach**. According to PD1, this proactive strategy entailed extensive market research to identify new clients, followed by strategic outreach at conferences and networking events, aiming to demonstrate their capabilities in handling energy transition projects.

According to SM1 and 2, to facilitate this proactive engagement, **strategic groups** were formed, each concentrating on a specific market within the energy transition sector. These groups, composed of professionals from sales, operations, and technology, leverage their collective expertise to effectively engage with the market. Their responsibilities were strategically designed to showcase the organization's competencies at each project phase: sales experts focused on market opportunities, operational members evaluated the company's operational capabilities and needs, and technology specialists concentrated on managing various technological aspects. Considering the lack of knowledge in these projects for companies like Fluor as well, these groups were formed to also build internal expertise and maintain their current awareness of the different market dynamics and evolving changes.

PD1 noted a significant shift from standard practices, with contractors proactively suggesting project ideas, moving away from the traditional client-initiated conversation model. This change marks a crucial transition from the reactive nature of traditional energy project management to a more proactive engagement model in energy transition projects. According to SM2, this proactive engagement strategy was not limited solely to new or non-traditional clients but also extended to established clients in the traditional energy sector with whom companies like Fluor have long standing relationships. Therefore, this expansion of proactive engagement practices could be observed to encompasses all clients, regardless of their background or previous engagement with the company.

Beyond the proposal stage, the focus of the interview participants could be observed to shift to **early and continuous engagement** with clients. This, according to PM5, involves a thorough understanding of client requirements and drivers, such as time-to-market or regulatory compliance and tailoring the approach accordingly. For clients who are unclear about their objectives or lack experience in energy transition projects, strategic groups (EM1, PD1, SM1&2), Project control specialists (PC1 &2) and Project managers (PM 4,5&7) adopted an **educational approach**. They assisted clients in understanding the various stages of project development and conducted workshops on relevant tools and methodologies. PM1 emphasized the need for continuous communication with the clients to validate assumptions and prevent misunderstandings at later stages of the project. This approach could also be considered as a shift from traditional energy project management where the role of contractor was more following what was assigned to them rather than guiding the client with them.

12 out of the 18 participants also highlighted the critical role of external stakeholders in the context of client engagement for financial or regulatory reasons. Therefore, following the early client engagement phase, PM9 employed a **robust stakeholder framework**. This framework was specifically designed to scrutinize the varieties and interdependencies of these stakeholders. Its implementation aimed to ensure that all relevant perspectives and requirements were comprehensively integrated into the project management approach, acknowledging the significant influence these stakeholders have on the direction of energy transition projects.

Considering the main complexity of trust, PM3 tried **establishing allies** within the client's organization. However, this approach had its limitations due to the clients' existing commitments to external stakeholders. An alternative method, known as the **'zipper approach'** was employed by PM1 which involved aligning efforts at every level between the client and the contractor teams to establish a level of trust between both sides, this approach was also deemed as a best practice amongst the other participants. However, the participants also noted that the efficacy of these various approaches also depends on the client's mindset and the nature of their organizations.

5.3.3 LINK TO EXISTING MANAGEMENT APPROACHES

The management approaches identified from practice for the people aspect are further linked to the existing management approaches of Control, Hands-off and Combined approach as shown below (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011).

CONTROL ORIENTED APPROACH (PREDICT & CONTROL/SYSTEMS MANAGEMENT)

None of the practical management approaches of the people aspect were observed to align with the control-oriented approach.

HANDS-OFF APPROACH (PREPARE & COMMIT/INTERACTIVE MANAGEMENT)

PROACTIVE CLIENT ENGAGEMENT: In conventional energy projects, contractors responding reactively to clients with a set vision signify a more control-oriented approach. This approach emphasis well-defined structures and plans, where the contractor's role is less about being a key member and shaping the project's vision and more about delivering specific tasks within the constraints of the pre-established, scope, time, and cost. However, in energy transition projects, a shift can be observed towards a more proactive strategy. This includes market engagement, strategic outreach, networking, and contractors suggesting project ideas, aligning more with the Hands-off approach. Characterized by flexibility, adaptability and a forward-thinking perspective, this approach which a departure from the rigid, plan-focussed mindset of the control approach and more towards a more adaptive and collaborative method.

EDUCATIONAL APPROACH WITH CLIENTS: Educating clients and helping them understand project stages and tools with the use of workshops and webinars aligns with the interactive, collaborative nature of the hands-off approach. It focusses on understanding and aligning the stakeholder's perspectives and expectations.

COMBINED APPROACH

FORMATION OF STRATEGIC GROUPS: This strategy combines the elements of both Control oriented and Hands-off approach, essentially employing a combined approach. The need to create predictability by deploying the strategic groups into various energy transition projects to gain knowledge and utilize established strengths to demonstrate capabilities in a structure manner signifies the control-oriented approach. While the formation of the strategic groups is structured, their purpose to adapt to and engage with the evolving market dynamics, reflects the adaptive nature of the Hands-off approach.

EARLY AND CONTINUOUS ENGAGEMENT WITH CLIENTS: This strategy demonstrates a combined approach. It integrates elements of both control (strong focus on front end development to understand client requirements and tailoring approach) and interaction (continuous communication and validation of assumptions).

ROBUST STAKEHOLDER FRAMEWORK: Developing a framework to manage the various diverse stakeholders including the external stakeholders, reflects the combined approach's need to balance control (structure stakeholder analysis) with interaction (integrating varied perspectives and requirements).

ZIPPER APPROACH & BUILDING TRUST: the zipper approach, ensuring alignment between the client and contractor at all levels, embodies the essence of the combined approach. It integrates a structure alignment (control) while also fostering mutual trust and continuous engagement (Hands-off).

In conclusion, the practical management of the people aspect in Energy transition projects seem to integrate all three aspects of the existing project management approaches. The initial formation of the strategic group to create predictability mirrors the control approach, while the adaptive and collaborative client interactions reflect the Hands-off approach. The overall strategy, however, leans more towards the combined approach, balancing structured planning and control with flexibility, stakeholder interaction, and trust building.

5.3.4 CHALLENGES, OPPORTUNITIES AND LESSONS LEARNED

Practitioners acknowledge that managing the complexity of people in energy transition projects is fraught with challenges. Despite employing various approaches, there are persistent difficulties in effectively managing this aspect. Consequently, this presents both challenges and opportunities, leading to valuable lessons learned for future implementation.

CHALLENGES

The primary challenge highlighted by participants was the client's lack of experience in developing energy transition projects. This inexperience, coupled with increasing time pressures for securing funding or meeting regulatory deadlines, often leads to **unrealistic expectations** regarding time and cost. PM4 observed that clients are frequently unaware of the necessary steps or sequences required for successful project completion. Additionally, the urgency to meet business viability often results in clients either **compressing or skipping the front-end development phase**, aiming to reduce time and cost estimates.

A further challenge arises from the lack of trust between clients and contractors, leading to excessive **control or micromanagement**. For instance, PC1 mentioned the requirement to prepare a detailed 260-page monthly progress report, followed by extensive explanations, which consumes time and further delays the project timeline. In some instances, clients hire consultants, often IT consultants due to a misunderstanding of the project's needs, to act as intermediaries. This approach, while common in other projects, is problematic in energy transition projects due to the mismatch in methodologies and the inherent message of distrust it conveys towards the contractor.

Another significant challenge is the **mismatch in approach** and understanding within client organizations, especially those like traditional energy producers who often hire individuals with diverse backgrounds from various sectors. This diversity in experience and approach leads to internal alignment challenges, further complicated by the need to align these varying backgrounds with the project's methodology.

Optimism bias presents an additional challenge on both the client and contractor sides. Clients often overestimate their engineering capabilities, leading to a realization of additional engineering requirements only when engaging with contractors. Conversely, contractors sometimes overpromise capabilities or conform to clients' unrealistic expectations in an effort to secure a market share in this new sector.

Therefore, the challenges in managing the people aspect of energy transition projects primarily include unrealistic expectations regarding schedule and cost, insufficient project management skills, issues stemming from control or micromanagement, and a prevalent optimism bias.

OPPORTUNITIES

Despite facing numerous challenges in managing the 'people' aspect of energy transition projects, participants also recognized significant opportunities. One key opportunity is the potential to **engage with new clients** and develop **innovative value propositions**. Participants found this aspect particularly intriguing, as it opens doors to new business avenues. They believe that successfully navigating such complexities can **demonstrate their capabilities** to clients, leading to increased trust and potentially **more future projects**. This not only enhances their business prospects but also allows them to firmly establish their position in the market.

LESSONS LEARNED

Considering the challenges and opportunities encountered, participants recognized the need for a strategic shift in their approach towards clients. They emphasized the importance of **early engagement** and a deep understanding of the client's nature, whether a startup, a traditional energy producer, or a consumer. This involves dedicating time to comprehend each client's unique drivers and motivations.

Furthermore, the participants learned that importance of investing time and money into front-end development phase as they realised in projects such as these energy transition projects given the uncertainty in these projects this phase is now important more than ever as they need to go through each step in this phase to gain the certainty needed to execute these projects and simply compressing or skipping them would only lead to further delays and risks in the project.

PM4 highlighted a need for a change in client engagement strategies. The current approach, often leading to arguments, was seen as ineffective. Instead, he proposed **immersing a team of experts** within the client's organization. This team, potentially comprising strategic group members and project management professionals, would work closely with the client in the initial phase. Their role would be to assist clients in defining their project objectives, aligning their goals, and setting realistic expectations. This approach aims not only to foster a better understanding of project development but also to align the client's decision-making processes with practical realities.

Another critical lesson learned by participants was the importance of **asserting their expertise** and resisting the urge to say yes to unrealistic client expectations. By confidently presenting their knowledge and capabilities, they can guide clients towards more feasible project goals.

On the other side, clients learned the value of **developing in-house expertise** to reduce dependency on external parties, aiming for a more balanced distribution of power in energy transition projects.

5.4 TECHNOLOGY

5.4.1 COMPLEXITY INDICATORS

Various interviewees noted novel technology as a main complexity as PM2 mentioned, *"When dealing with new technology, that in itself represents complexity".* When zooming out and looking at how it was with traditional energy projects and how it is now with energy transition projects with regards to the **novel technology**, SOT2 noted that with traditional technologies, for example, either petrochemical, oil, or refining projects, they typically had high technology readiness levels because these processes were well-proven and had been around for decades. On the other hand, energy transition projects, typically involve relatively new technologies like lithium processes, batteries, and recycling, resulting in a wave of new lower maturity technologies.

This sentiment was echoed by PD1 who felt that when it comes to novel technologies, often times complexity could turn into a risk, making the situation even more complex. as it is uncharted territory for the companies, leading to a higher chance of overlooking critical aspects, leading to potential safety concerns or functional issues, as noted by PM3. In fact, PM2 felt that this risk was more pronounced in the preliminary phase of the project. When looking at the comparison, PM2 also noted that the fundamental risks were the same with traditional projects and energy transition projects, however, the exposure was different, as PM2 mentioned *"I believe the fundamental risks remain the same, but their exposure might differ. In a traditional project, when there's a technological issue, it's often with technology we're familiar with. We've encountered such problems before, so we understand the associated risks and how to mitigate them. With new technology, however, the uncertainties can be greater. The potential impact might be more significant, leading to increased exposure. As a result, the overall risk is higher."*

Furthermore, the participants noted that what set these new technologies apart was the potential reputational impact on the company, if this complexity turned into a risk. Given that Fluor would like to gain a significant market share in these energy transition markets, where the successful realization of these projects was the cornerstone for securing future projects. They also felt that it was less about familiarizing themselves with this new technology but ensuring performance guarantees for these unproven technologies making it all the more complex processes. Considering this novelty aspect and the associated risks, a shift in risk acceptance was also noted as lumpsum contracts have become less appealing in these projects, as noted by PM2, *"To put it bluntly, we'd often prefer not to undertake such lumpsum projects. And nowadays, even the market seems less inclined towards lump sum execution."*

What was observed to make this technology aspect even more complex was the **evolving nature** of these technologies. As PM2 noted *"While some changes stem from evolving technological developments - since new technologies can advance faster than the project's progress ".*

Another important aspect was the **absence of clear regulations**, as highlighted by CM2 and PM3, adds another layer of complexity, making it difficult to strategize and ensure compliance. This is especially true when dealing with technologies like carbon capture or green hydrogen, which are at the forefront of the energy transition but still lack established regulatory frameworks. This sentiment was also echoed by CM1 who noted that with the lack of these clear regulations, is hard for them to discern which technology would prevail, and that this complexity was compounded by the fact that it wouldn't be a singular technology but rather a mix of them, highlighting the **interconnectedness between these technologies.**

With relation to the interconnectedness aspect, PM4 noted another complex aspect related to the technology, where this new technology would need to be **integrated into an existing facility**, while maintaining operational continuity as completely shutting down the facility until the integration was complete, was not financially viable. These types of energy transition project which require integration with the existing facility or system, were noted as brownfield projects, whereas the new standalone projects were categorized as greenfield projects. As noted by PM 4 *"This situation is new for many companies accustomed to simply replacing parts in their existing facilities, like buying a new car without concerning themselves with its internal workings. However, these projects are more complex, requiring integration of entirely new units into existing infrastructure."*

This interconnecting aspect was not just observed between the new technology and the existing facilities, but also within the different energy transition projects as SOT 1 mentioned, *"what I see is that it's the interconnecting aspects of things that you've never done before. For example, a new license, a new package, new green hydrogen on one side, CO2 capture from another side, and new methane technology somewhere else".*

Going back to the novelty aspect, PM1 noted that what makes it more complex for them is that Fluor doesn't own most of technology, therefore they need to collaborate with various technology providers who typically have a wide range of choices, creating a dependency on these technology providers and these providers have a wide **variety of technological options**, making the scope broad. Given this novelty and **lack of ownership**, a large portion of the scope is sub-contracted which needs to be integrated into the overall scope, as noted by PM1, *" We must integrate these components into the overall design, as is common in large projects, but in this case, the percentage of scope provided by other companies is particularly high. This, in itself, is a complex process."*

PM4 also noted with these technologies it was more about developing it from an idea into something that you can finance completely. This sentiment was also echoed by SM1 who noted that with scaling unproven technologies, there was less certainty regarding the end product and the project cost, as opposed to traditional energy projects where there is a lot more certainty related to the cost as there have been successful operating facilities. highlighting a strong relation between the technology and the financial complexity aspects of these projects.

Therefore, the technology related complexities in energy transition projects can be summarized as **'Novel technology', 'Evolving technology', 'lack of clear regulations', 'Operational experience', 'Integration into existing facilities/systems, and 'Varying technological options.**'

5.4.2 MANAGEMENT APPROACH EMPLOYED IN PRACTICE

Interviews highlight that managing new technology in energy transition projects involves more than just technological adaptation. It encompasses dealing with its evolving nature and understanding how to make it both technologically and financially feasible. Once feasibility is established, the next challenge is integrating this technology with existing systems. This process requires careful consideration of the various interconnections with other technologies, the unique dynamics of different energy transition projects, and the diverse roles of individuals involved. Managing these complexities is an endeavour that aims to enhance operational experience while simultaneously mitigating risks and ensuring safety. Thus, it presents a multifaceted and challenging task for practitioners in the field. the following stipulates how these various aspects were managed in practice:

As a preliminary step in handling a variety of novel technologies, participants utilized a **Technology Readiness Level (TRL) tool** to assess the maturity levels of different technologies. This tool measures maturity on a scale from one to nine, with nine indicating full operational maturity. Employing the TRL tool enabled participants to evaluate the maturity of various technologies, preferring those with higher TRL levels due to their lower risk and greater certainty for project implementation. Although TRL tools are also used in traditional energy projects, their application in energy transition projects is more frequent and often involves assessing technologies with lower TRL levels.

On the client side, it was revealed that they commonly **engage consultants** to assist in selecting appropriate technology options. This approach marks a departure from traditional energy projects, where clients usually have a thorough understanding of the technologies involved. In energy transition projects, due to a lack of familiarity, clients find it necessary to rely on technology consultants or companies like Fluor for guidance in this selection process.

In addressing the challenge of choosing between two novel technology options, CM1 mentioned that some projects adopted a **dual pre-feed strategy**. This approach was crucial for determining the most suitable technology option. Alongside using tools such as TRL and consulting experts, this method helped in making informed decisions.

A significant complexity in these projects, as noted earlier, is aligning technology with financial feasibility. To address this, **technology-to-financial feasibility studies** were also conducted to assess the various technologies. These studies comprehensively evaluated various factors, including environmental impact, social implications, technological viability, and economic feasibility. The thoroughness of these studies is crucial as they equip clients with detailed information necessary for convincing investors of the project's viability.

Participants recognized this approach as being particularly relevant to energy transition projects. Unlike traditional energy projects, energy transition projects require a more nuanced and detailed feasibility analysis, given the novel nature of the technologies involved.

After selecting the technology, participants acknowledged the challenges posed by its novelty, often not owning the technology themselves. To address this, they adopted strategies such as **early engagement with licensors**, using a comprehensive evaluation criterion for licensor selection. In certain instances, they also opted to subcontract a significant portion of the technology scope, ensuring expertise in areas outside their core competencies.

Given the unfamiliarity and unproven nature of these novel technologies on a large scale, **pilot testing** was a crucial step. Participants conducted tests on a smaller scale to validate the technology's efficacy and feasibility before proceeding to full-scale implementation. This approach helped mitigate risks associated with deploying untested technologies.

Handling novel technologies, especially in brownfield energy transition projects where integration with existing facilities is required, is inherently complex. To navigate these challenges, **experts or innovation partners** were involved to lend their insights and expertise. Their involvement was pivotal in managing the intricacies of integrating new technologies with existing structures.

Strategic groups were utilized not only for managing the people aspect of projects but also for the technological dimension. These groups proactively engaged with licensors and the market to deepen their understanding of various technologies in energy transition projects. A core principle for these groups was maintaining a focus on **safety**, ensuring it was a key consideration in their exploration and evaluation of different technologies.

5.4.3 LINK TO EXISTING PROJECT MANAGEMENT APPROACHES

The management approaches identified from practice for the technology aspect are further linked to the existing management approaches of Control, Hands-off and Combined approach as shown below (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011).

CONTROL ORIENTED APPROACH (PREDICT & CONTROL/SYSTEMS MANAGEMENT)

USE OF TECHNOLOGY READINESS LEVEL (TRL) TOOL: Applying tools such as the TRL to assess the technology maturity is a systematic approach that aligns with the control-oriented approach. It provides a structured way to evaluate the level of certainty and risk associated with each technology, a key characteristic of a control-oriented mindset.

TECHNOLOGY-TO-FINANCIAL FEASIBILITY STUDIES: Conducting comprehensive feasibility studies that consider various factors including, environmental, technological, economical, and social reflects the control approach's emphasis on predictability and detailed planning.

PILOT TESTING FOR NOVEL TECHNOLOGY: Testing novel technologies on a smaller scale before scaling them is a risk or change-averse strategy typical of the control-oriented approach.

HANDS-OFF APPROACH (PREPARE & COMMIT/INTERACTIVE MANAGEMENT)

ENGAGEMENT WITH CONSULTANTS FOR TECHNOLOGY SELECTION: Client's reliance on external consultants or technology companies for guidance indicates a more open, flexible approach aligning with the Hands-off approach. It highlights an external focus by acknowledging the need for external expertise and willingness to adapt based on expert advice.

DUAL PRE-FEED STRATEGY FOR CHOOSING TECHNOLOGIES: Employing a dual pre-feed strategy to determine the best technological option for the project, demonstrates flexibility and adaptability in the decision-making, a key characteristic of the Hands-off approach.

SUBCONTRACTING PORTIONS OF TECHNOLOGY SCOPE: Choosing to subcontract areas outside of the core competencies portrays a willingness to embrace external expertise and collaboration, aligning with the Hands-off approach.

COMBINED APPROACH

EARLY ENGAGEMENT WITH LICENSORS AND INNOVATION PARTNERS: This strategy represents a combination of the control oriented (focus on front end development through early engagement and criteria for licensor selection) and Hands-off (flexibility and collaboration) approaches. This signifies that the combined approach strikes a balance between systemic evaluation with adaptive collaboration.

STRATEGIC GROUPS FOR TECHNOLOGICAL DIMENSION: Employing strategic groups to gain knowledge about the different technologies related to energy transition projects demonstrates a combined approach. These groups maintain a focus on safety (control) while proactively engaging with the market and licensors (Hands-off).

Therefore, in practice, the management of the technology aspect involves a blend of Control oriented, Hands-off and Combined approaches. Employment of systematic tools like TRL and conducting feasibility studies reflect the Control oriented approach's emphasis on detailed planning and creating predictability. The engagement of consultants, adoption of flexible strategies like Dual Pre-Feed, and subcontracting technology scope indicate elements of the hands-off approach, which focuses on adaptability and external collaboration. The overall approach, particularly, the early engagement of licensors or Innovation partners suggests a Combined approach that aims to create predictability when dealing with new technologies and also adapt to their advancements.

5.4.4 CHALLENGES, OPPORTUNITIES AND LESSONS LEARNED

CHALLENGES

Participants identified a significant challenge in the cost of maintaining **team flexibility**, particularly the difficulty of dedicating full-time resources to strategic groups. This issue presents a substantial constraint in efficiently managing energy transition projects.

Additionally, the challenge extends beyond just the evolving nature of technologies; it also pertains to the **mindset of engineers.** While the innate drive of engineers to innovate and seek optimization is generally viewed positively, it becomes problematic when dealing with unproven and constantly evolving technologies. This tendency to continuously seek improvements can clash with the strict schedules of these projects, creating additional complexity in project management.

OPPORTUNITIES

Despite the challenges in maintaining team flexibility and allocating resources to strategic groups, participants recognized a valuable opportunity in these circumstances. They saw it as a chance for **skill development** within their teams, viewing the constraints as a catalyst for enhancing team capabilities and expertise.

LESSONS LEARNED

A key lesson learned by the participants was the importance of involving **technology experts** and **subject matter experts** early in the project. They realized that assembling the right combination of people is crucial for effectively managing the complexities of novel technologies. Additionally, given the increased risk associated with these new technologies, participants recognized the need for a **better risk-sharing mechanism**, moving away from traditional lump-sum or turnkey approaches. They learned to adopt a more problem-solving mindset, which is better suited to the dynamic and uncertain nature of these projects.

5.5 Financial

5.5.1 Complexity indicators

A significant complexity in energy transition projects arises from the reliance on **external funding**, whether through investors or subsidies. Clients often have to navigate the diverse requirements set by regulatory authorities and funding sources, integrating these into the project's design and development. Particularly challenging is the uncertainty and **lack of clarity** regarding the criteria for availing subsidies. Interestingly, many of these projects are perceived more as products than projects. This perception necessitates the need for **offtake agreements**, ensuring there is a guaranteed buyer for the output, thereby adding another layer of dependency and complexity.

5.5.2 Management approaches used in practice

In response to these financial complexities, a shift in management approaches had been observed. The dependency on offtakers and various funding sources necessitates a complex process of incorporating diverse requirements.

Recognizing the urgency and specific requirements of funding sources, the interview participants often **expedited the estimation process**, even before finalizing a design, and provide early estimates with a relatively high margin of error (around 20-30%). This approach, necessitated by time pressures, differs significantly from traditional energy projects, where estimates are made only after completing a thorough design.

Addressing the dependency on offtakers, participants now not only provide capital expenditure (CAPEX) estimates but also **operational expenditure** (OPEX) estimates. They assist clients in **securing offtakers** to ensure the viability of the business case. This comprehensive support includes conducting feasibility studies during the technology assessment phase to strengthen the overall business case.

5.5.3 Link to existing project management approaches

The management approaches identified from practice for the financial aspect are further linked to the existing management approaches of Control, Hands-off and Combined approach as shown below (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011).

Control oriented APPROACH (Predict & control/Systems management)

Expedited estimation process: Providing early estimations with a high margin of error aligns with the control approach. This method, although expedited, is still about exerting control over the financial aspect by giving an early, albeit less precise, picture of the costs involved.

Hands-off APPROACH (Prepare & Commit/Interactive management)

Adapting to funding sources requirements: Understanding and adapting to the specific requirements of the different funding sources and making the process more agile compared to conventional energy projects represents a more flexible approach that incorporates the interests of the external stakeholders, aligning with the Hands-off approach. It portrays a willingness to adjust the process in response to the external environment.

Assisting clients in securing offtakers: Providing comprehensive financial support to the client, including helping them secure the offtakers, shows a more collaborative approach which aligns with the Hands-off approach. It goes beyond the traditional financial management by also conducting activities that ensure the viability of the business case.

COMBINED APPROACH

Providing both CAPEX and OPEX estimates: Providing both the capital and operational expenditure shows a holistic approach towards the financial management. This method combines the detailed planning aspect of control-oriented approach (providing thorough financial estimates to increase certainty) with the adaptive, client focussed aspect of the Hands-off approach (ensuring the project's long-term viability and addressing specific client needs).

Therefore, the financial management of energy transition projects, involves elements of the Control oriented, Hands-off and Combined approaches. The expedited estimation process aligns with the structured systematic elements of the Control oriented approach. Meanwhile, the adaptability to each funding source and assistance in securing offtakers aligns with the flexibility and responsiveness of the Hands-off approach. Providing both the CAPEX and OPEX estimates, suggests a combined approach that blends the detailed financial planning with adaption to the clients' and external stakeholder needs.

5.5.4 CHALLENGES, OPPORTUNITIES AND LESSONS LEARNED

CHALLENGES

Given the increased time pressure in energy transition projects, participants noted that the project environment has become **highly competitive** and **pressured**. This is largely influenced by funding sources **dictating requirements** and, in some cases, even mandating the hiring of specific, yet sometimes incompatible, consultants as a precondition for funding. These funders also demand a high level of project definition, complicating the management process. Furthermore, participants expressed concerns about the **lack of transparency** from clients regarding their requirements. This lack of clarity in communication further complicated the process, often resulting in work having to be revised and redone multiple times to meet these undisclosed requirements.

Despite efforts to expedite processes and provide early estimates to meet funding deadlines, participants faced challenges with **high margins of error** in these estimates. This risk of inaccuracy could potentially lead to **loss of control over the project design**. Many tasks in these projects need to be executed swiftly and **concurrently**, with each task often dependent on the completion of the previous one and the timely transfer of data. This level of concurrency increased the risk of immature or **inaccurate data** being passed along, potentially leading to incorrect decisions. Subsequent changes required to rectify these errors can be detailed and time-consuming, involving multiple disciplines working in parallel. Explaining these complexities and the necessity for changes to clients often results in contention, particularly in an environment where trust may already be lacking. Therefore,

OPPORTUNITIES

According to the participants, opportunities specifically related to managing the financial aspect of energy transition projects were not particularly pronounced. The primary advantage they noted was gaining **increased certainty** regarding funding. This heightened certainty, in turn, enhances the likelihood of the project's progression. However, it could be perceived more as an outcome of effectively managing the complexities inherent in these projects, rather than a direct opportunity.

LESSONS LEARNED

A key lesson learned by participants was the importance of encouraging clients to be **more transparent about their financial requirements**. This transparency would enable the integration of these requirements into the project work more effectively.

5.6 RESOURCES

5.6.1 COMPLEXITY INDICATORS

The findings highlighted the pronounced complexities related to resources, primarily due to the interlinked nature of time constraints and financial aspects. This complexity is not inherently a characteristic of the projects themselves, but rather a consequence of current adversities such as the ongoing global pandemic and geopolitical tensions, like the War, which have led to these complexities.

CM1 and CM2 observed substantial financial investments by entities like the European Union and the U.S., which have significantly ramped up the demand for infrastructure and energy transition projects Consequently, CM2 noted that initiatives such as the EU's Horizon package and the Green Energy Fund have specifically created a surge in demand, leading to a bottleneck in the supply chain, especially affecting contractors and suppliers with limited capacity.

Consequently, a key complexity arises from the significant mismatch between the current supply base's **capacity** and the growing market **demand.** As CM1 exclaimed *"the EU's ambitious plan to invest 200 billion annually until 2030 for energy transition effectively doubles the market demand, far exceeding the capabilities of approximately 1,000 available suppliers and contractors"*.

Furthermore, **technological requirements** add another layer of complexity. The example provided by CM1 of green hydrogen facilities illustrates this: the demand for electrolysers with capacities far exceeding current manufacturing capabilities presents a risk, as even the manufacturers are uncertain of meeting such high demands. This is compounded by the fact that only a few companies worldwide produce critical components like electrolytes, and their production capacities are insufficient to support the escalating number of projects. This sentiment was also echoed by PM3 who stated *"Despite the belief that all these projects will be up and running by 2030, it's just not feasible. There are limitations in engineering capacity, construction capacity, and localized transformer capacity, especially regarding electrical distribution transformers."* Additionally, the long delivery times for essential components, such as transformers in Europe, further exacerbate this complexity.

When addressing the human resource aspect, it was revealed that post-COVID-19 workforce reductions have led to a shortage of skilled labor, intensifying competition for resources, and creating practical constraints. It less about the availability of the resource itself and more about the **availability of 'skilled' resources**, as PM4 succinctly captures *"It's not just about are there enough people, but are there people with enough experience to actually take on the challenges that we have in energy transition? It's, of course, a big question."* Moreover, the **volatility** in the prices of crucial materials, like steel and cables, and the rapid market dynamics add to the unpredictability and complexity of managing resources effectively.

The participants also acknowledged a shift from a buyer to a seller's market which has also altered the negotiation dynamics. High demand and limited company capacities allow suppliers to dictate terms, posing challenges for clients, particularly newcomers who might not fully understand these new market dynamics and need to make their business case financially viable.

Therefore, considering these various aspects and dynamics at play, the complexities related to the resource aspect of energy transition projects can be summarized as follows: **'Demand vs Capacity', 'dynamic supply chain market', 'availability of skilled resources', 'variety and interdependencies of resources', and 'technological requirements.'**

5.6.2 MANAGEMENT APPROACH USED IN PRACTICE

In energy transition projects, a noticeable shift in the subcontracting approach has been observed. Participants acknowledged moving towards a more **cautious approach**, primarily due to the involvement of novel technologies. They recognized situations where certain equipment might be highly bespoke or specialized, potentially leading to designs that are either too unique or too complex, misaligning with market capacity or cost-effectiveness. Consequently, there has been a realization about the importance of aligning technological aspects with suppliers and contractors. This has led to an **early engagement with key supply chain parties** to gauge their capacity and expertise, essentially turning them into "technical support" and fostering a more collaborative approach.

Traditionally, clients would approach contractors with clear instructions, transferring the risk and responsibility onto them. These contractors would then delegate tasks to their subcontractors. However, this landscape is changing. Clients in energy transition projects often lack a clear understanding of their requirements, and contractors face similar uncertainties about client needs. This ambiguity has necessitated a reliance on the supply chain, as they are the ones actively involved in building and supplying.

This shift has manifested in a more extensive involvement of key suppliers and contractors during the design phase, fostering **collaborative and alliance partnerships**. Various forms of engagement have emerged, such as inviting key parties to participate in equipment specifications development or subcontracting certain design scopes to them. As CM1 exemplified, *"For instance, if we need a custom design to align with local norms, like in Germany, we're likely to collaborate with local technology providers. This might mean subcontracting aspects that we used to do in-house due to our prior capabilities."* Such a shift signifies a move towards more collaborative subcontracting.

With this approach, when key parties develop bespoke or customized equipment, they make significant investments. Consequently, they seek reassurance that their investments will be recouped, leading to **direct partnerships with clients** to sell their machines and secure a return on investment.

Moreover, the time pressure in these projects necessitates a quicker estimation process, as highlighted by PM5. The traditional sequence of design and then estimation is often bypassed to bring the supply chain into the process earlier and adjust strategies accordingly. This has led to more reliance on **in-house pricing** instead of market quotes. PM8 contrasted this with traditional projects: *"For instance, in my project, subcontracting activities were heavily accelerated to have a certain amount of the contract value in place much earlier than you would have in a traditional project, where you typically place a contract with sufficient definition in engineering and so on."*

5.6.3 LINK TO EXITING PROJECT MANAGEMENT APPROACHES

The management approaches identified from practice for the Resource aspect are further linked to the existing management approaches of Control, Hands-off and Combined approach as shown below (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011).

CONTROL ORIENTED APPROACH (PREDICT & CONTROL/SYSTEMS MANAGEMENT)

Direct manufacturer-client relationship: Establishing direct partnership for selling the machines indicates a need to gain certainty about the return on investment, which aligns with the control-oriented approach.

HANDS-OFF APPROACH (PREPARE & COMMIT/INTERACTIVE MANAGEMENT)

Collaborative and Alliance partnerships: The shift towards a more collaborative subcontracting, including involving key supply chain parties to participate in equipment specifications development, emphasizes leveraging external expertise through a more network type of relationship, a key element of the Hands-off approach.

Combined approach

Early engagement with key supply chain parties: The early engagement aspect relates to the control-oriented approach as it emphasizes a strong focus on the front-end development phase. While the collaborative approach adopted relates more to a network relationship of the Hands-off approach. Therefore, a combined approach could be observed.

Accelerated subcontracted activities: The practice of accelerating subcontracting activities in Energy transition projects to have a contract value in place earlier than conventional energy projects represents a blend of both Control oriented (Structured and quick decision-making) and Hands-off (flexibility and adaptability to project timelines) approaches.

Quicker estimation process with In-house pricing: Bypassing the traditional sequence of design then estimation to involve the supply chain early and adjusting the strategies accordingly demonstrates a combined approach. It blends financial planning (control) with responsive and adaptable estimation processes (Hands-off).

Therefore, a mixture of all three management approaches could be observed in the resource management of Energy transition projects. Direct partnerships between the client and manufacturer are fostered to provide certainty related to the return on investment, thereby adopting a Control oriented approach. The shift towards collaborative and alliance type contracting methods with subcontractors aligns with the Hands-off approach. Lastly, accelerating the subcontracting activities and a quicker estimation process with In-house price balances both the Control oriented and Hands-off approach, thereby adopting a Combined approach.

5.6.4 Challenges, Opportunities and Lessons learned

Challenges

The participants recognized several challenges in managing subcontracting activities in energy transition projects. While accelerating these activities is encouraged, it comes with significant hurdles.

A notable issue arises when approaching the market early with limited scope definition. The participants frequently found that they did not receive the **quality of bids** they expected. This is often because subcontractors are either reluctant to take on the associated risks or they submit bids that significantly exceed the project's budget.

Unlike traditional projects, where there is typically a clear definition in the engineering phase before market engagement, energy transition projects often involve refining the scope as the project progresses. This approach leads to more of a **trial-and-error method**, necessitating ongoing adjustments and negotiations with supply chain parties.

Early engagement of supply chain parties for estimates poses another challenge, especially when there is uncertainty about securing funding. Supply chain parties often seek some form of commitment, but without guaranteed funding, this places them in a precarious position. They **risk remaining idle** and losing potential business from other prospects. If the funding fails to materialize, their investments could be wasted, leading them to attempt to shift some of the risk onto main contractors like Fluor.

Additionally, it was also found that given the market volatility, a lot of these subcontractors were also going bankrupt, risking more delays in these projects.

From a human resources perspective, the participants acknowledged the challenge of developing a long-term organizational strategy. This involves predicting future project types and determining the necessary resources. Although they could conduct such a market analysis, there is still uncertainty about which market segments will align with their predictions and what would actually materialize. This **unpredictability** makes strategic planning for human resources particularly challenging in the dynamic landscape of energy transition projects.

OPPORTUNITIES

During the interviews, several key opportunities were identified in managing the resource aspect of energy transition projects, particularly in terms of engagement with supply chain parties. These opportunities centred around the development of knowledge, the fostering of trust, and the securing of suitable partners for the projects.

A key opportunity that came to light was the role of involving supply chain parties as an integral part of the process. This approach didn't just enhance their understanding of the project but also played a crucial role in **trust-building**. This newfound trust was seen as vital for fostering future collaborations. Moreover, the **knowledge** these parties gained was not only beneficial for the current project but was also carried onto their future projects, leading to the establishment of strong, collaborative relationships that went beyond the scope of a single project.

Another significant opportunity identified was the ability to pinpoint **genuinely interested** parties early in the project's lifecycle. This early identification was crucial in ensuring that the project was progressing forward with the right partners. The confidence in these partnerships grew as it became evident that these parties were not only interested but also perfectly suited to meet the specific needs of the project.

Additionally, engaging with supply chain parties early in the project proved to be beneficial in terms of **gaining access to crucial information and resources**. This early access was deemed critical for securing the necessary resources in a timely manner, thereby significantly mitigating many of the risks and uncertainties that are typically inherent in energy transition projects.

LESSONS LEARNED

Throughout the interviews, participants shared several key lessons they learned while managing the resource aspect in energy transition projects. A crucial takeaway was the need for a **dynamic resource strategy** that accounts for the changing market conditions. PM6 emphasized, *"You cannot simply transfer a strategy adopted on another project into a new project. The market has dramatically changed over the past 8 to 10 years, with much less availability of capacity. So, you need to recognize these changes."*

Participants also learned the importance of **adapting to the supply chain**. They noted that clients who made decisions early often found themselves at the front of the queue for various products and benefitted from better pricing. PM1 highlighted this advantage, and PM8 echoed the sentiment, stating, *"Clients need to see the commercial advantages of getting involved in a project early and securing their resources for it. They need to see the clear benefit."* The time pressure in these projects has led participants to realize the importance of early market engagement. PM5's experience reinforced this, revealing that early engagement and **feedback** can lead to better-informed decisions about the available tools and products in the market.

A significant lesson shared by CM1 pertained to managing idle periods. They suggested requesting **compensation** from the clients for themselves and their subcontractors to mitigate the loss of business during these times. This approach helps in overcoming the challenge of idle time while waiting for project confirmation or funding.

Regarding human resources, participants learned the importance of **expanding their teams** with individuals or specialists experienced in new technologies. This expansion helps increase the learning curve and adaptability to new project requirements. PM3 noted the necessity of adapting **standard staffing practices** for energy transition projects, which often involve multiple studies and simultaneous FEED phases. By understanding the staffing needs across various projects, they could allocate their efforts more effectively, ensuring adequate personnel distribution where needed.

5.7 Legal & Regulations

5.7.1 Complexity indicators

In energy transition projects, the complexities stemming from legal and regulatory aspects play a significant role in their progression. PM3 highlighted a critical issue where projects sometimes fail to materialize due to lack of support from entities such as the European Union and the Dutch government. This challenge is further exacerbated by the **lack of clear regulations**, as emphasized by CM2, particularly in projects like hydrogen production where regulatory guidelines are essential for certification and strategizing.

The **permitting stage**, as CL1 noted, is fraught with complexity. Initiating this procedure requires extensive documentation and studies, and achieving success in this phase introduces numerous conditions, further complicating the project. CL1 observed that while the permitting process is complex for all infrastructure projects, those in energy transition face greater challenges due to the higher stakes involved.

The **environmental aspect** also adds to the complexity. The Ministry's decision regarding nitrogen oxide emissions, as mentioned by CL1, requires projects to prove they won't significantly harm the environment. This is a common challenge across both transition and non-transition projects, necessitating additional efforts to comply with environmental regulations.

Political influence and public opinion are significant factors affecting energy transition projects. PM4 shed light on how shifts in the political landscape can lead to delays in critical decision-making, especially regarding subsidies. He expressed concern over the impact of elections on project timelines, noting, *"So the election is going to be in November, and it will take another few months before there's a new government. So, before you know it, we lose another eight, nine months."* This highlights the vulnerability of these projects to political events and the subsequent impacts on their progress.

Additionally, public opinion plays an increasingly influential role in shaping the direction and pace of energy transition projects. PM2 and PM6 emphasized the growing societal awareness and scrutiny surrounding topics like "energy transition" and "green energy." This heightened public attention places additional pressure on these projects, as they are closely monitored and critiqued by a more informed and environmentally conscious public. The heightened awareness leads to more stringent expectations and can significantly influence project timelines and approaches.

SOT 2 pointed out the **complex regulatory framework** in Europe, where funds and mechanisms are in place to incentive investments in these projects and make them financially viable. Despite these supportive structures, clients often encounter significant challenges in navigating this intricate landscape of incentives and legislative requirements. This complexity can substantially affect the implementation of projects, as clients must align their strategies and operations with a multifaceted and sometimes convoluted regulatory environment. The task of deciphering and complying with these regulations and leveraging available incentives becomes a critical aspect of project management, influencing both the pace and the direction of project execution.

PM5 discussed the variability in securing subsidies, especially in multi-location projects. He mentioned how a project's part in France received subsidies, aligning with the French government's focus on rapid energy transition, whereas the part in the US faced suspension due to regulatory delays and funding issues. This disparity also affected manpower availability, illustrating how regional focus on energy transition can influence project viability, posing challenges for projects spread across multiple locations.

5.7.2 MANAGEMENT APPROACH USED IN PRACTICE

In managing the legal and regulatory complexities of energy transition projects, the significance of certain key strategies and practices has been highlighted for ensuring successful outcomes. One critical approach, as underscored by CL1, is the development of **'strong', 'positive', and 'long-term relationships' with external authorities** involved in the permitting process. This approach is not just about navigating current project requirements but extends to building a mutual understanding of the importance of the project and a cooperation that can benefit future projects as well. CL1 elaborated on this approach by sharing a practical example of their engagement efforts: *"For instance, we invite authorities to visit our project site every Tuesday, offering them a cup of coffee and a tour."* This gesture demonstrates the need for **continuous engagement** with regulatory bodies for a smooth permitting process.

CM2 pointed out the significant role of regulations in shaping project strategies. They emphasized that an in-depth understanding of these regulations is essential, and having a **policy specialist** on board is also critical. This specialist's role is to demonstrate the implications of various regulations on the project to be prepared for all outcomes.

The identification of necessary permits is a critical component, as highlighted by CL1. Engaging specialists who can accurately **determine the required permits** and **develop a detailed plan** for obtaining them is crucial. This planning involves considering the time needed to prepare the required documentation and ensuring that all regulatory requirements are met.

Specialized roles during the permitting process are also essential, as discussed by CL1. For example, assessing noise levels for large installations requires specialists who **understand the specific conditions**, such as the impact of the ground being frozen in winter. Additionally, the environmental aspects, like the presence of wildlife in the area, necessitate experts who are knowledgeable about ecological factors.

Additionally, CL1 highlighted the crucial **role of consultants** in managing the legal and regulatory aspects of energy transition projects. These consultants are not just tasked with identifying and acquiring the necessary permits but also bear the responsibility of effectively communicating their findings.

5.7.3 LINK TO EXISTING PROJECT MANAGEMENT APPROACHES

The management approaches identified from practice for the Legal & Regulations aspect are further linked to the existing management approaches of Control, Hands-off and Combined approach as shown below (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011).

CONTROL ORIENTED APPROACH (PREDICT & CONTROL/SYSTEMS MANAGEMENT)

SPECIALISED ROLES DURING PERMIT PROCESSING: Employing specialists for specific tasks, like noise level assessment or ecological factors, represents the Control oriented approach's emphasis on defining the roles and responsibilities based on task execution.

ENGAGING POLICY SPECIALISTS: Having a policy specialist on board to understand and navigate the necessary permits reflects an informed approach to create the predictability. It's about being prepared and knowledgeable in the regulatory matters.

HANDS-OFF APPROACH (PREPARE & COMMIT/INTERACTIVE MANAGEMENT)

Development of strong relationships with authorities: Building long term relationships with external authorities firstly, shows an external focus which is typical of a Hands-off approach and secondly, it implies a more proactive engagement to understand the stakeholders' requirements which also a key element of the hands-off approach.

Continuous engagement with Regulatory bodies: Inviting the authorities for regular site visits and maintaining a continuous engagement with them suggests adaptability and relationship-building, a key element of the Hands-off approach. It's a more organic and relational way of approaching the legal & regulations related complexity. Understanding that regulations shape the direction of the project and being prepared for all possibilities show an adaptable and flexible mindset, aligning with the Hands-off approach. It indicates a readiness to adjust strategies based on the dynamics of the regulatory framework.

Combined approach

Use of consultants: Consultants play a crucial role in identifying and acquiring the necessary permits and mainly to effectively communicate their findings based on the audience. Their involvement showcases a combined approach, blending the task-based execution of the Control oriented approach with the flexibility to adapt based on their insights (Hands-off).

Holistic planning for permitting: Developing a detailed plan for permit acquisition, considering the regulatory requirements and documentation, portrays a combined approach. This involves making a detailed plan (control oriented) while also incorporating the external requirements (Hands-off).

Therefore, managing the legal and regulatory complexity requires a blend of the Control oriented, Hands-off and Combined approaches. Clearly defining the roles and responsibilities for specialised roles and engaging stakeholders based on task execution such as the policy specialist, represents a Control oriented approach. Whereas, developing strong and continuous relationship and engagement with the authorities reflects a more Hands-off approach. Lastly, the use of consultants and holistic planning for permitting, suggests a combined approach that involves detailed planning (Control-oriented) while also balancing the flexibility towards incorporating the requirements of the dynamic regulatory framework.

5.7.4 Challenges, opportunities and lessons learned

Challenges

One of the key challenges highlighted by PM4 involves the **lengthiness of processes**, particularly regarding subsidy acquisition. For example, a client's expectation of securing subsidies quickly was opposed by reality, as PM4 noted, *"the client initially informed us they were close to securing subsidies... However, it wasn't until July of this year that the European Commission approved these subsidies, after approximately five months of discussions, negotiations, and positioning."*

CM1 discussed the challenges that well-established companies often face in energy transition projects, particularly regarding their **understanding of permitting and technology requirements**. This gap in comprehension can lead to significant uncertainty. For instance, in a notable project involving the construction of a large green hydrogen facility, the company, despite being well-funded and committed, encountered hurdles in the permitting process. As CM1 explained, *"They are deeply invested in the project, but the challenge arises when regulators or policymakers stipulate that the permit application cannot be accepted unless certain conditions are met."* This situation highlights the challenges that even experienced, and resource-rich companies can face when managing the legal & regulation aspect of energy transition projects.

PM4 also touched upon the **intense negotiations** that often occur between clients and governments in energy transition projects, particularly regarding subsidies. These negotiations are critical as clients aim to secure maximum subsidies, arguing the importance of their projects in helping governments achieve their 2050 environmental goals. PM4 noted the intensity of these discussions, where clients emphasize the scale and significance of their energy transition initiatives to persuade government bodies to provide substantial support. However, this process of negotiating for maximum subsidies can lead to further delays in project timelines. Therefore, striking a delicate balance of securing sufficient government backing and moving projects forward in a timely manner underscores the challenge when managing the legal & regulation aspects of energy transition projects.

PM6 underscored the challenges surrounding the **government funding allocation** in energy transition projects. He posited a scenario where a government earmarks a significant budget, say 1.5 billion, for green initiatives. The challenge arises when the costs of one project escalate. PM6 questioned, *"If one project becomes more expensive, will the 1.5 billion budget increase, or will another project be cancelled or postponed?"* This scenario reflects the dilemmas faced in resource allocation, where budget overruns in one project could potentially jeopardize others.

The complexity of this situation is exacerbated by the bureaucratic processes involved. The maze of procedures and approvals necessary for reallocating funds adds another layer of challenge. Such bureaucratic intricacies can hinder the efficiency and speed of fund distribution, impacting which countries or regions ultimately benefit from the allocated budget. This scenario underscores the multi-level challenges at play, extending from individual project considerations to broader national and regional implications in the realm of government-funded green projects.

In summary, these challenges underscore the intricacies involved in navigating the legal and regulatory frameworks of energy transition projects, where delays, uncertainty, and strategic negotiations play a significant role in project progression.

OPPORTUNITIES

The only and significant opportunity identified was when a project is sufficiently engaged with the relevant authorities and its significance is recognized by entities such as the Ministry of Economic Affairs, it can be granted a **'special status.'** This designation marks the project as vital to the energy transition, which can significantly streamline various processes. Such support from the Ministry of Economic Affairs and the European Union can smooth out the permitting process, making it less cumbersome and more straightforward, as noted by CL1. Additionally, this recognition can facilitate easier access to funding, as projects with 'special status' are often prioritized and viewed more favourably in funding decisions. This enhanced status not only aids in overcoming bureaucratic hurdles but also in securing the necessary financial support more efficiently.

LESSONS LEARNED

In their experiences with energy transition projects, interview participants shared several key lessons learned, particularly in navigating the legal and regulatory challenges.

One crucial insight was regarding the ownership of the permitting process. SM2 pointed out that while their company can assist with technical information or technology assessments, the primary responsibility of managing the permitting process should fall on the clients. This distinction is important as it defines the **roles and responsibilities for funding** in the project, ensuring that each party understands their part in navigating the complex legal framework. This was also concurred by the client who felt that contractors might lack the level of patience needed for this process.

Delays in subsidy acquisition were another significant issue highlighted by SOT 2. In a specific instance involving a large blue hydrogen plant project, the client anticipated a three-month wait for subsidies, which realistically would take closer to six months. Such delays are a common reason for the slow progression of projects. SOT 2 suggested a shift in focus, advising clients to emphasize **refining the project's definition over just optimizing the financial aspects**. This broader view can help in understanding the comprehensive scope of a facility, including peripheral considerations often overlooked when focusing solely on the core process.

The different regulatory approaches between Europe and the US were also discussed. SM1 observed that while Europe tends to apply a penalty system, the US offers incentives for energy transition projects. This contrast in approaches leads to varying degrees of innovation and project development in the respective regions. In the US, the incentivizing approach has spurred more innovation and progression in fuel market projects, as opposed to Europe, where the penalty system seems to slow down project advancement. Highlighting the need for a **shift in the policy side** of the EU for these energy transition projects to gain momentum.

These insights underscore the importance of clear roles and responsibilities, the need for realistic timelines in funding and project planning, and the impact of regional regulatory approaches on the success of energy transition projects.

5.8 PROJECT MANAGEMENT & EXECUTION METHODS

5.8.1 COMPLEXITY INDICATORS

In energy transition projects, PM1 and PM5 highlighted the **interdependencies between different project phases and activities**, which is largely caused by the time pressure. PM1 pointed out the necessity to initiate EPC activities concurrently with feed phases, highlighting the need for parallel processing in these projects. PM5 further elaborated on this high level of interface, noting that disciplines like processes and mechanical often have to work simultaneously rather than in the traditional sequential manner. This kind of interdependence extends to **different business verticals** within the company as well. Unlike traditional energy projects, energy transition projects often require collaboration across various business verticals, each with its distinct management style, thereby creating an intricate web of interdependencies between them.

Adding to these complexities is the **variation in work approaches and terminologies used**, as these energy transition projects often involve individuals from diverse backgrounds like power, oil & gas, and metals. PM3 highlighted these differences, noting the power industry's reliance on repetition and efficiency, in contrast to the oil and gas industry's focus on detailed engineering and documentation. This leads to a fundamental mismatch in approaches, with the power industry typically adopting a bottom-up approach where they start with specific tasks and then aggregate them into larger project components and the oil and gas industry favoring a top-down methodology where they start with the project's main goals or objectives and then break them down into individual tasks or activities.

Regarding the execution methods, PM8 observed that the complexities in energy transition projects are **not drastically different** from traditional energy projects. However, they acknowledged that their execution methods are generally tailored for large-scale projects, and energy transition projects are often smaller in scale as many are still in the pilot testing phase. This difference makes it challenging to downscale well-established execution processes, adding another layer of complexity to these projects.

5.8.2 MANAGEMENT APPROACH USED IN PRACTICE

A key method adopted is the **'baseline-centric execution approach'**, which focuses on schedule, risk, and contracts. This approach, encompassing **seven core elements** defining the project baseline, has been effectively utilized within Fluor, as PM3 describes it as a crucial part of their project execution strategy. PM3 states, *"We have seven elements that define our baseline, and that's what makes it effective"*.

Despite the additional complexities in energy transition projects, traditional execution models continue to be applied. PM1 asserts that these models need to adapt to the complexities presented by energy transition projects, but their fundamental principles remain effective. *"We try to apply our traditional execution model. I think it works pretty well, but it needs to withstand the waves of the additional complexities,"* says PM1. The execution process generally stays consistent, involving material specification and construction, among other standard activities, as stated by PM7.

This baseline-centric approach **delineates clear expectations** and what needs to be done, ensuring collective effort from the team in executing the project. PM3 emphasized the importance of this approach, describing it as a **continuous process** that guides the execution of the project. *"So, it's a continuous process, and we refer to it as baseline execution"* PM3 explains. Furthermore, the participants acknowledged that this approach allows them to kickstart the projects quickly as they don't have to establish many of the requirements from scratch, leading to a streamlined initiation process.

Educating the client about this approach is also crucial. PC2 explains that outlining the project's prime contract, schedule, risk profile, and cost as part of the baseline documentation sets clear expectations. This approach also involves explaining the change management procedure to the client, ensuring they understand potential deviations and their implications given the high level of concurrency in these projects. As PC2 captures, "*in general, it boils down to what we need to do, when we need to do it, and the effort required."*

The participants highlighted the importance of making a baseline plan and **continuously verifying** if everyone is on the same page. As PM3 notes, *"Discussions, meetings, scrums, you name it – just keep putting things on the table and validating your assumptions"*.

PM9 shed light on a significant shift towards a more **agile approach** in project management methods for energy transition projects. This shift is primarily driven by the need to adapt to the time pressures inherent in these projects. In the traditional method, a designated individual would meticulously document the minutes of each meeting, producing extensive, detailed reports. However, with the increasing demand for speed in energy transition projects, this approach has evolved.

Now, instead of comprehensive minutes, the focus is on capturing the essential points in bullet form during meetings. This streamlined method not only accelerates the process but also reduces the need for extensive personnel involvement, making meetings more efficient and focused. This shift towards agility, as PM9 notes, could also reflect a broader trend with how projects within the energy sector are being executed.

Change management is another critical aspect of these projects. PM3 and PM5 discussed the significance of informing clients about potential scope changes and the importance of contract clauses in managing these changes. This approach ensures that deviations from the agreed contract are addressed effectively with the required level of transparency.

5.8.3 LINK TO EXISTING PROJECT MANAGEMENT APPROACHES

The management approaches identified from practice for the Project management & execution methods aspect are further linked to the existing management approaches of Control, Hands-off and Combined approach as shown below (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011).

CONTROL ORIENTED APPROACH (PREDICT & CONTROL/SYSTEMS MANAGEMENT)

No control-oriented approaches were observed related to the Project management and execution methods aspect.

HANDS-OFF APPROACH (PREPARE & COMMIT/INTERACTIVE MANAGEMENT)

SHIFT TOWARDS A MORE AGILE APPROACH: The move towards a more agile project management approach such as capturing the minutes of the meetings in bullet points instead of having a designated member to comprehensively take down the minutes of the meeting, shows adaptiveness to the situation which is indicative of a Hands-off approach. It indicates a departure from the traditional, rigid control-oriented methods.

CHANGE MANAGEMENT: Having an informed and robust change management process indicates more acceptance and transparency towards change, which is a key characteristic of the hands-off approach. Clearly informing the client about the change management process indicates an incorporation of the stakeholder's interests, which is another element of the Hands-off approach.

COMBINED APPROACH

BASELINE-CENTRIC EXECUTION APPROACH: This approach focusses on the main scope, time and cost which is indicative of the control-oriented approach. While constantly validating the assumptions and educating the client indicates a more hands-off approach. Therefore, this approach incorporates a more combined approach.

The project management and execution methods aspect in Energy transition projects is addressed with a blend of Control-oriented, Hands-off and Combined approach. No control-oriented approaches were observed to be employed in this aspect. In fact, a shift was observed towards the Hands-off approach with more agility in their management and acceptance towards change. Lastly, the Baseline centric execution method could be observed to have features of both the control oriented (focus on scope, time and cost) and hands-off approach (Continuous validation of assumptions).

5.8.4 CHALLENGES, OPPORTUNITIES AND LESSONS LEARNED

CHALLENGES

In managing the complexities of project management and execution in energy transition projects, practitioners have faced a variety of challenges. One significant issue is clients' specific **working preferences** and **scrutinizing contractors' processes**, this was especially seen in startup/novel type clients, as noted by PM8: *"Clients like to have a specific way of working, and when we present our work process, they may scrutinize it, question it, or express disbelief. Defending our work process can be quite energy consuming ."* This challenge is compounded by the need to align the **variety of project management terminologies** used between the different clients, as mentioned by PM3: "*we can invest considerable effort into it, all centered around the meaning of a word"*. Managing a steady group of people familiar with the processes and tools, especially in smaller projects, was also mentioned as a challenge by PM3.

Additionally, changes in projects often lead to **contention with clients** and can result in project delays, as noted by PM2: *"Any change can be a source of contention with the client."* Furthermore, the high level of concurrency in these projects can lead to **errors** and challenges in **adapting changes across disciplines**, as PM5 points out: *"That level of concurrency then leads to errors because ultimately, all these changes need to be adapted by each and every discipline in parallel".*

Lastly, SOT 2 noted that while traditional tools and methods are still in use, clients' reactions may vary. Some clients find these **tools overwhelming and have less appreciation for formality or procedures**, especially smaller startup type clients who are concerned about the costs. As SOT 2 shared, *"clients' reactions vary… some might find it overwhelming".*

OPPORTUNITIES

PM9 offered an insightful perspective on turning challenges into opportunities. They noted that the intense scrutiny by clients, often perceived as a hurdle, can actually serve as a **catalyst for positive change**. This constant questioning about methodologies encourages contractors to critically assess and potentially refine their long-established practices. It presents an opportunity to innovate and optimize traditional approaches, thereby improving efficiency and effectiveness in project execution.

LESSONS LEARNED

A key lesson highlighted by PM6 emphasizes the importance of **knowledge sharing**, not just within the company but also with clients and other project stakeholders. As noted, *"knowledge sharing helps us arrive at the best solutions."* The participants felt that this approach was essential for collectively bridging the knowledge gap in these projects.

Additionally, PM5 emphasized the critical role of **advanced data change management** in enhancing project efficiency. They noted, *"What I now learned in my project is that... data management allows you to be even quicker to get more accurate data to have a better understanding of where you are with the project"*. PM5 also stressed the importance of having a project automation manager for each project. They advocated for every discipline to collaborate with this role to ensure that their respective discipline's data is automated. This approach ensures that in case of any changes, all disciplines are promptly informed, thereby mitigating the challenges associated with such changes to a significant extent.

Furthermore, PM1 shared insights on integrating **more checkpoints** in the execution model, which is a response to the multifaceted challenges of energy transition projects. Stating, *"What I've experienced in these projects is that intensity is a factor, and it takes more energy. You have to juggle more balls and keep them in the air. You need to be more focused, and the risk of some of those balls being dropped is also there."*

Lastly, PM3 emphasized the need for **standardizing the execution plan** for energy transition projects. They suggested that this sort of a standardization could ensure consistency across different projects while offering the necessary flexibility to scale the plans up or down according to specific project needs.

5.9 Key takeaways

This chapter delved into the specific complexities, management approaches, challenges, opportunities and lessons learned in Energy transition projects based on semi-structured interviews conducted with 18 practitioners. The results revealed six major themes, namely, people, technology, financial, resources, legal & regulations and project management & execution methods. Table 9 summarizes the various complexities identified under the six themes and these complexities are then compared with Table 6: Internal and external complexities by Kian Manesh Rad et al. (2017), identified from Literature. This comparison revealed that some complexities are similar to conventional energy projects, while some vary slightly and some are unique to energy transition projects, based on this comparison Framework A was supplemented with the practical insights in Table 10.

TABLE 9: COMPLEXITIES IN ENERGY TRANSITION PROJECTS FROM EMPERICAL STUDY

Complexities in Energy transition projects	
People	Varying client types (PM 1,3,4,5,6,7,8) (PC2) (SM2)
	varying client drivers (PM 1, 3,4,5,6,7,8)
	Lack of experience (PM 1,2,3,4,5,6,7) (PC1) (PC2) (EM1)
	Lack of trust (PM 1,2,7,8) (CL1) (PC1)
	Unclarity regarding objectives (PM 1,4,8)
Technology	Novel technology (PM 2,3,7,9) (CM1) (SOT1) (SOT2) (SM1)
	Evolving technology (SM1) (PM2, PM3) (CM1)
	Lack of clear regulations (PM3) (CM1)
	Interconnectedness between technologies (CM1, EM1)
	Integrate new technology into existing facility (PM4) (CM1)
	Variety of technology option (PM4) (CM2)
	Lack of ownership (PM1)
Financial	External funding dependency (PM 1,2 3,4,5,6,8,9) (CM1) (EM1) (SM2) (SM1)
	Variety & lack of clarity regarding financial requirements (PM3) (CM1) (SOT2)
	Dependency on offtake agreements (PM4,8)

Resources	Demand vs Capacity (PM 3,6,7) (CM1)
	Technological requirements of resources (CM1) (PM5)
	Availability of skilled resources (PM 1,2,4)
	Dynamic supply chain market (PM 1,3,5,7) (CM1) (SOT2)
Legal & regulations	Local laws & regulations (permitting & environmental regulations) (CL1) (SM2) (CM2)
	Political influence (PM 3,4) (CL1)
	Complex regulatory framework (PM8) (CL1) (SM2)
	Variability in securing subsidies (PM3,4) (CM1) (EM1)
Project management & Execution methods	Interdependencies between tasks & phases (PM 1,5)
	Variety & interdependencies between business verticals (PM 1)
	Variety in work approach & terminology (PM 1 3,4)

TABLE 10: KIAN MANESH RAD ET AL. (2017)'S FRAMEWORK SUPPLEMENTED WITH THE COMPLEXITIES FROM ENERGY TRANSITION PROJECTS

(green)	Mentioned in both literature & practice
(red)	Identified from practice

INTERNAL COMPLEXITIES	
WHAT?	
Objectives	Variety in goals and objectives
	Interdependence of objectives
	Transparency of objectives
	Scope Changing
	Variety in client drivers (red)
	Unclarity in objectives (red)
Technical	Level of innovation
	Technological experience and capabilities
	Repetitiveness of process
	Specifications interdependencies
	Technological varieties (green)
	Variety of system components
	Changing technology (green)
	Lack of ownership (red)
	Novel technology (red)
	Integration of new technology into existing facilities (red)
	Interconnectedness between technologies (red)
WHO?	
Capital resources	Size of Capital investment
	Variety of investors, and financial resources (green)
	Variety & lack of clarity regarding financial requirements (red)

	Dependency on external funding sources
	Dependency on offtake agreements
Disciplines	Contract types
	Variety of institutional configurations
	Support from permanent team
	Team cooperation & communication
	Variety & interdependencies between business verticals
People	Dynamic and evolving team structure
	Lack of trust with contractor
	Diversity of participants
	Availability of skilled resources
	Lack of Experience & Capabilities with teams
	Interest & perspectives among stakeholders
	Varying client types
Physical resources	Resource & raw material interdependencies
	Variety of resources
	Availability of Physical resources
	Demand vs Capacity
	Technological requirements of resources
	Dynamic supply chain market
HOW?	
Information	Availability of information
	Reliability of information platforms
	Interdependence of information systems
	Level of processing and transferring information
Tasks	Diversity of sites and location
	Process interdependencies
	Dependencies between tasks
	Number of activities
	Unpredictability of tasks
	Diversity of activity elements
Time	Duration of project
	Dependencies between schedules
	Intensity of project schedule
Tools & Methods	Applicability of project management methods & tools
	Variety of project management methods & tools
	Variety in work approach & terminology

External Complexities	
Economy	Changing economy
	Market competition
	Market unpredictability and uncertainty
Environment	Stability of project environment
	Interaction between technology system and external environment
Legal & Regulations	Local laws and regulations
	Complex regulatory framework
Politics	Political influence
Social	Cultural configuration and variety
	Cultural differences
	Significance on public agenda

The results of this chapter highlighted a shift in management approaches from conventional energy projects, where a control-oriented approach was predominantly used, to a more Hands-off and Combined management approach in Energy transition projects. The results suggest that the people aspect tends to be more Hands-Off and Combined, focusing on proactive engagement, adapting to diverse client needs, and building trust through continuous interaction. The technology aspect still leans towards a control-oriented approach, given the novelty and risks associated with new technologies. The financial aspect has also shifted to a more Hands-Off and Combined approach to deal with uncertainties related to funding sources, incorporating a more agile estimation process. The resource aspect exhibits a blend of Control-oriented, Hands-Off, and Combined approaches, with a shift towards more alliance-type contracting and partnerships rather than traditional subcontractor assignments. A more Combined approach was observed in navigating the intricate and dynamic legal and regulatory landscape. Lastly, the project management and execution methods have shifted from a Control-oriented approach towards a more Combined approach, accommodating high levels of concurrency, interdependencies, and the need for faster decision-making. In summary, the results from the semi-structured interviews suggest that while conventional energy projects predominantly used a Control-oriented approach due to their predictable and stable nature, energy transition projects require more flexible, adaptive, and collaborative approaches to effectively manage their dynamic nature.

Table 11 summarizes the complexity category, the associated management approach, challenges, opportunities and lessons learned from the empirical study and also highlights the link between the management approaches used in practice with the three main project management approaches from literature: Control oriented, Hands-off, and Combined approach (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011). Following which, the next chapter translated these management approaches, challenges, opportunities and the lessons learned identified from the empirical study into guiding steps to navigate the complexities in energy transition projects and help them progress into the execution phase.

Control oriented	(red)
Hands-off	(yellow)
Combined	(green)

TABLE 11: MANAGEMENT APPROACHES, CHALLENGES, OPPORTUNITIES & LESSONS LEARNED UNDER THE SIX THEMES

Complexity Category	Management Approach Identified	Challenges	Opportunities	Lessons learned
People	Proactive Client engagement (SM2) (CM2) (PD1)		• Engage with new clients (PM1)	

	Educational approach (PC1) (PC2) (EM1) Early and continuous engagement (PM1,2) Strategic groups (SM1) (PM1,2) (SM2) (EM1) Robust stakeholder framework (PM9) Zipper approach (PM3)	• Unrealistic expectations (CM1) (PM1) (PC2) (PD1) • Compressing or skipping the front-end development phase (PM 4,6) (SM2) • Control or Micromanagement (PM7) (PC2) • Mismatch in approach (PM4) • Optimism bias (PM3)	• innovative value propositions (PM6) • Securing future projects (PM2)	• More early engagement (PM4,5,7) (PD1) • Immersing a team of experts (PC4) • Asserting expertise (PC2) • Developing in-house expertise (CL1)
Technology	Technology readiness level tool (SM1) (PD1) Technology to financial feasibility studies (PD1) Pilot testing (PD1) Engaging consultants (PM4) Subcontracting portions of technology scope (PM4) Dual pre-FEED study (CM2) Early engagement with licensors and Innovation partners (PM5) (CM2) (PC2) (PD1) (SM2) Strategic groups (PD1) (EM1) (SM1)	• Team flexibility (PM3) • Mindset of engineers (PM7) • Highly competitive & pressured environment (PM5)	• Skill development (PM6) (PD1)	• Involve technology and subject matter experts (PD1) • Better risk sharing mechanisms (PM4) (CM1)

Financial	Expedited/agile estimation process (PM 5,9)			
	Adapting to funding sources requirements (CM1, PM5) Securing offtakers (PM6) Calculate CAPEX and OPEX (PM2)	• funding sources dictating requirements (PM3) • lack of transparency (PM3) • High margins of error (PM5) • loss of control over design (PM5) • Inaccurate estimate/ data passed through disciplines (PM2,5)	• Increased certainty (PM3)	• Urge clients to be more transparent about financial requirements in early engagement (PM2,5)
Resources	Direct manufacturer-client partnership (CL1) (CM1) Collaborative and alliance partnerships with subcontractors (CM2) Early engagement with key supply chain parties (PM1) Quicker estimation with In-house pricing (PM5) Accelerated subcontracting activities (CM1, PM3)	• Reduced quality/high price of bids (PM1,2) • Risk remaining idle (CM1) • Unpredictability of market position for long term strategy development (PM3)	• Trust building (PM3) • Knowledge transfer of key supply chain parties to future projects (PM3,6) • Identify genuinely interested parties (PM1) • Gain early access to crucial information and resources (PM5)	• Dynamic resource strategy (PM5) • Adapting to the supply chain (PM4) • Gain early feedback from key supply chain parties (PM4) • Idle time compensation (CM1) • Expanding project teams with specialists (PM1,2,3,5) • Standardizing staffing practices (PM5)

Legal & Regulations	Specialised roles during permitting process (CL1) Policy specialist (CL1) (CM1) Continuous engagement with regulatory bodies (CL1) Strong & long-term relationships' with external authorities (CL1) Holistic planning for permitting (CL1) Engaging consultants (CL1)	• Lengthiness of processes (CL1) • Understanding the permitting and technology requirements (CL1) • Intense subsidy negotiations (PM4) • Government funding reallocation dynamics (CM1)	• Project awarded 'special status' as significant contributor to energy transition (CL1)	• Clarify roles and responsibilities for funding (PM8) • Refine project definition over optimizing financial aspects (EM1) • Need a shift in the policy side (CM1)
Project management & Execution methods	Agile approach (PM9) Robust change management (PM8,5) Baseline centric execution approach (PM7)	• Clients have specific working preferences (PM7) • Scrutinize contractor's processes (PC1) • Change as source of contention with clients (PM8) • High level of concurrency (PM5) • Tools overwhelming for smaller clients and less appreciation for formality and procedures (PD1)	• Catalyst for positive change (PM9)	• Knowledge sharing (PM8) (CL1) • Advanced data change management (PM5) • More checkpoints (PM8) • Standardizing the execution plan for energy transition projects (PM1)

6 GUIDING STEPS & EXPERT VALIDATION

Based on the empirical study, this chapter delves into the development of guiding steps to get an energy transition project started in section 6.1. Following which the steps are subjected to a round of expert validation in section 6.2 and lastly, based on the insights from the expert validation, the steps are converted into a checklist in section 6.3.

6.1 SEVEN STEPS TO GET AN ENERGY TRANSITION PROJECT STARTED

The challenge of initiating energy transition projects was a recurring theme during the interviews. PM4 articulated this difficulty succinctly: *"Well, I think the biggest issue is that it's difficult to develop these projects and get to the starting line. The steps to take until you can confidently say, 'Now, I know exactly what I want to build. I have a cost estimate, I have the financial resources, and I have the money to invest,' are crucial. Getting to that point is extremely difficult."* Echoing this sentiment, PM6 indicated that it takes at least five years for these projects to even start conceptually. PM8 added that very few energy transition projects are seen progressing into the EPC phase.

6.1.1 GUIDING STEPS DEVELOPMENT

These observations highlight the intricate nature and obstacles that are commonly encountered while starting energy transition projects. In order to tackle these challenges, a set of seven steps has been formulated to navigate the complexities by integrating theoretical knowledge and practical expertise. The objective of this approach is to optimize the process and surmount the usual challenges faced while initiating energy transition projects. As a precursor to these steps, the results of the empirical study have highlighted that it is essential to conduct a complexity-based risk assessment at an early stage of the project to understand the complexities and asses the risk level of the project based on the complexities identified in Table 9. The steps have been formulated by taking a step back to look at the complexities and also by holistically understanding the challenges, opportunities to incorporate the lessons learned into these steps. This sort of a step-by-step format has been adopted for practitioners to have a proper guide of what should be addressed first and second and so on. Additionally, formulating it as steps also creates a sense of ease for the practitioners. The sequence of these steps and the different aspects of complexity they address have been adapted from Figure 9 of the empirical study as shown in Figure 11. Additionally, an extra step 3 is added to address the interface as the results of the empirical study have highlighted concurrency between the phases, activities and the steps owing to the time pressure in these projects. Therefore, from the management approaches and the lessons learned section of the Project management & execution methods aspect, step 3 has been formulated to address the concurrency.

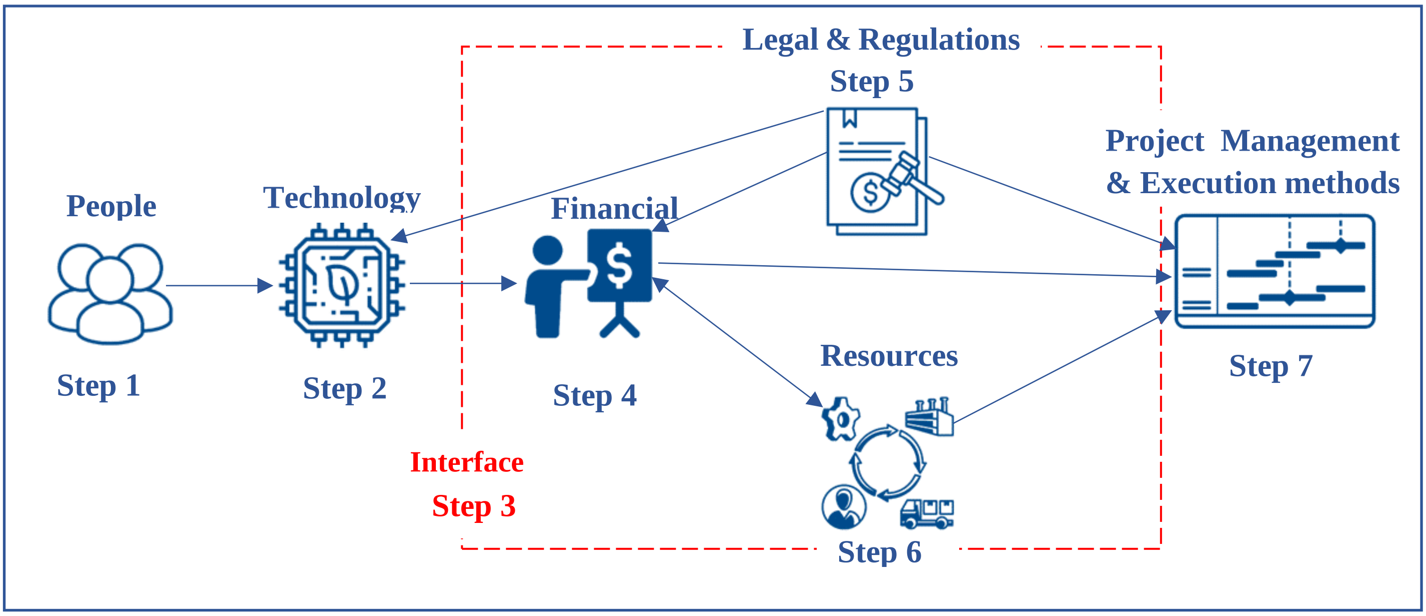


FIGURE 11: SEQUENCE AND RELATION BETWEEN THE STEPS BASED ON THE EMPERICAL STUDY

Table 12 summarizes the steps, key actions within each step, and the key considerations required for each step in the sequence of implementation. Additionally, it stipulates the complexity category each step addresses, including the management approach adopted. Following this, the chapter delves into explaining each of these steps.

TABLE 12: SUMMARY OF THE SEVEN STEPS, THEIR KEY ACTION, CONSIDERTATION, COMPLEXITY CATEGORY ADDRESSED AND THE MANAGEMENT APPROACH FROM LITERATURE THAT WAS ADOPTED (BRAM KOOL, 2013)

Step	Key Action	Key considerations	Complexity category addressed	Management approach adopted (Bram Kool, 2013)
1	**Establish an Embedded team to Address Objectives**	Forming an Embedded team	**People**	**Combined**
		Educative Approach		
2	**Address the Various Facets of the Technology Aspect**	Technology Readiness Level tool & Consultant Engagement	**Technology**	**Control oriented**
		Dual Pre-feed		
		Technology to financial Feasibility Study		
		Early Licensor Engagement		
		Collaboration with Technology/Innovation Partners & Pilot Testing		
		Forming Strategic Groups		
3	**Address the Interface Between The Steps, Tasks and Business Lines**	Data Management and Automation	**Project management & execution methods**	**Hands-off**
4	**Address the Interdependence Between Finance and Subsidy Aspects**	Clarification of Roles and Responsibilities	**Financial**	**Combined**
		Ensure business case viability		
		Expedite/ Agile estimation process		

5	**Address the Legal & Regulation Aspects**	Engaging Consultants/Specialists for Permit Identification	**Legal & Regulations**	**Combined**
		Developing a Detailed Plan for Permit Acquisition		
		Cultivating Strong Relations with Permitting Authorities		
6	**Address the Interdependencies in the Contractual and Resource Management During Early Engagement**	Idle Time & Financial Closure Contingency Plan	**Resources**	**Combined**
		Direct Manufacturer-Client Relationships		
		Expand and standardize project teams		
7	**Address the Need for Management of Change and Scalability of Execution Method**	Establish a Robust Change Management Process	**Project management & Execution methods**	**Combined**
		Adapting & standardizing the Structured Baseline Execution Approach for Energy Transition Projects		

STEP 1: Assess client type & establish an embedded team to address objectives

The first step addresses complexities related to **'People'** aspect of Energy transition projects. It integrates lessons learned from the People theme in the empirical study, such as establishing an embedded team that embodies various practical approaches identified in this theme. This includes proactive, early, and continuous client engagement, transforming the concept of a strategic group into this embedded team. The aim is to apply the zipper approach, aligning contractor and client teams as identified in the management approaches of the People theme. This step also adopts the educative approach, responding to the highlighted challenges in the people-related aspects of the empirical study. Furthermore, it employs a Combined management approach from literature (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011), blending elements of the control-oriented approach, such as focusing on the front-end development phase with early engagement, and aspects of the Hands-off approach, like fostering collaborative and network-style relationships. This is exemplified by the contractor assuming a more functional role, moving beyond mere task execution, to facilitate a more cooperative partnership. The steps involved in this approach include:

1) **Forming an embedded Team**: Begin by assembling an embedded with expertise relevant to the project's scope, including technical knowledge in energy transition, project management skills, and understanding of regulatory environments and mainly based on the nature of the client organization this could typically involve, process directors, project controls, sales managers, operational managers, etc. This team acts as the primary interface between the service provider and the client.

    a) **Immersing the Team in the Client's Organization or team**: Next, deploy this team to the client's site or immerse them with the client's team. This immersion is critical for gaining a deep understanding of the client's operational environment, experience, culture, and specific needs, providing firsthand insights into their objectives, challenges, and expectations.

2) **Educative approach**: Recognizing that many clients, especially startups or those new to sustainable practices, may lack experience in energy transition projects, the team's role extends to education. They must assess the client's current level of understanding and knowledge gaps.

    a) **Supporting Unstructured Startups**: In the case of startups, which often lack a structured approach, the team can provide critical support in organizational structuring. This might include placing a counterpart within the startup to ensure smooth communication and project progression, thereby avoiding potential delays.

    b) **Engaging with Traditional Energy Clients**: When dealing with traditional energy consumers or producers, the team's focus should shift to identifying and engaging with the right level of authority. This ensures that decisions and actions are taken efficiently and that the project aligns with the client's organizational hierarchy and decision-making processes.

    c) **Conducting Workshops and Webinars**: Implementing educational programs like workshops and webinars is an effective way to convey necessary information. These sessions can cover a range of topics, from the basics of energy transition to more detailed aspects like regulatory compliance, technological innovations, and project management strategies.

        i) **Tailoring Educational Content:** The content of these educational initiatives should be tailored to the specific needs and knowledge level of the client. For instance, a startup might require more fundamental knowledge and should not be overwhelmed by the multitude of tools & methods used, while a more experienced client may benefit from advanced discussions on integrating sustainable practices into their existing operations.

3) **Setting Realistic Expectations:** One of the key objectives of educating clients is to help them form realistic expectations about the project. This involves clarifying the complexities, potential challenges, timeframes, and costs associated with energy transition projects. This can help avoid unrealistic expectations at later stages of the project.

4) **Aligning Client teams and Project Goals:** Education ensures that the client's objectives are aligned with the practical realities of energy transition projects. Furthermore, aligning the teams on both sides, known as the 'Zipper approach' is crucial for the successful execution and outcome of the project.

5) **Building a Strong Relationship**: Finally, use the governance team's presence within the client's organization to build a strong, collaborative relationship, fostering trust and ensuring alignment with the client's vision.

In summary, the establishment of a governance or embedded team and their immersion in the client organization is a critical first step. It ensures that the project is developed with a clear understanding of the client's unique drivers, objectives, and context, leading to a more effective, tailored, and successful energy transition project.

STEP 2: Address the various facets of the technology aspect

The second step addresses complexities related to **'Technology'** aspect of Energy transition projects, it integrates the management approaches used in practice as identified through the empirical study for managing the technology aspect. This step adopts a Control oriented approach from literature (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011), as it emphasizes structured methodologies like using a technology readiness level tool, pilot testing, engaging consultants, which are aimed at creating predictability and controlling the risks in technology management, a key characteristic of the control-oriented approach. The steps involved in this approach include:

1. **TRL & Consultant engagement**: When dealing with novel technology, start by dedicating more time to the front-end development phase. Use tools like the Technology Readiness Level (TRL) to assess the maturity of various technologies. Consider engaging consultants with expertise in the specific technology to ensure smooth adoption.

2. **Dual Pre-feed**: If there are multiple technology options, conduct a dual pre-feed study along with a technology feasibility study. This helps in selecting the technology that best aligns with the project's goals.

3. **Technology to financial feasibility study**: Next, conduct a bankable feasibility study to evaluate the financial viability of the technology. This includes aspects like rate of return, operational expenses (OPEX), and skill requirements.

4. **Early licensor engagement**: Once the technology is selected, address the issue of ownership. This may involve licensing the technology, engaging early with the licensor, or subcontracting part of the technology scope.

5. **Collaboration with technology/innovation partners & Pilot testing**: When working with unfamiliar technology, collaborate with technology/innovation partners to incorporate their insights into the process design. Engage a process design and optimization group to pilot test the technology before scaling.

6. **Forming Strategic Groups**: Finally, establish strategic groups that are dedicated to exploring and understanding the diverse markets within the energy transition sector. These groups should thoroughly investigate the spectrum of available technologies and consistently stay updated on

the latest advancements. The dynamic nature of energy transition technologies necessitates that these groups play a pivotal role in maintaining the project's alignment with current trends, innovations, operational capacities, and market shifts. Their responsibilities encompass technological assessment, market analysis, and ensuring alignment with operational capabilities, thereby providing valuable insights for informed decision-making and strategic planning.

In summary, these steps emphasize the importance of a detailed, multi-faceted approach to managing technology in energy transition projects, from initial assessment and selection to integration and operationalization.

STEP 3: Address the interface between these steps, tasks and business lines (*Should be setup in step 3 and implemented from step 4*)

This step addresses the complexities associated with the 'Project Management & Execution Methods' aspect of energy transition projects. The empirical study highlighted the necessity for high concurrency among various tasks, business lines, and steps due to time constraints in these projects. Consequently, this step integrates lessons learned from the Project Management and Execution Methods section, particularly the engagement of a data management and automation process. It involves appointing a project automation manager to ensure that all disciplines are aware of the data maturity in the preceding discipline. This step adopts a Hands-off approach as the management of interface is considered a shared task where all the discipline leads need to coordinate with the project automation manager and make sure the data monitoring is set up appropriately before starting step 4 (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011).

In energy transition projects, where time constraints often necessitate parallel execution of multiple steps, effective interface management becomes crucial. With various tasks and disciplines expedited to start concurrently, each task often depends on the completion of its predecessor, leading to a high degree of concurrency. Interface management is essential to minimize reworking at later stages and to ensure the accurate transfer of data across different disciplines which is the case for step 4-6. Moreover, energy transition projects typically require increased collaboration among diverse business lines, such as energy solutions and mining and metals, each having its unique operational approach. Thus, managing the interfaces between steps, tasks, and business lines at the beginning stage is vital. The following approach can be adopted to address this aspect:

1. **Data Management and Automation:** Initiate the process by designating representatives from each discipline or business line to work with the automation manager concurrently from step 3 until the completion of step 5. Their role will be to streamline and automate data, ensuring clear visibility of project status and task progression for all team members. This plan should detail the flow of project design information between disciplines throughout each phase of the project, ensuring that all parties are consistently informed and aligned.

By addressing these aspects, Step 6 ensures that energy transition projects are managed effectively, with a focus on maintaining clear, efficient communication and data management across various concurrent project components.

STEP 4: Address the interdependence between finance and subsidy aspects

Once the technology for an energy transition project is chosen and its integration process established, the focus shifts to financing and regulatory compliance. In energy transition projects, external funding is often crucial, especially for startups lacking private equity. Many clients are incentivized to invest in these projects due to subsidies. The financial and regulatory aspects are intertwined, particularly due to the subsidy component. Complying with the myriad of requirements for funding sources (subsidies or external investments) is critical, as non-compliance can delay projects and create uncertainty about funding availability. Moreover, the regulatory framework for these projects is complex and evolving, often involving numerous permits and strict adherence to regulations before project commencement. Therefore, addressing the fiscal aspect and regulatory compliance concurrently or in an intertwined manner is essential for project progression.

Therefore, the third step addresses complexities related to **'finance'** aspect of Energy transition projects. It integrates lessons learned from the legal and regulations aspect, specifically clarifying roles and responsibilities regarding funding. Additionally, it adopts management approaches identified through the empirical study, such as expediting the estimation process. This includes strategies for aligning deliverables with funding requirements, a practical approach observed in the study. Moreover, the step encapsulates the practice of calculating both CAPEX and OPEX under the umbrella of 'ensuring business case viability'. This step employs a combined management approach as outlined in literature (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011). It incorporates elements of control-oriented approach by clearly defined roles and responsibilities, fostering predictability by verifying business case viability. Simultaneously, it incorporates the flexibility of the Hands-off approach to meet the requirements of clients and external funding authorities, demonstrated through an agile estimation process and the provision of OPEX estimates.

Approach for Addressing the Financial Aspect:

1. **Clarification of Roles and Responsibilities:** First, define clear lines regarding roles and responsibilities related to funding. The client should liaise with funding sources and communicate requirements to the main contractor, who in turn informs subcontractors, ensuring clarity at all levels.

2. **Expedite/agile estimation process:** Funding often times hinges on accurate estimates and designs. Therefore, convey these prerequisites to the contractors to facilitate proper planning. This step may include prioritizing estimations over proper design to secure funding, leveraging in-house pricing, and engaging collaboratively with key supply chain parties for early definition. Strive for a balance to mitigate the risk of receiving higher bids due to premature market engagement, fostering alliance-style relationships. It's crucial to accurately estimate the resource needs for these activities, factoring in contingencies in the schedule. This integrated approach ensures both deliverables and financial aspects of the project are in sync, supporting a smoother progression towards securing necessary funding.
3. **Ensure Business case viability:** Along with calculating the capital expenditure, also provide the operating expenditure and secure offtakers for the product developed in the project to strengthen the business case viability.

This step is critical in ensuring that energy transition projects are not only technically feasible but also fiscally viable and compliant with the relevant legal framework.

STEP 5: Address the legal & regulation aspects (*SHOULD BE CONDUCTED IN PARALLEL TO STEP 4)*

In energy transition projects, the permitting process is notably complex and demands considerable effort, particularly in proving that the project will not significantly harm the environment, such as through nitrogen oxide emissions. This complexity stems from stringent environmental regulations. Adhering to these regulations not only ensures compliance but could also lead to the project receiving 'Special recognition' from the Ministry of Economic Affairs and Climate Policy for its contribution to the energy transition. Such recognition can facilitate the process of obtaining government subsidies, thereby enhancing the project's business viability. This makes the legal aspect a critical component in the development of energy transition projects.

Therefore, this step addresses the complexities related to 'Legal & regulations' aspect of Energy transition projects. This step was developed by incorporating the management approaches identified from the empirical study for the legal and regulations aspect such as Engaging consultants or specialists for identifying the necessary permits, developing a detailed engagement plan for acquiring the permits and developing long and strong relationships with permitting authorities. The results of the empirical study highlight the need to conduct this step in parallel to step 3 given the time pressure of these projects and also to have the necessary permits in place to avail the funding. This step adopts a Combined approach from literature as it focuses on engaging stakeholders based on task execution such as consultants or policy specialists (Control oriented) while also developing strong relationships with external authorities highlighting an external focus (Hands-off) (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011).

Approach for Addressing the Legal Aspect:

1. **Engaging Consultants/specialists for Permit Identification**: Start by engaging consultants or specialists to identify all necessary permits. This should be one of the earliest steps to ensure a comprehensive understanding of the legal landscape and to inform subsequent planning.
2. **Developing a Detailed Plan for Permit Acquisition**: With the assistance of the consultants, develop a detailed plan for obtaining these permits. This plan should include a comprehensive checklist of application requirements. Start this process well in advance to accommodate lengthy procedures, such as ecological studies, and ensure you're accounting for various authorities (provincial, regional, national) relevant to the project. Integrate this plan into the project schedule, considering time needed for this permitting process.
3. **Cultivating Strong Relations with Permitting Authorities**: Concurrently with the above steps, begin cultivating strong relationships with external authorities involved in the permitting process. Establishing these relationships early can facilitate smoother communication and understanding throughout the project lifecycle.

STEP 6: Address the interdependencies in the contractual and resource management during early engagement (*SHOULD BE CONDUCTED IN PARALLEL TO STEP 4)*

Following the complexity of securing funding, various other intricate aspects arise during the process of obtaining this funding. For instance, obtaining an early definition from the market necessitates that the main contractor engages a subcontractor. Consequently, there is a dependency wherein the subcontractor's contract award is contingent upon the main contractor receiving their contract. However, in energy transition projects which are characterized by funding uncertainty, this interdependence becomes more complex. Subcontractors need to be involved earlier for an early definition, but they do not receive full commitment of the contract, placing their business at risk as their personnel are kept on standby until funding is secured. Therefore, this step addresses the complexities associated with the 'Resource' aspect of energy transition projects. It integrates lessons learned from the empirical study's Resource aspect, such as compensating contractors and subcontractors for idle time and standardizing project teams to ensure knowledge continuity in energy transition projects. Furthermore, this step incorporates the management approach identified from the empirical study, which involves early engagement with key supply chain parties in the resource aspect. This includes applying lessons learned about obtaining iterative feedback from these key parties. This step adopts a combined approach from literature as it incorporates the need for standardization and early engagement (control oriented) while engaging the subcontractors as key members of the project (Hands-off) (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011).

In such situations, the following approach can be utilized if feasible:

1. **Idle time & Financial Closure Contingency Plan:** The client could compensate for the idle time of both the contractor and the subcontractors, utilizing a portion of their private equity to initiate smaller segments of the contract work. This approach helps in mitigating the risk for subcontractors and maintaining the project's momentum even amongst funding uncertainties.

When addressing subcontractor involvement in energy transition projects, resource management, encompassing both physical and human resources, becomes a crucial aspect. Current global challenges, such as the volatility in the supply chain market due to the pandemic and geopolitical tensions, significantly impact energy transition projects. This situation is exacerbated by a mismatch between demand and capacity in the market. Despite ambitious project deadlines and targets set for specific years, there is often a discrepancy between achievable goals and the availability of essential physical resources, like feedstock, needed for these projects.

Moreover, the availability of skilled human resources poses another challenge. It's not just about having enough personnel, but ensuring these individuals are equipped with the necessary knowledge and expertise to effectively contribute to energy transition projects.

To navigate these complexities surrounding physical and human resources, the following approaches can be employed:

Physical resources:

1. **Early engagement with key supply chain parties**: Engage with key supply chain parties early in the project to incorporate their feedback and knowledge into the design information necessary for creating funding estimates. Foster collaborative and alliance partnerships with subcontractors to have an even risk profile. Additionally, make the resource strategy dynamic by adapting to the supply chain.

2. **Direct Manufacturer-Client Relationships**: Facilitate direct interactions between manufacturers and the client. This can assure manufacturers of a return on their investments and aid in their equipment sales. It also contributes to building trust between the client and the contractor.

Human Resources:

1. **Expand and standardize project teams**: Expand the project teams by including specialists experienced in handling novel technologies and standardize the staffing across the different energy transition projects.

STEP 7: Address the need for management of change and scalability of execution methods

Although the interface between various activities starting in parallel and ways to address it have been established in the previous step, there is still a scope for inaccurate data to be passed through the disciplines considering the high level of concurrency in these projects. Therefore, the management of change becomes a crucial aspect. Most energy transition projects are in their nascent stage therefore most of them are smaller projects, however, organizations that are used to executing large projects have their execution methods tailored to these large projects which now need to be scaled down to cater to these smaller energy transition projects. Therefore, these aspects can be addressed as follows:

Change management:

1) **Establish a Robust Change Management Process**: Begin by setting up and publicizing a comprehensive change management process. This process should include a workflow for obtaining necessary approvals, which varies based on the potential impact of the change on the project's cost and schedule. It should also incorporate a change log to track modifications and methodologies to accelerate the handling of changes, especially in the early stages of the project.

   a) **Regular Communication of Change Status by Project Management Team**: The project management team should consistently and clearly communicate the status of approved changes. This ensures that once changes are approved, they are promptly implemented, maintaining project momentum, and reducing delays.

   b) **Educating Participants on the Impact of Late Changes**: Inform all project participants about the significant impact that major changes, especially those made in the later stages of the project, can have on meeting cost and schedule requirements. This awareness is crucial to minimize last-minute alterations that could derail the project's progress.

Execution methods:

1. **Adapting the Structured Baseline Execution Approach for Energy Transition Projects**: Standardize a baseline execution approach that can be applied to all sizes of energy transition projects. This structured approach should include a comprehensive plan outlining key elements like objectives, deliverables, timelines, resource allocation, budget, and performance metrics. This plan serves as a reference point throughout the project execution. By standardizing this approach for energy transition projects, it can then be flexibly scaled up or down to suit the specific requirements of different types of energy transition projects.

6.2 Expert Validation

Expert validation was conducted with experts from organizations such as Worley and Technip to broaden the applicability of the guiding steps. The interviews were carried out for 60 minutes via Microsoft Teams meetings. This section discusses the selection of experts in Table 13, followed by the interview procedure in Subsection 6.2.2. Lastly, the section explores the feedback provided by the experts in Subsection 6.2.3, which pertains to the sequence and bundling of the steps, their feasibility and timeline, the preferred visualization of the steps, and, finally, the relevance of these steps to energy transition projects.

TABLE 13: EXPERT SELECTION

Code	Role Description	Years of experience
E1	Current Vice President of Project management at Worley, worked in Fluor for 18 years before transitioning to current role to purse energy transition development. Has published articles such 'Projects and People: Organizational Effectiveness' and 'Organizational Effectiveness: Collaboration in an Integrated Project Team' along with Prof. Hans Bakker & Prof. Marian Bosch-Rekveldt. Additionally, an integral part of the TU Delft Moocs course: 'Mastering Project Complexity.'	30+

E2	Current Managing director at Technip Energies, worked in Fluor as a Project director before transitioning into current role and was also V.P Special projects focussing on energy transition projects.	30+
E3	Project Manager at Technip Energies, currently focused on energy transition projects.	20

6.2.1 Interview Procedure

The interviews were conducted individually, starting with a general introduction, followed by a brief overview of the thesis journey up to that point. Subsequently, the questions were tailored to validate the sequence and arrangement of the steps outlined in Guiding steps & Expert Validation. This was followed by questions about the optimal visualization of these steps and to ensure that the terminology used is universally applicable across various organizations and not just theoretically focussed. Following which, the feasibility and timeline of these steps were posed as questions to the interviewees. The latter part of the interview shifted to a broader and more introspective analysis, focusing specifically on the relevance of the seven steps to energy transition projects. This segment emphasized distinguishing factors between energy transition projects and other types of complex projects, with a particular emphasis on exploring the 'why' aspect of these differences.

6.2.2 Expert Feedback

Sequencing & Bundling

In the discussion about the sequencing and bundling of steps, E1 emphasized that there is no 'one size fits all' approach. They highlighted the complexity arising from the interaction between various steps, illustrating how focusing on one aspect, like technology, can suddenly bring financing or environmental impacts into the equation, necessitating a shift in focus. E1 acknowledged that while there's no definitive right or wrong sequence, understanding the dynamic and interconnected nature of these steps is crucial. He advocated for a holistic approach, taking into account the entire complexity and varying perspectives, as different stakeholders and drivers influence project outcomes.

E1 suggested that in practical scenarios, the steps need to be customized to the specific complexities, the people involved, and their drivers, calling for a flexible adaptation to the most prudent and logical situation at that point of time. This approach emphasizes considering all variables holistically and employing a framework adaptable enough to suit various situations, focusing more on the awareness created by these steps rather than offering a one-stop solution.

E2 and E3 agreed, noting that the sequence and bundling of steps would differ based on the type of client. They proposed adding a precursor to the first step: assessing the client type to tailor the steps accordingly. For instance, a startup might require a more hands-on approach like an embedded team, whereas for a traditional energy producer, integrating the embedded team with the client's team might be more efficient. Thus, they recognized the importance of not altering the current sequence of steps but enhancing it with an initial assessment of the client and project complexities, ensuring a holistic and tailored approach to each project.

Visualization & Wider applicability

During the discussion on visualizing the seven steps for their respective project teams, the experts proposed different approaches. E1 suggested that the steps could be represented as a decision tree, allowing for a structured visualization of decision-making processes at each step. E2, on the other hand, recommended portraying the steps as parallel workstreams, with each step having its own timeline, emphasizing the concurrency of the different steps in these projects. E3 proposed visualizing the seven steps in a roadmap format, which would allow project teams to see the steps as guiding principles or guidelines. They emphasized that this approach would be user-friendly and offer the flexibility to reflect on the applicability of each step for individual projects. By serving more as a reference or guide, the roadmap format would facilitate a clear and adaptable framework for teams Additionally, they also mentioned it could serve as a checklist that could facilitate teams in first assessing the complexities of the project and then determining the necessary steps, thereby enhancing clarity and structured progression in project execution.

FEASIBILITY & TIMELINE

When discussing the feasibility and time required for implementing the seven steps, E1 pointed out that feasibility is context dependent. For instance, in the embedded team approach, feasibility would vary based on the business model, particularly for service providers like Fluor. Here, feasibility boils down to whether there is a willingness to pay for the service, and if the client recognizes its value. E2 remarked that while the seven steps are 'potentially relevant', their practical applicability would vary from one project to another.

On the topic of timelines, E3 noted that ideally, these steps would be completed within six months, but realistically, it might extend to 12 months, acknowledging that clients often prefer shorter timelines. E3 also mentioned that the timeline for executing these steps would be influenced by factors such as the type of energy transition project and the maturity of the technology involved, indicating that more complex or less mature technologies might lead to longer project durations.

RELEVANCE TO ENERGY TRANSITION PROJECTS

In exploring the relevance of these approaches to energy transition projects as opposed to any other complex project, E1 reflected on the concept of causality. In traditional energy projects, there's a clear cause-effect relationship; specific actions yield predictable outcomes, much like the iron triangle where actions directly impact time, cost, or quality. However, energy transition projects introduce a higher degree of uncertainty, as the outcomes of actions are less predictable. This unpredictability challenges the conservative and rigid methodologies traditionally used in energy projects, which rely heavily on best practices, procedures, and specifications, highlighting the ‘need to know’. E1 emphasized that the dynamic nature of energy transition projects cannot cope with this sort of a rigidity and demands adaptability, highlighting the importance of the seven steps in navigating this new landscape. He pointed out that our accumulated knowledge and experience might be less applicable in these projects, underscoring the need for a fresh approach that differs from conventional methods used in oil and gas projects.

E2 and E3 agreed with E1's perspective, noting that energy transition projects are characterized by novel technologies, business viability challenges, subsidies, feasibility issues, and evolving legislation, which are also the differentiating factors from other complex projects. These features contribute to the heightened uncertainty in such projects, creating a broad scope at the outset. They emphasized that the seven steps provide essential guidance in navigating this complexity, allowing them to narrow the scope.

6.3 KEY TAKEAWAYS

This chapter delved into the development of guiding steps based on the insights gathered from empirical study. Practitioners noted the challenges surrounding starting the energy transition projects, therefore these steps combined management approaches and lessons learned from practice to navigate the different complexities at each step to reach the execution phase. Furthermore, these steps were linked to the management approaches that were adopted from literature. Following which, the steps were subjected to a round of expert validation with experts from Worley and Technip such as the Managing director, Vice president and Project manager, which yielded several valuable insights. Firstly, the experts recommended that the steps should be adaptable to specific projects, beginning with an assessment of the client type as a precursor. This is crucial since the feasibility of the steps heavily depends on the client's preferences. Secondly, they proposed various methods for visualizing the steps, such as a decision-tree, roadmap, and checklist. Lastly, the experts reflected on the applicability of these steps to energy transition projects. This reflection unveiled the factor of causality, emphasizing that energy transition projects are dynamic and cannot adhere to the rigidity of traditional methods. Therefore, the approaches need to be flexible. Consequently, based on these insights, the steps were transformed into a checklist format, with each step becoming a checkpoint. Practitioners, noted that they are juggling a lot of balls in these projects, and expressed a preference for additional checkpoints to make sure they do not drop any of the balls (PM8). This transformation also addresses the inherent linearity of the previous format; converting the steps into a checklist enhances their flexibility, allowing practitioners to select and adapt each checkpoint according to the specific needs of their energy transition projects, thus maintaining effective control over the project's progression and thereby reducing the possibility of delays from risks at later stages.

Checkpoint 1: Assess client type & establish an embedded team that is either immersed in the client’s team or organization

☐Assess whether the type of client is a novel/startup or a traditional energy producer or a traditional energy consumer and their level of experience as shown in figure 10.

☐ Form an embedded team and either immerse the team in the client’s organization or team

☐ Adopt an Educative approach

Checkpoint 2: Address the various facets of the technology aspect

☐TRL & Consultant engagement

☐Dual Pre-feed

☐Technology to financial feasibility study

☐Early licensor engagement

☐Collaboration with technology/innovation partners & Pilot testing

☐Forming Strategic Groups

Checkpoint 3: Address the interface between these steps, tasks and business lines (*Should be setup in step 3 and implemented from step 4*)

☐Initiate a data Management and Automation process

Checkpoint 4: Address the interdependence between finance and subsidy aspects

☐Clarification of Roles and Responsibilities

☐ Ensure business case viability

☐Expedite/ Agile estimation process

Checkpoint 5: Address the legal & regulation aspects *(should be conducted in parallel to checkpoint 3)*

☐Engage Consultants/specialists for Permit Identification

☐ Developing a Detailed Plan for Permit Acquisition

☐ Cultivating Strong Relations with Permitting Authorities

☐ Developing an Engagement Plan

Checkpoint 6: Address the interdependencies in the contractual and resource management during early engagement *(should be conducted in parallel to checkpoint 3)*

☐ Idle time & Financial Closure Contingency Plan

☐ Early engagement with key supply chain parties

☐ Foster Direct Manufacturer-Client Relationships

☐ Expand project teams

Checkpoint 7: Address the need for management of change and scalability of execution methods

☐Establish a Robust Change Management Process

☐Regular Communication of Change Status by Project Management Team

☐Educate Participants on the Impact of Late Changes

☐Adapting the Structured Baseline Execution Approach for Energy Transition Projects

The checklists designed for guiding energy transition projects are instrumental in streamlining and accelerating these projects by offering a structured and adaptable framework. The checklist allows for customization according to the specific needs and drivers of the different clients. This is crucial in energy transition projects where the type of client, ranging from startups to traditional energy companies, significantly influence the approach and its feasibility. Additionally, the results of the empirical study have highlighted some complexities and challenges specific to energy transition projects, including changing regulations, funding uncertainties, and novel technology. The checklists provide a clear roadmap for navigating these complexities, ensuring each aspect of the project, from technology assessment to legal compliance are thoroughly addressed.

The checklist facilitates proactive engagement with the stakeholders, agile responses to changing circumstances, and continuous adaption, which is required to deal with the dynamic and rapidly evolving landscape of energy transition. By clearly delineating the steps for stakeholder engagement, resource management and interface management between various project components, the checklist promotes effective collaboration and communication among the different parties. The clear checkpoints enable a faster and more efficient decision-making process which crucial to maintain the momentum of the project in the face of time pressures and high level of concurrency. Furthermore, the checklist allows for flexibility in its implementation while also providing a structured approach. This balance is needed when handling the dynamic nature of these projects. Lastly, this checklist provides a holistic view of the challenges and potential risks at the early stages of the project, reducing the likelihood of delays and unforeseen circumstances. Thereby, facilitating a successful initiation and acceleration of energy transition projects which could in turn address the overall slow progression of Energy transition.

7 DISCUSSION

This chapter aims to 'zoom out' once more, juxtaposing theoretical insights with practical findings, and contextualizing the differences within the broader scope of energy transition projects. Its primary goal is to unravel the 'why' behind these differences (Section 7.1). Additionally, the chapter will delve into addressing the complexities in energy transition projects (Section 7.2). Lastly, this chapter concludes with the contribution made to the existing body of knowledge (Section 7.3).

7.1 THE 'WHY' ASPECT

Literature identifies complexities as being Structural, Dynamic, or Representational (Benbya & McKelvey, 2006; Floricel et al., 2016; Whitty & Maylor, 2009). However, the findings of this thesis indicate that complexities in energy transition projects are predominantly dynamic. This observation stems from the empirical study, which attributes dynamic complexity to the evolving nature of technologies and market conditions. Unlike structural complexities, which are more static, dynamic complexities in these projects arise from continual technological advancements and fluctuating market landscapes. The study also reveals that stakeholder interests and relationships are not static but evolve as the project progresses, potentially leading to conflicting interests among stakeholders like venture capitalists, regulatory authorities, the public, and investors. In contrast to structural complexities, which are internally oriented and involve internal systems and interactions, the dynamic complexity in energy transition projects is significantly influenced by external factors such as political and regulatory environments. These external elements are dynamic and necessitate navigating evolving policies and regulations that could alter project scope, schedule, costs, and objectives.

The literature presents an uncertain relationship between complexity, risk, and uncertainty (Daniel & Daniel, 2018). However, in the context of energy transition projects, the empirical study provides direct examples suggesting that complexity is a source of uncertainty. For instance, evolving technologies and dynamic market conditions significantly contribute to uncertainty. This aligns with a significant portion of the literature that views complexity as a source of uncertainty (Daniel & Daniel, 2018; Danilovic & Browning, 2007; Dikmen et al., 2021; Williams et al., 1995). In terms of the relationship between complexity and risk, the empirical study demonstrates that complexity often translates into risk, especially when adopting new technologies or encountering delays due to funding uncertainties, corroborating the literature's view of complexity as a source of risk (Kian Manesh Rad et al., 2017; Vidal & Marle, 2008).

The importance of the front-end development phase is underscored in both literature and practice (Bosch-Rekveldt, 2011). The empirical study particularly emphasizes its significance in projects involving new technologies, such as those in energy transitions. Practitioners noted the frequent need to compress or skip this phase due to time pressures. However, they also acknowledged that neglecting this phase could create additional risks in later stages of the project.

The empirical study has highlighted several distinctive complexities in energy transition projects as compared to conventional energy projects Kian Manesh Rad et al. (2017). The results of this thesis suggest that these complexities arise from a unique interaction and interplay among different features of energy transition projects, specifically Novelty, New and Different Relationships, Subsidy Component, Time Pressure, and Business Case, as outlined by Toonen (2022). Additionally, the empirical study underscores that the uniqueness lies not only in the genesis of these complexities from the interplay of different features but also in how they manifest as challenges within energy transition projects, consequently affecting their progression.

When examining the distinctive complexities related to the '**People**' aspect from the empirical study, it appears that they originate from the interplay of **Novelty, New and Different Relationships, and Time Pressure**. For example, the aspect of New and Different Relationships leads to a diverse client base with specific drivers in these projects. Being new, these relationships lack foundational trust between the client and contractor. This situation is exacerbated by the Novelty feature, which contributes to a lack of knowledge among participants, as these projects are new and lack historical experience, resulting in unclear project objectives. When compounded by Time Pressure, these factors manifest as challenges in energy transition projects, such as unrealistic expectations regarding schedules and costs, due to the absence of prior project development experience and the urgency imposed by time constraints. Similarly, the lack of trust, stemming from New and Different Relationships, leads to control or micromanagement by the client. This is exemplified in the empirical study where a participant (PC2) described having to submit extensive 260-page monthly reports to a client focused on closely monitoring every aspect, necessitating additional time, money, and resources, which in turn further delays the progress of these projects, leading to the people aspect identified as the major aspect where focus needs to be placed from the empirical study.

When examining the distinctive complexities related to the **'Technology'** aspect in energy transition projects, as identified in the empirical study, their origin can be traced to the interplay between **novelty and changed business cases**. The study indicates that due to the evolving business case feature, there is a necessity to develop new technologies, which is directly related to the novelty aspect. This novelty often results in a lack of defined boundaries in these projects, as observed in the empirical study, coupled with an absence of established regulations since they have yet to be formulated. Additionally, the novelty factor contributes to a wide range of technological options, as there is no singular, tried-and-tested path to follow, thus expanding the project's scope. This situation is further compounded by the fact that, due to the novelty, many companies do not own the technology, as indicated by the empirical findings. These factors lead to challenges such as the need for constant optimization amidst the novelty of the technology. However, a notable challenge is optimizing while simultaneously adhering to the constraints imposed by time pressure.

In examining the distinctive **financial** complexities of energy transition projects, as identified in the empirical study, it becomes evident that these complexities emerge from a combination of factors. These include the **novelty** of the technology, the evolving **business case**, the reliance on **subsidies**, and the pressure of time constraints. The innovative nature of the technology necessitates a revision of the traditional business model, which, as the study shows, often leads to a dependence on external funding, off-take agreements, and subsidies. This situation, compounded by the urgency to complete projects, results in a high degree of concurrency in project activities. Consequently, estimates are made with significant margins of error, leading to challenges like the circulation of inaccurate data across disciplines, necessitating rework, and ultimately causing delays that slow down the progress of energy transition projects.

Regarding the distinctive **resource**-related complexities in energy transition projects, the empirical study highlights their emergence from the interaction between the **novelty** of these projects and **time pressures.** The urgency to implement these projects quickly clashes with the limited capacity available in the market. This issue is exacerbated by the novel nature of the technology, which demands bespoke resources which may not yet be available or whose feasibility is uncertain. Additionally, this novelty creates a knowledge gap, impacting not just the availability of resources but also the availability of skilled resources. These distinctive features of energy transition projects, namely novelty and time pressure and the complexities arising from their interaction manifest in various challenges. Notably, there is often a reduction in the quality or an increase in the price of bids, diminishing the viability of the business case. This, as observed in the empirical study, poses a significant obstacle to the progression of energy transition projects.

When delving into the complexities associated with **legal and regulatory** aspects of energy transition projects, as revealed in the empirical study, it's clear that these complexities primarily stem from the interplay of **novelty**, **time pressure**, and **subsidy** dynamics. The introduction of new technologies, a characteristic feature of these projects, necessitates the development of new regulations. This situation often leads to unclear boundaries within the project scope, especially when compounded by the urgency imposed by time constraints. This urgency can result in a rapid development of different regulations, which project stakeholders must carefully navigate. Furthermore, the novelty of these technologies requires a viable business model, linking closely to the subsidy aspect. Given their innovative nature, energy transition projects often attract various forms of subsidies, each with its own set of rules and requirements. This diversity adds another layer of complexity to project management. These factors collectively manifest in challenges such as prolonged negotiations to secure maximum subsidies and uncertainty regarding funding allocation. Such issues can lead to significant delays, and in some cases, as indicated by the empirical study, can even result in the halting of projects if funding fails to materialize.

In examining the unique complexities associated with **project management and execution methods** in energy transition projects, as revealed by the empirical study, these complexities can be traced back to the interplay of the evolving **business case**, and **time pressure**. The changing nature of business cases in these projects often necessitates collaboration across diverse sectors, such as mining, metals, and energy solutions, leading to a convergence of different industrial backgrounds. This diversity results in varied work approaches and terminologies, as indicated by the study findings. Additionally, the urgency associated with time pressure in these projects leads to a high level of concurrent activities, aiming to expedite project progress. However, the interaction of these features –, the evolved business cases, and the intense time pressure – manifest as significant challenges. These challenges can create obstacles to the advancement of energy transition projects, as observed from the results of the empirical study. For instance, the high level of concurrency could lead to inaccurate data which would in turn require change and this change can often becomes a source of contention with clients. This discrepancy can observe to further exacerbate trust issues between the client and contractor, leading to increased micromanagement or scrutiny of the contractor's methods. Such situations inevitably result in further delays, consuming more time and resources and thereby slowing the overall progress of these projects, as noted by the practitioners.

Based on the findings of this thesis, it is evident that the complexities in energy transition projects, when compared to traditional energy ventures, stem not only from their distinct features but also from the interplay of these features. Among these, the **'Novelty'** aspect emerges as the most pronounced and recurring theme across all facets of energy transition projects. This feature significantly influences various dimensions, ranging from People, Technology, Financial, Legal & Regulations, Resource-related, to Project Management and Execution Methods. In the People aspect, the Novelty aspect directly contributes to a lack of foundational trust and knowledge among participants, leading to unclear project objectives and unrealistic expectations. In Technology, Novelty presents central challenges in developing new technologies, increasing the risk profile of these projects. Financially, the novel nature of the technology necessitates a shift from traditional models based on private equity to a reliance on external funding and subsidies. In terms of Resources, Novelty again demands bespoke equipment, creating a knowledge gap that affects both the availability and feasibility of required resources.

The introduction of new technologies, another facet of the Novelty feature, requires the development of new regulations. This leads to unclear boundaries and the need to navigate through a myriad of emerging regulations. Lastly, the interplay of Novelty with changing business cases leads to variations in work approaches and terminologies, exacerbating issues due to time pressure and resulting in misunderstandings among project stakeholders. Lastly, the thesis also highlights several opportunities arising from effectively managing these complexities, though these could be observed as more outcomes of effective complexity management rather than direct opportunities.

7.2 ADDRESSING THE COMPLEXITIES IN ENERGY TRANSITION PROJECTS

Literature highlighted three main approaches to managing complexity in projects: the control-oriented approach, hands-off approach and a combined approach(Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011). When linking these approaches to the findings from the empirical study, a pivotal shift could be observed in project management approaches from conventional to energy transition projects. Historically, conventional energy projects have predominantly utilized a control-oriented approach, as indicated by the results of the empirical study. This approach in conventional projects is characterized by rigid, formal structures, well-defined processes based on best practices, and a strong emphasis on hierarchical control. The predictability of outcomes concerning scope, time, cost, and quality in these projects often lends itself to a management style that places stringent control over key project elements, directly linking this approach to the success of the projects.

In contrast, energy transition projects, as illuminated by the empirical study and expert validation interviews, require a distinct approach. The practitioners highlighted that the outcomes of actions on key project elements such as time, cost, and quality are less predictable in energy transition projects, necessitating a more exploratory and adaptive approach. These projects are dynamic by nature, rendering the rigidity of traditional control-oriented methods less effective. Instead, energy transition projects demand flexibility and adaptability, leading to the adoption of a more dynamic approach to project management (Hertogh & Westerveld, 2010). This shift reflects the concept of causality, where the direct outcomes of specific actions are not always clear, prompting the use of a combination of approaches to ascertain the most effective strategy, as observed in the empirical study results and corroborated by expert insights.

Responding to the practitioners' call for adaptability and flexibility in managing energy transition projects as observed from the results of the empirical study, a comprehensive checklist has been developed. This tool is designed to holistically address and navigate the multifaceted complexities inherent in these projects, thereby facilitating their accelerated progression towards execution. According to practitioners, managing an energy transition project involves juggling numerous challenges simultaneously. There's a constant risk of oversight or missing critical elements, which this checklist aims to mitigate. It serves a dual purpose: providing practitioners with a holistic view of potential obstacles and offering tangible evidence of progress as they systematically check off completed items.

The checklist's development, informed by notable academic literature and insights from industry experts with over twenty years of experience, lends it significant legitimacy. This robust foundation is pivotal in potentially breaking the vicious cycle of blame observed between clients, contractors, and regulatory authorities. Such a cycle often emerges from a lack of clear success stories and structured approaches to manage the interdependencies among the various complexities in energy transition projects. These complexities often interlink aspects like people, technology, finance, legal and regulatory issues, resources, and project management and execution methods, creating a 'chicken and egg' dilemma about where to start and who should be responsible for each aspect.

Each checkpoint's relevance is underscored by its unique application in the context of energy transition projects, as opposed to conventional energy projects. For instance, the 'Financial and Subsidy' checkpoint, while also common in traditional projects, is approached differently in the context of energy transition. Practitioners aim to be more agile in the estimation process, a strategy not typically employed in conventional projects. This sort of a unique application in other checkpoints as well, highlights their distinct relevance and criticality in the successful management of energy transition projects. But this checklist was developed in an ideal state whose feasibility and timeline of implementation can vary based on various factors including the type of energy transition project and the type of client involved. Therefore, the checklist would need to be adapted to the specific needs of each project and their stakeholders.

7.3 CONTRIBUTION MADE TO EXISTING RESEARCH

This research challenges and extends the existing body of knowledge by providing specific insights into the management of complexity specifically in the context of energy transition projects. Although, existing research has addressed the complexities in energy related projects(Kian Manesh Rad et al., 2017), this study provides an in depth understanding into the distinctive complexities of energy transition projects and how they come about and related to the different features of energy transition projects, such as integration of new technologies into existing facilities or systems. This thesis also provided insights into the associated challenges and opportunities when managing the different aspects of complexities in energy transition projects, which have not been extensively addressed in the current research body.

Additionally, this study also highlights a shift towards more hands-off and combined approaches as opposed to the control-oriented approaches (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011), suggesting the critical role of stakeholder engagement when managing complexity. This study also emphasizes the importance of adopting a holistic approach, as suggested by Gatzert and Kosub (2016), underscoring the need to adequately consider the unique features of energy transition projects when managing the complexity, a perspective that significantly adds to the existing body of knowledge.

Therefore, this study not only corroborates various findings from the existing literature but also provides specific insights and perspectives from practice for managing energy transition projects. The study also emphasizes the need for tailoring the management approaches based on the specific context and characteristics of the projects, thereby adding to the rising body of knowledge related to energy transition project management.

8 CONCLUSION & RECOMMENDATIONS

This chapter encompasses the concluding aspects of this thesis, along with recommendations for practice. It begins by answering the research questions in Section 8.1, where each sub-research question is addressed, serving as a building block for the next and collectively answering the main research question in Section 8.2. Subsequently, in Section 8.3 and 8.4, the theoretical and practical implications of this research are formulated respectively. Section 8.5 delves into the recommendations suggested for practice to address the problem defined in this research. The chapter concludes with a personal reflection on the thesis journey in Section 8.5.

8.1 ANSWERING THE RESEARCH QUESTIONS

8.1.1 WHAT ARE COMPLEXITIES IN THE CONTEXT OF ENERGY TRANSITION PROJECTS?

The complexities inherent in energy transition projects encompass dimensions such as '**People**', '**Technical**', '**Financial**', '**Legal & Regulations'**, **'Resources'**, and '**Project Management & Execution Methods**' as suggested from the empirical study of this thesis. Each of these dimensions comprise their own set of complexities. Some of these complexities mirror those found in traditional energy projects, while others either vary slightly or are entirely unique to energy transition projects. This diversity in complexities arises from the distinctive characteristics specific to energy transition projects and their interplay, namely '**novelty**', '**time pressure'**, '**new and different relationships'**, '**subsidy component'**, and the '**business case'** (Toonen, 2022). These elements were found to contribute to the dynamic and multifaceted nature of complexities in these projects. Furthermore, the results also suggested complexities to be the source of uncertainty and risk in these projects which corroborated with a significant portion of the literature (Daniel & Daniel, 2018; Danilovic & Browning, 2007; Dikmen et al., 2021; Kian Manesh Rad et al., 2017; Vidal & Marle, 2008; Williams et al., 1995). Additionally, a strong link between complexity, front-end development phase and performance was observed in the results of both literature and the empirical study(Bosch-Rekveldt, 2011).

8.1.2 WHAT ARE THE EXISTING PROJECT MANAGEMENT APPROACHES TO ADDRESS COMPLEXITY?

The existing project management approaches suggested in literature for managing complexity encompasses three main approaches: **Control oriented**, **Hands-off**, and **Combined approach** (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011). The control-oriented approach perceives projects as systems that can and need to be controlled by placing stringent focus on scope, time and cost. In contrast, the Hands-off approach acknowledges that projects cannot be predicted and hence cannot be controlled by adopting a more flexible mindset and acceptance towards change. Literature advocates for a combination of these two approaches, balancing the negatives and positives of both the approaches to effectively manage project complexity, yielding the combined approach. However, these approaches do not adequately consider the distinctive features of energy transition projects. This oversight highlights a significant gap in tailoring these management approaches to the features of energy transition projects.

8.1.3 How is the management of complexity currently practiced in energy transition projects?

In the practical management of energy transition project complexities, approaches often involve **proactive** and **early engagement**, **educational approaches**, and the formation of **strategic groups** for **proactive market engagement** and **internal expertise development**. The management of complexity has also evolved to be more **agile** and **flexible**, with practitioners emphasizing the critical importance of **building trust** at every stage, understanding **underlying drivers**, and maintaining **continuous engagement**.

Approaches to engaging supply chain parties have shifted toward more **alliance-type relationships**, as traditional contracting methods are deemed too risky for these projects. This shift also leans towards a more **collaborative approach** and understanding interdependencies, using **robust stakeholder frameworks** and **data & change management** processes. Additionally, there is an increased focus on the **front-end development phase**, suggesting a departure from the conventional project management mindset towards the clients, market, and execution methods. Therefore, the management of complexity has shifted from a control-oriented approach typically used in conventional energy projects to a more hands-off and combined approach in energy transition projects to deal with its dynamic nature (Bram Kool, 2013; Hertogh & Westerveld, 2010; Koppenjan et al., 2011).

8.1.4 What challenges and opportunities emerge in the process of managing complexities in Energy transition projects?

The major challenges in energy transition projects as highlighted by 12 out the 18 interview participants include **micromanagement**, **control**, and **unrealistic expectations** by clients towards the contractors. Additionally, **optimism bias**, and an **engineer's mindset** focused on constant optimization by losing site of the project schedule was observed on both the contractor and client's side. These challenges were found to often consume more time, cost and resources than needed, thereby further delaying the projects. Additionally, a **mismatch between demand and capacity** in resources present significant difficulties as observed from the empirical study.

Conversely, key opportunities were observed related to developing **new value propositions** and **enhancing reputation**, which led to **more future projects**. These projects also offered chances for **skill and experience development**, as well as the opportunity to **rethink** and **innovate traditional project management methods**, serving as a catalyst for positive change.

These challenges have led practitioners to learn valuable lessons including, **changing their approach towards clients** to foster more collaboration and build a foundational sense of trust, investing **more time and resources in the front-end development phase** to avoid risks at later stages that could further hinder the progress of these projects, involving **technology experts and key supply chain parties** early in the process to integrate their knowledge when assessing the technology and preparing the estimates for funding approval, adopting a **problem-solving mindset** to be more flexible towards the dynamic nature of the complexities, and **standardizing** their execution methods across different energy transition projects to have a quick start of the execution phase. Additionally, practitioners emphasized the need for enhanced **data and change management** to effectively handle inaccurate data passed through the disciplines owing to the high concurrency needed in these projects to cope with the time pressure, **adaptability** towards market changes, and mainly acceptance of the fact that **projects take the time they need** and thinking otherwise would only lead to more risks which acct as obstacles to the progression of energy transition projects.

8.1.5 WHAT ADAPTATIONS IN PROJECT MANAGEMENT APPROACHES ARE NEEDED TO ADDRESS THE COMPLEXITIES OF ENERGY TRANSITION PROJECTS?

A noticeable difference exists between the management of complexity in literature and practice, as practitioners need to dynamically adapt to the distinctive features of energy transition projects. Consequently, adaptations required include more agile and flexible project execution methods with a stronger focus on early and proactive stakeholder management, primarily centred on building trust. This involves moving away from traditional contracts, methods, and mindsets, and being open to a collaborative approach with clients, stakeholders, and forming alliances with supply chain parties. There's also an emphasis on team and knowledge continuity.

Adopting tools like the **Technology Readiness Level (TRL**) to assess the maturity of novel technologies becomes crucial, along with **conducting feasibility studies**. **Securing offtakers** and calculating **operational expenditure** are also important to strengthen the business case's viability. Cultivating **stronger relationships with permitting authorities** can smooth the permitting process and potentially earn the project a **'special status'**.

Adapting approaches to the distinctive features of energy transition projects and considering the interplay between these different features when choosing a management approach is essential. Developing a comprehensive **understanding of the complexities early** in the project is key to effectively managing these challenges.

8.2 HOW CAN COMPLEXITIES IN ENERGY TRANSITION PROJECTS BE EFFECTIVELY ADDRESSED?

Based on the results of this thesis, effectively addressing complexities in energy transition projects requires a shift form the traditional project management methodologies that traditional focus on control to a more **flexible hands-off** and **combined approach** to adapt to the dynamic nature of these projects. This means also understanding the interdependence between the various project aspects from initial client engagement to technology assessment, financial, legal & regulations consideration, resource management, interface management and standardizing the execution methods. These various aspects can be addressed by the checklist formulated in this thesis based on the input of nine project managers and nine follow up interviews with roles such as project controls, contract managers, engineering manager, process director, sales managers, and a client who are actively involved in implementing energy transition projects.

This checklist was formulated encompassing seven checkpoints to effectively navigate the complexities and progress these projects towards the execution phase to accelerate them and meet the overarching climate goals. The checklist renders a complicated, seemingly overwhelming concept such as complexity, into bite sized pieces for the consumers of this thesis. This also extends to clients who are new to the field of energy transition, by providing them a step-by-step format of what it means to develop these projects creating a sense of transparency and reduce the level of apprehension for practitioners who want to implement energy transition projects but are afraid or do not know where to start. Effectively addressing complexities in energy transition projects involves adopting a **holistic approach** that accounts for the unique interplay of all distinctive features. This includes adapting the project management approach to be more proactive and responsive to changes, enhancing the focus on the front-end development phase, and shifting away from traditional methods toward a more agile and flexible working style.

8.3 THEORETICAL IMPLICATIONS

The findings of this research make a significant contribution to the existing body of knowledge in construction management and engineering, particularly with respect to energy transition projects. This research challenges and broadens our current understanding of complexity and its management by incorporating the unique aspects of energy transition projects. It underscores the importance of acknowledging distinct features such as 'novelty', 'business case', 'new and different relationships', 'time pressure', and 'subsidy component', which are often overlooked in traditional project management approaches.

Moreover, this study has uncovered a notable gap between theoretical frameworks and practical application, especially in the realm of managing complexity. This suggests that theoretical models which have historically emphasized on predictability and control need to be re-evaluated as the findings suggest that adaptive methodologies, which are flexible and collaborative, are better suited for the dynamic nature of these projects. Such adaptability should also extend to redefining complexity, as this research highlights the dynamic and evolving nature of complexity, challenging traditional definitions that predominantly focus on 'interdependence' or 'variation'.

The empirical research was not limited to project managers; it delved into various roles, either through the project manager's delegation or referral, including sales managers, process directors, engineering managers, contract managers, and project controls. This approach underscores the importance of multidisciplinary roles and disciplines in managing complexity, advocating for an interdisciplinary perspective within the theoretical models.

8.4 PRACTICAL IMPLICATIONS

The practical implications of this research are particularly crucial for professionals who need to maintain a holistic view when managing complexities in energy transition projects, without getting lost in the 'matter at hand.' This implies a rethinking of the traditional project management methods and tools used. These management approaches should incorporate tools and strategies that allow for early engagement with the stakeholders, foster partnerships and alliances as opposed to the traditional contracting methods, understanding the interdependencies between the various project activities and business lines given the high level of concurrency, and emphasizing the importance of the front-end development phase. This thesis also emphasizes the need to build trust, understand the various drivers and diverse expectations, and adopt a more proactive stance.

This study has highlighted a significant shift in the construction industry regarding the execution of energy transition projects. Practitioners are reevaluating their traditional methods, tools, and overall mindset. There is a discernible need for a more agile and flexible approach to effectively manage the dynamic nature of energy transition projects. This includes being responsive to changes in technologies, as well as adapting to shifts in the industry and regulatory environment. Additionally, as Expert 1 noted, a major challenge is that practitioners are applying conventional energy project mindsets and experiences to situations that may require a completely different approach, as this is often the only tool in their toolbox. This implies that practitioners are encouraged to develop their skill set and critically assess which aspects of their past experience can they take with them to these new types of projects. Moreover, the study suggests that navigating the complexities in energy transition projects hinges on maintaining a holistic understanding of their complexities. It advocates for a more integrated approach that considers various aspects of these projects from the initial client engagement, technology assessment, financial, legal & regulatory considerations, resource management, interface and change management, which are addressed in tandem rather than an isolated manner in this thesis

This thesis strongly advocates for an increased focus and effort in the front-end development phase, suggesting the allocation of more resources to this phase to mitigate the risks associated with the complexities and distinctive features of these projects. In conclusion, the management of complexities in energy transition projects require a fundamental shift in the project management methods from a traditional, control-oriented approach (except for the technology aspect) to a more flexible, adaptive hands-off and combined approach which fosters collaboration amongst all the stakeholders.

8.5 RECOMMENDATIONS FOR PRACTICE

Given the problem statements of energy transition progressing too slowly, the following recommendations have been formulated to accelerate the execution of these projects to meet the overall energy transition goals.

1. **Agile and Flexible Management Approaches:**
    - **Streamlining Meeting Processes:** Instead of producing comprehensive minutes, shift to concise bullet-point summaries during meetings. Utilize a shared document for real-time notetaking, focusing on key decisions and action items. This approach not only saves time but also ensures swift decision implementation and keeps the team focused on essential tasks.
2. **Effective Stakeholder Engagement:**
    - **Revamping Contracting Methods:** Transition from traditional contracting to alliance-type partnerships with subcontractors and key supply chain parties. This method not only leverages their experience for the current project but also facilitates knowledge transfer to future projects, enhancing efficiency and speed.
    - **Implementing Project Learning and Reflection Phases:** Conduct regular reflection sessions either at the end of each project phase or upon project completion. These sessions should involve the project team and, if feasible, all stakeholders, to review successes, challenges, and lessons learned in a constructive manner. This practice fosters a problem-solving mindset and encourages continual learning and improvement.
3. **Strengthen front-end development phase**: A well-planned front-end development phase can significantly impact the performance of projects. Therefore, investing more time and resources in this phase can help avoid risks at later stages, thereby avoiding changes and accelerating project progression.
4. **Cross-Project Knowledge Sharing:**
    - Encourage sharing of experiences and insights across different energy transition projects. Organize forums where project managers and teams can exchange knowledge, thereby enriching each project with lessons learned from others. This collaborative approach helps in bridging knowledge gaps and accelerates the efficiency of subsequent projects.

8.6 LIMITATIONS

This section highlights the limitations of this study, emphasizing its subjectivity and relevance. Firstly, the thesis focused on project-based organizations and the perspectives of stakeholders connected to these organizations, which may lead to inconsistencies when viewed through the lens of different types of organizations. To address this, experts from other project-based organizations were included to broaden the applicability of the research findings. However, incorporating additional experts and organizations could further enhance the value of this thesis.

Regarding the semi-structured interviews, the goal was to maintain an open-minded approach to minimize response bias. Nonetheless, individual biases were somewhat inevitable, as was the tendency for respondents to veer off-topic. Furthermore, the researcher's interpretation of the findings might exhibit a degree of bias and subjectivity when considered from another researcher's perspective. The thesis involved interviews with 18 individuals, but a larger sample size could have enriched the findings.

Moreover, this research made a compromise between offering a holistic view and focusing on details. While it maintained a holistic approach, delving deeper into the specifics of each energy transition project case study might have provided a more detailed perspective.

8.7 FUTURE WORK

A crucial area for future work to focus on is the contracting strategies for energy transition projects. These contracts should not be viewed merely as something to fall back on, but rather as proactive tools that foster collaboration, alliance, and better risk-sharing mechanisms for these projects. Given the knowledge gap in these projects, future work should also explore how knowledge can be effectively captured and reused across different energy transition projects.

Further research could extend this study to a broader range of organizations and case studies of energy transition projects. This would deepen our understanding of complexity at various levels, including strategic and tactical, and how these levels interact to contribute to overall complexity. Additionally, conducting long-term studies to understand the performance and outcomes of energy transition projects, in relation to the management approaches studied in this research, would offer insight into the long-term efficacy of these approaches.

By delving into these varied areas, future research could make a significant contribution to the evolving field of energy transition project management.

8.8 PERSONAL REFLECTION

Embarking on this thesis has been a significant journey and a real eye-opener, offering an enlightening experience both professionally and personally. Initially, I realized that although there are many interesting topics to pursue, narrowing them down can be daunting. Fortunately, my supervisors provided critical support, helping me find what I truly wanted to pursue, as my company supervisor always said, *"Just follow your gut."* Often times, it was hard to stay motivated, but solely my interest in the topic drove me to work on it every day.

One major gain from this journey is the confidence I can carry into my professional career. Whether its practitioners valuing my research or being validated by some of the biggest minds in the industry, this experience has opened great opportunities for me professionally. Remembering my progress on days where I felt that I wouldn't be able to reach the finish line, helped me trust myself again and move ahead.

A friend's words, *"Criticism of your work is not criticism of your worth,"* resonated with me throughout my thesis journey. This mindset helped me view feedback more constructively, separating my work from my self-worth.

I often found it hard to put my thoughts into words, which can be frustrating. What helped during my report writing was to simply jot down all my thoughts, regardless of coherence. This 'word vomiting' approach made me feel lighter and allowed me to view my thoughts more holistically, structuring them better without getting lost in details.

Setbacks are common in any thesis journey, but what helped me was the constant reminder by my mother and what she taught me all my life: to "*pick yourself up, dust yourself off, and just keep moving"*. I realised that each time I did this, I only came back more structured, focussed, and mainly more resilient.

Therefore, this thesis journey, with all its ups and downs, has been a rollercoaster ride. However, I chose to take only the 'ups' with me and the confidence I gained each time I overcame a 'down' to the next phase of my career.

REFERENCES

Al Swaidi, S. J. (2023). b: Project Management Approached in Healthcare Business Development. *NILES journal for Geriatric and Gerontology*, *6*(1), 333-343.

Andersen, E. (2014). Erling S. Andersen: Two Perspectives on Project management, pp. 140-149, in Rolf A. Lundin and Markus Hällgren (eds.): Advancing Research on Projects and Temporary Organizations, Copenhagen Business School Press, Copenhagen 2014. In (pp. 140-149).

Armaroli, N., & Balzani, V. (2007). The future of energy supply: challenges and opportunities. *Angewandte Chemie International Edition*, *46*(1-2), 52-66.

Atkinson, R., Crawford, L., & Ward, S. (2006). Fundamental uncertainties in projects and the scope of project management. *International journal of project management*, *24*(8), 687-698.

Baccarini, D. (1996). The concept of project complexity—a review. *International journal of project management*, *14*(4), 201-204. https://doi.org/https://doi.org/10.1016/0263-7863(95)00093-3

Bakhshi, J., Ireland, V., & Gorod, A. (2016). Clarifying the project complexity construct: Past, present and future. *International journal of project management*, *34*(7), 1199-1213. https://doi.org/https://doi.org/10.1016/j.ijproman.2016.06.002

Benbya, H., & McKelvey, B. (2006). Using coevolutionary and complexity theories to improve IS alignment: a multi-level approach. *Journal of Information technology*, *21*, 284-298.

Bosch-Rekveldt, M., Bakker, H., & Hertogh, M. (2018). Comparing Project Complexity across Different Industry Sectors. *Complexity*, *2018*, 3246508. https://doi.org/10.1155/2018/3246508

Bosch-Rekveldt, M., Jongkind, Y., Mooi, H., Bakker, H., & Verbraeck, A. (2011). Grasping project complexity in large engineering projects: The TOE (Technical, Organizational and Environmental) framework. *International journal of project management*, *29*(6), 728-739. https://doi.org/https://doi.org/10.1016/j.ijproman.2010.07.008

Bosch-Rekveldt, M. G. C. (2011). Managing project complexity: A study into adapting early project phases to improve project performance in large engineering projects.

Bram Kool, M. B.-R. M. H., Maarten Kraneveld. (2013). *Perceptions on project complexity: ignore or exploit?*

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77.

Cicmil, S., & Marshall, D. (2005). Insights into collaboration at the project level: complexity, social interaction and procurement mechanisms. *Building Research & Information*, *33*(6), 523-535.

Clarke, V., & Braun, V. (2017). Thematic analysis. *The journal of positive psychology*, *12*(3), 297-298.

Commerce, O. o. G. (2009). *Managing successful projects with PRINCE2*. The Stationery Office.

Daniel, P. A., & Daniel, C. (2018). Complexity, uncertainty and mental models: From a paradigm of regulation to a paradigm of emergence in project management. *International journal of project management*, *36*(1), 184-197. https://doi.org/https://doi.org/10.1016/j.ijproman.2017.07.004

Danilovic, M., & Browning, T. R. (2007). Managing complex product development projects with design structure matrices and domain mapping matrices. *International journal of project management*, *25*(3), 300-314.

Dao, B., Kermanshachi, S., Shane, J., Anderson, S., & Hare, E. (2017). Exploring and Assessing Project Complexity. *Journal of Construction Engineering and Management*, *143*(5), 04016126. https://doi.org/doi:10.1061/(ASCE)CO.1943-7862.0001275

Dikmen, I., Qazi, A., Erol, H., & Birgonul, M. T. (2021). Meta-modeling of complexity-uncertainty-performance triad in construction projects. *Engineering Management Journal*, *33*(1), 30-44.

Engwall, M. (2003). No project is an island: linking projects to history and context. *Research policy*, *32*(5), 789-808.

Eriksson, P. E., Larsson, J., & Pesämaa, O. (2017). Managing complex projects in the infrastructure sector—A structural equation model for flexibility-focused project management. *International journal of project management*, *35*(8), 1512-1523.

Erol, H., Dikmen, I., Atasoy, G., & Birgonul, M. T. (2020). Exploring the relationship between complexity and risk in megaconstruction projects. *Journal of Construction Engineering and Management*, *146*(12), 04020138.

EU-Commission. (2021). *The European Green Deal*. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International journal of qualitative methods*, *5*(1), 80-92.

Floricel, S., Michela, J. L., & Piperca, S. (2016). Complexity, uncertainty-reduction strategies, and project performance. *International journal of project management*, *34*(7), 1360-1383. https://doi.org/https://doi.org/10.1016/j.ijproman.2015.11.007

Gatzert, N., & Kosub, T. (2016). Risks and risk management of renewable energy projects: The case of onshore and offshore wind parks. *Renewable and Sustainable Energy Reviews*, *60*, 982-998.

Geraldi, J., Maylor, H., & Williams, T. (2011). Now, let's make it really complex (complicated) A systematic review of the complexities of projects. *International Journal of Operations & Production Management*, *31*(9), 966-990.

Geraldi, J. G. (2009). Reconciling order and chaos in multi-project firms. *International journal of managing projects in Business*, *2*(1), 149-158.

Gibson Jr, G. E., Wang, Y.-R., Cho, C.-S., & Pappas, M. P. (2006). What is preproject planning, anyway? *Journal of Management in Engineering*, *22*(1), 35-42.

He, Q., Luo, L., Hu, Y., & Chan, A. P. C. (2015). Measuring the complexity of mega construction projects in China—A fuzzy analytic network process analysis. *International journal of project management*, *33*(3), 549-563.

Hertogh, M., & Westerveld, E. (2010). Playing with Complexity. Management and organisation of large infrastructure projects.

Hutchinson, R., & Wabeke, H. (2006). Opportunity and Project Management Guide. *Shell International Exploration and Production BV INCOSE.(2004). INCOSE Systems Engineering Handbook. Kunz, J., & Fischer, M.(2012). Virtual design and construction: themes, case studies and implementation suggestions. CIFE, Stanford University, Stanford, CA, CIFE Working Paper, Version*, *14*, 89-93.

Institute., P. M. (2021). *A Guide to the project management body of knowledge (PMBOK® guide) (7th ed.)*.

Jaafari, A. (2001). Management of risks, uncertainties and opportunities on projects: time for a fundamental shift. *International journal of project management*, *19*(2), 89-101.

Jaafari, A. (2003). Project management in the age of complexity and change. *Project Management Journal*, *34*(4), 47-57.

Jalali Sohi, A., Nezami, M. R., Bakker, H., & Hertogh, M. (2021). Inter-Organizational Co-Creation: An Approach to Support Energy Transition Projects. 151-166.

Kaldellis, J. K., & Kapsali, M. (2013). Shifting towards offshore wind energy—Recent activity and future development. *Energy Policy*, *53*, 136-148.

Kemp, R. (2010). The Dutch energy transition approach. *International Economics and Economic Policy*, *7*(2), 291-316. https://doi.org/10.1007/s10368-010-0163-y

Kermanshachi, S., Nipa, T. J., & Dao, B. (2023). Development of complexity management strategies for construction projects. *Journal of Engineering, Design and Technology*, *21*(6), 1633-1657.

Kian Manesh Rad, E., Sun, M., & Bosché, F. (2017). Complexity for megaprojects in the energy sector. *Journal of Management in Engineering*, *33*(4), 04017009.

Koppenjan, J., Veeneman, W., Van der Voort, H., Ten Heuvelhof, E., & Leijten, M. (2011). Competing management approaches in large engineering projects: The Dutch RandstadRail project. *International journal of project management*, *29*(6), 740-750.

Kreye, M., & Balangalibun, S. (2015). Uncertainty in project phases: A framework for organisational change management. 15th Annual Conference on the European Academy of Management,

Loorbach, D. (2007). Transition management. *New mode of governance for sustainable development. Utrecht: International Books*.

Loorbach, D., & van Raak, R. (2006). Transition management: toward a prescriptive model for multi-level governance systems.

Müller, R., Geraldi, J. G., & Turner, J. R. (2007). Linking complexity and leadership competences of project managers. Proceedings of IRNOP VIII (International Research Network for Organizing by

Projects) Conference. Brighton, UK, CD-ROM. Universal Publishers. http://centrim. mis. brighton. ac. uk/events/irnop-2007/papers-1/Mueller% 20et% 20al. pdf,

Paraschiv, M. (2023). CMO Opportunity-Identifying Framework for Complex Sustainable Construction Projects.

Pegels, A., & Lütkenhorst, W. (2014). Is Germany′ s energy transition a case of successful green industrial policy? Contrasting wind and solar PV. *Energy Policy*, *74*, 522-534.

Rehman, M. S. U. (2022). Reengineering Project Management Processes for EPC Contractors: A Case study. *The Twelth International Conference on Construction in the 21st Century (CITC-12)*, 1-7.

Rotmans, J., & Loorbach, D. (2009). Complexity and Transition Management. *Journal of Industrial Ecology*, *13*, 184-196. https://doi.org/10.1111/j.1530-9290.2009.00116.x

Sauser, B. J., Reilly, R. R., & Shenhar, A. J. (2009). Why projects fail? How contingency theory can provide new insights–A comparative analysis of NASA's Mars Climate Orbiter loss. *International journal of project management*, *27*(7), 665-679.

Shelley, A. (2023). 17. Projects as vehicles of learning. *Research Handbook on Project Performance*, 240.

Shenhar, A. J. (2001). One size does not fit all projects: Exploring classical contingency domains. *Management science*, *47*(3), 394-414.

Shenhar, A. J., & Dvir, D. (1996). Toward a typological theory of project management. *Research policy*, *25*(4), 607-632.

Smyth, H. J., & Morris, P. W. (2007). An epistemological evaluation of research into projects and their management: Methodological issues. *International journal of project management*, *25*(4), 423-436.

Sommer, S. C., & Loch, C. H. (2004). Selectionism and learning in projects with complexity and unforeseeable uncertainty. *Management science*, *50*(10), 1334-1347.

Taipalus, T., Seppänen, V., & Pirhonen, M. (2020). Uncertainty in information system development: Causes, effects, and coping mechanisms. *Journal of Systems and Software*, *168*, 110655.

Toonen, S. (2022). Dealing with uncertainty in the challenge of the energy transition.

Turner, J. R. (2008). *The handbook of project-based management*. The McGraw-Hill Companies, Inc.

Turner, J. R., & Cochrane, R. A. (1993). Goals-and-methods matrix: coping with projects with ill defined goals and/or methods of achieving them. *International journal of project management*, *11*(2), 93-102.

Vidal, L.-A., Marle, F., & Bocquet, J.-C. (2011). Measuring project complexity using the Analytic Hierarchy Process. *International journal of project management*, *29*(6), 718-727. https://doi.org/https://doi.org/10.1016/j.ijproman.2010.07.005

Vidal, L. A., & Marle, F. (2008). Understanding project complexity: implications on project management. *Kybernetes*, *37*(8), 1094-1110.

Wassermann, S., Reeg, M., & Nienhaus, K. (2015). Current challenges of Germany's energy transition project and competing strategies of challengers and incumbents: The case of direct marketing of electricity from renewable energy sources. *Energy Policy*, *76*, 66-75.

Wesz, J. G. B., Formoso, C. T., & Tzortzopoulos, P. (2018). Planning and controlling design in engineered-to-order prefabricated building systems. *Engineering, Construction and Architectural Management*.

Whitty, S. J., & Maylor, H. (2009). And then came Complex Project Management (revised). *International journal of project management*, *27*(3), 304-310. https://doi.org/https://doi.org/10.1016/j.ijproman.2008.03.004

Wideman, R. M. (1992). Project and program risk management: a guide to managing risks and opportunities. *Project Management Institute, Pennsylvania, PA*.

Williams, T. (2005). Assessing and moving on from the dominant project management discourse in the light of project overruns. *IEEE Transactions on Engineering Management*, *52*(4), 497-508.

Williams, T., Eden, C., Ackermann, F., & Tait, A. (1995). Vicious circles of parallelism. *International journal of project management*, *13*(3), 151-155.

Williams, T. M. (1999). The need for new paradigms for complex projects. *International journal of project management*, *17*(5), 269-273.

Winch, G. M. (2015). Project organizing as a problem in information. *Construction Management and Economics*, *33*(2), 106-116.

Xia, W., & Lee, G. (2004). Grasping the complexity of IS development projects. *Communications of the ACM*, *47*(5), 68-74.

Yeo, K. T., & Ning, J. H. (2002). Integrating supply chain and critical chain concepts in engineer-procure-construct (EPC) projects. *International journal of project management*, *20*(4), 253-262. https://doi.org/https://doi.org/10.1016/S0263-7863(01)00021-7

Yergin, D. (2022). Bumps in the Energy transition

Despite a growing global consensus, obstacles to reducing net carbon emissions to zero are stark *International Monetary Fund*. https://www.imf.org/en/Publications/fandd/issues/2022/12/bumps-in-the-energy-transition-yergin

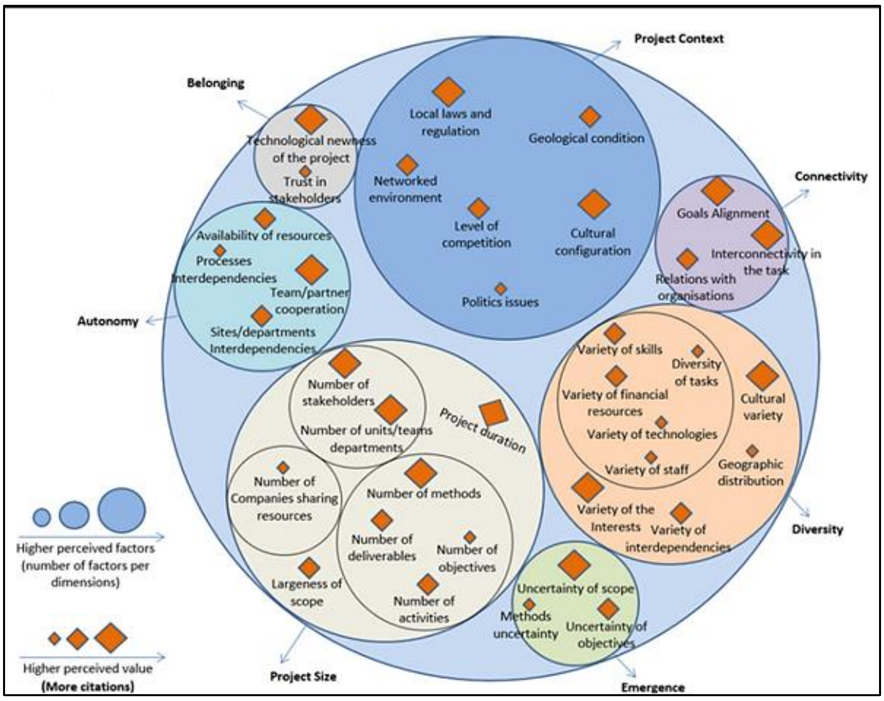
Zolin, R., Turner, R., & Remington, K. (2009). A model of project complexity: distinguishing dimensions of complexity from severity. International research network of project management conference (IRNOP),

APPENDIX A

1. Complexity elements with significant link to performance

T Technical Complexity (17 elements)	O Organizational Complexity (17 elements)	E External complexity (13 elements)
High number of project goals	**High project schedule drive**	Level of competition
Non–alignment of project goals	**Lack of Resource & Skills availability**	Instability of project environment
Unclarity of project goals	Lack of Experience with parties involved	Company internal strategic pressure
Uncertainties in scope	Lack of HSSE awareness	**Lack of experience in the country**
Strict quality requirements	Interfaces between different disciplines	Remoteness of location
Project duration	Number of financial sources	**Interference with existing site**
Size in CAPEX	Number of contracts	Required local content
Number of locations	Type of contract	**Lack of company internal support**
Newness of technology (world–wide)	Number of different nationalities	Political influence
Lack of experience with technology	Number of different languages	Dependencies on external stakeholders
High number of tasks	Presence of JV partner	**Variety of external stakeholders' perspectives**
High variety of tasks	Involvement of different time zones	Number of external stakeholders
Dependencies between tasks	Size of project team	External risks
Uncertainty in methods	Incompatibility different pm methods / tools	
Involvement different technical disciplines	**Lack of trust in project team**	
Conflicting norms and standards	Lack of trust in contractor	
Technical risks	Organizational risks	

2. Complexity elements from (Bakhshi et al., 2016)



INTERNAL COMPLEXITIES

The internal elements are further subdivided into **'what'** aspects, which relate to the **project's characteristics** (*'What is the project?)*; **'who'** aspects, which concern the **project delivery team and organization** (*'Who is going to implement the project?'*); and **'how'** aspects, which pertain to the **delivery process** (*'How is the project going to be implemented?'*)

'WHAT ASPECT'

The 'What' aspect relates to the content, characteristics, and objectives of the project, essentially encapsulating the initial idea and motivation behind the project, which signifies its goals. This 'What' category is further subdivided into two aspects, namely, **'Objectives'** and **'Technical'** as shown in Table 1.

TABLE 14: THE 'WHAT' ASPECT FROM PAGE 5, TABLE 2 OF KIAN MANESH RAD ET AL. (2017)

WHAT?		
level 2	**level 3**	**level 4**
Project Characteristics	**Objectives**	Variety in goals and objectives
		Interdependence of objectives
		Transparency of objectives
		Scope Changing
	Technical	Level of innovation
		Technological experience and capabilities
		Repetitiveness of process
		Specifications interdependencies
		technological varieties
		Variety of system components
		Changing technology

Firstly, the **'Objectives'** aspect encompasses elements related to what the project needs to achieve or what kind of business case idea the project stakeholders aim to attain. Delving deeper into the complexity elements within this aspect, it involves the complexity that arises from having numerous different objectives and goals, their interdependence, and the degree to which these goals and objectives are clear, open, and easily understood by all project participants. Furthermore, it also encompasses the complexity that emerges from the scope constantly changing through additions, modifications, or reductions.

Secondly, the **'Technical'** aspect pertains to the specifications and characteristics of the product being developed in the project, as well as the technology employed. The elements within this aspect encompass the complexity arising from the level of novelty or innovation required in the project's technical aspects, the utilization of new technologies, and consequently, the experience and capabilities needed to manage the technology effectively. It also considers the diversity of technologies involved, the frequency of process repetition or standardization, the extent to which specifications are interconnected, the variety of system components, and the resulting level of interconnectivity among them. Lastly, it considers the complexity stemming from the dynamic nature of the technology.

THE 'WHO' ASPECT

The ‘who’ aspect related to the parties involved in the project, their associated organizations and individuals that **contribute** by any means to the delivery of the project. The ‘who’ aspect is further divided into four aspects, namely, **‘Capital resources’**, **‘Disciplines’**, **‘People’**, and **‘Physical resources’** as shown in Table 2.

TABLE 15: THE 'WHO' ASPECT FROM PAGE 5, TABLE 2 OF KIAN MANESH RAD ET AL. (2017)

WHO?		
level 2	**level 3**	**level 4**
Organization/ team of delivery	**Capital Resources**	Size of capital investment
		Variety of investors and financial resources
	Disciplines	Contract types
		Variety of institutional configurations
		Support from permanent team organizations
		Team cooperation and communication
	People	Availability of human resources
		Level of trust (within/between teams)
		Diversity of participants
		Dynamic and evolving team structure
		Experience and capabilities within teams
		Interest and perspectives among stakeholders
	Physical resources	Resource and raw material interdependencies
		Variety of resources
		Availability of physical resources

The **‘Capital Resources’** aspect delves into the complexities arising from the amount of money invested, the diversity and multitude of investors, and the various sources of funding. It highlights the dependency on these external sources and how the project is constrained by the size of the investment. Essentially, this section addresses the complexities related to the financial resources available for investment and the project's reliance on them

The **'Disciplines'** aspect pertains to the complexities arising from various contract types used in the project, be it fixed price or reimbursable, as conditions can vary significantly from one contract to another. Secondly, there is the complexity stemming from the organizational arrangements involved in the project, where each entity may have its own protocols, hierarchies, or decision-making processes. Thirdly, complexities arise from the reliance on the main organization or sponsor board for resources, approvals, or expertise. Lastly, the level of collaboration needed within the project team, as effective communication and cooperation are essential when managing a complex project.

The **'People'** aspect applies to the various participants involved in the project, extending to clients, contractors, consultants, project teams, sub-contractors, and supply chain parties, focusing on their interplay within the project. This aspect includes complexities arising from the availability and accessibility of human resources, the level of trust among various parties—both within individual project teams and between different teams—as well as the diversity of project stakeholders, encompassing their varying interests, perspectives, and skill sets. Additionally, it relates to the complexities stemming from the levels of experience and competency within the project teams.

The **'Physical Resources'** aspect pertains to the non-human resources required for the project's delivery. This includes complexities arising from the availability of different types of resources needed for the project, as well as the interdependencies between these resources

THE 'HOW' ASPECT

The **'How'** aspect focuses on the execution process, encompassing the activities, information, and time-related issues required to deliver the project. Essentially, it addresses the complexities that arise during project delivery. This aspect is further subdivided into **'Information', 'Tasks', 'Time', and 'Tools & Methods'** as shown in Table 3.

TABLE 16: THE'HOW' ASPECT FROM PAGE 5, TABLE 2 OF KIAN MANESH RAD ET AL. (2017)

HOW?		
level 2	**level 3**	**level 4**
Process of delivery	**Information**	Availability of information
		Reliability of information platforms
		Interdependence of information systems
		Level of processing and transferring information
	Tasks	Diversity of sites and location
		Process interdependencies
		Dependencies between tasks
		Number of activities
		Unpredictability of tasks
		Diversity of activity elements
	Time	Duration of project
		Dependencies between schedules
		Intensity of project schedule
	Tools and Methods	Applicability of project management methods and tools
		Variety of project management methods and tools

The **'Information'** aspect pertains to complexities arising from the level of information accessible to the project team, the reliability of the systems used to store, retrieve, and communicate information, the interdependencies these systems create, and the level of understanding and communication required to process the information.

The **'Tasks'** aspect relates to the complexities stemming from the activities that need to be completed for project delivery, including the interdependencies, unpredictability, quantity, and differentiation of processes and tasks.

The **'Time'** aspect entails the complexities associated with the project's schedule, encompassing the available time, the necessity for tight planning, and the interdependencies between various other aspects.

The **'Tools & Methods'** aspect relates to the project management tools and methods used in the project. It encompasses the complexities related to their applicability to various projects and the variation in tools and methods used within the project team and among other teams.

EXTERNAL COMPLEXITIES

The external elements are further divided into 'Economy', 'Environment', 'Legal & Regulations', 'Politics', and 'Social', aiming to encompass all external factors that could add complexity to the project. Additionally, the external complexities were only divided as level 3 & 4 as shown in Table 4.

The **'Economy'** aspect relates to the elements of an economic system, including production, manufacturing, distribution, trade, market, and the individuals involved in the economy, such as competitors near the project's location. It encompasses complexities arising from the dynamic nature of the economy, the market, and market competition.

The **'Environment'** aspect pertains to the project environment, covering complexities related to volatile external conditions surrounding the project location and the degree to which technologies or systems used can be impacted by environmental factors.

The **'Legal & Regulations'** aspect relates to complexities caused by external regulations, such as the project's adherence to specific laws or regulations at its location.

The **'Politics'** aspect refers to the complexity that could arise from changes in local government or the sudden emergence of new parties who could potentially alter rules and regulations, thereby increasing project complexity.

TABLE 17: EXTERNAL COMPLEXITIES FROM PAGE 4, TABLE 1 OF KIAN MANESH RAD ET AL. (2017)

External	
level 3	**level 4**
Economy	Changing Economy
	Market competition
	Market unpredictability and uncertainty
Environment	Stability of project environment
	Interaction between the technology system and external environment
Legal & regulations	Local laws and regulations
Politics	Political Influence
Social	Cultural configuration and variety
	Cultural differences
	Significance on public agenda

TYPE 1 & 2 APPROACHES AND DYNAMIC APPROACH

In the Type 1 approach, projects are highly defined by clearly delineating the scope and activities from the outset, with a specific focus on the front-end development phase to create predictable outcomes. In contrast, the Type 2 approach does not strictly focus on the front-end development phase. Instead, the scope and responsibilities of the project members are defined as the project progresses, acknowledging that the scope cannot be fixed and will be subject to a level of change. This approach could enable a broader task definition and foster a higher level of collaboration between the contractor and technology providers. Regarding budget and schedule, the Type 1 approach places stringent control on these aspects, where contractors are closely monitored and incentivized based on task execution, such as completing tasks on time, staying within budget, or achieving key project milestones. Meanwhile, the Type 2 approach advocates for a more functional role among the project team, promoting collaboration where the contractor engages in a partnership or team-oriented approach rather than a hierarchical one.

This is suggested to make the contractor not just a service provider, but a key member of the project team by involving them in key decision-making processes (Koppenjan et al., 2011).

In the Type 1 approach, decision-making is more centralized with less scope for information exchange, whereas in Type 2, the decision-making process exhibits a predominantly horizontal structure, characterized by a more free and informal exchange of information among project stakeholders. Regarding the interface aspect, in Type 1, interfaces are managed by the main project manager, whereas in Type 2, they are managed by the project team. Lastly, in Type 1, change is seen more as an unfavourable outcome that needs to be avoided, whereas Type 2 considers change not only as an unavoidable occurrence but also as potentially advantageous, as this approach strongly advocates the need for flexibility in management (Koppenjan et al., 2011).

The Dynamic approach is suitable for projects with a high level of detail and dynamic complexity. Here, strategies focus on **balancing and combining both control and interaction**, with an emphasis on **'doing the extraordinary'**. Balancing in this context refers to finding a 'fit' between control and interaction strategies, aligning with the **configuration of the project delivery organization** and the **context** of the project. 'Doing the extraordinary' relates to going a step further at various levels within the project, such as achieving a **higher degree of collaboration**, the project delivery organization functioning as a **'project champion'**, having people with the right experience and competency, and capitalizing on the **'window of opportunity'**, which is often perceived as threats (Hertogh & Westerveld, 2010).

When examining each of these four management approaches, the strategies in the internal & content approach focus on **solving the problem** at hand without exploring other promising alternatives. This approach does not consider the requirements of project stakeholders or their 'satisfaction' and is solely focused on finding technical solutions to the perceived problem. The systems management approach is suggested for situations with high detail complexity. The strategies in this approach focus on **'control'** and **'break down'**, where the variety and interdependence of the components in the project are broken down into bite-sized pieces. Specific control is then placed on the main elements of scope, time, and budget to ensure the project is delivered as per the predetermined requirements. Additionally, the project team is encouraged to gather as much information as possible to minimize the chances of a change or an unfavourable unpredictable outcome. This approach is also similar to the predict & control approach (Hertogh & Westerveld, 2010; Koppenjan et al., 2011).

The Interactive Management approach is suitable for dynamic complexity, where strategies focus on considering the **various interests of stakeholders** to foster their support and **collaboration** in the project. This approach also has an **external focus**, primarily aimed at stakeholder satisfaction and **flexibility** to adapt to changes. Furthermore, it addresses social complexity, which considers the **characteristics of stakeholders** and the development of their interests as the project progresses. This approach facilitates a **common understanding** of the scope and problem definition, ensuring **alignment** at all levels of the project team with a consensus on how information is interpreted within the project. It relies on constant validation, and predictability is only considered for short-term events. This approach is similar to the Prepare & Commit approach (Hertogh & Westerveld, 2010; Koppenjan et al., 2011).

The Dynamic approach is suitable for projects with a high level of detail and dynamic complexity. Here, strategies focus on **balancing and combining both control and interaction**, with an emphasis on **‘doing the extraordinary’**. Balancing in this context refers to finding a ‘fit’ between control and interaction strategies, aligning with the **configuration of the project delivery organization** and the **context** of the project. 'Doing the extraordinary' relates to going a step further at various levels within the project, such as achieving a **higher degree of collaboration**, the project delivery organization functioning as a **‘project champion’**, having people with the right experience and competency, and capitalizing on the **‘window of opportunity’**, which is often perceived as threats (Hertogh & Westerveld, 2010).

Additionally, Hertogh and Westerveld (2010) also advocate combining various management strategies to effectively address complexities in a project, similar to. Similarities can be observed between the Systems Management approach and the Predict & Control approach, as well as between the Interactive Management approach and the Prepare & Commit approach. A combination of these approaches is suggested, known as the ‘Dynamic Management’ approach. The dynamic approach focuses on balancing and combining both the control and interaction strategies.

APPENDIX B

1. Interview Protocol

Theme 1: Understanding the unique complexities in Energy Transition Projects

1. Could you give me an example of a complexity you've encountered in an energy transition project?

(Follow up)

   a. *Was this complexity specific to energy transition projects?*

      i. *(If yes/no) Could you please explain why?*

   b. *What do you think contributes to this type of a complexity?*

      i. *When did you encounter this sort of a complexity?*

   c. *How do you think this type of a complexity influences your project's performance?*

Theme 2: Tailored management approaches for Energy transition projects

2. Could you elaborate with an example of how you then dealt with this sort of a complexity in your energy transition project?

(Follow-up) (coping or embracing)

   a. *Is this approach specifically for energy transition projects?*

      i. *(If yes/no) Could you please explain why?*

      ii. *Do you observe that this approach is generally effective across all types of energy transition projects?*

      i. *If yes, could you please explain why?*

      ii. *If no, could you please explain why?*

         a. *In hindsight, what changes or adaptations in your approach do you think could have been made to make it applicable to all energy transition projects?*

Theme 3: Learned from Energy transition projects.

3. Can you share your insights into the challenges and opportunities associated with the approach you've used?

(Follow-up)

   a. *(If yes), what are some of the key challenges you've faced while implementing this approach?*

i. *How did you or your team overcome this challenge?*

iii. *(If yes), conversely, could you highlight some of the opportunities that have arisen from adopting this approach?*

1. *How did you or your team capitalize this opportunity?*

b. *(If no), in hindsight, are there any aspects you believe could have been addressed differently to better capitalize on opportunities or overcome challenges?"*

4. Can you provide an example of specific roles or positions within the project organization that has been particularly effective in managing this type of a complexity in energy transition projects?

    a. Could you please explain why this role was effective?

        i. Can you share an instance where the absence of a specific role or expertise hindered the management of this complexity, and how was it resolved?

5. What did you learn for managing these types of complexities that you will be taking into your future energy transition projects?

    a. *Could you please explain why?*

2. Codes and Second order themes

Codes	Second order themes
Proactive Client Engagement (SM2, CM2, PD1)	People
Unrealistic Expectations (CM1, PM1, PC2, PD1)	
Compressing or Skipping Front-End Development Phase (PM4, PM6, SM2)	
Control or Micromanagement (PM7, PC2)	
Mismatch in Approach (PM4)	
Optimism Bias (PM3)	
Engage with New Clients (PM1)	
Innovative Value Propositions (PM6)	
Securing Future Projects (PM2)	
More Early Engagement (PM4, PM5, PM7, PD1)	
Immersing a Team of Experts (PC4)	
Asserting Expertise (PC2)	
Developing In-House Expertise (CL1)	
Educational Approach (PC1, PC2, EM1)	
Early and Continuous Engagement (PM1, PM2)	
Strategic Groups (SM1, PM1, PM2, SM2, EM1)	
Robust Stakeholder Framework (PM9)	
Zipper Approach (PM3)	
Varying Client Types (PM1, PM3, PM4, PM5, PM6, PM7, PM8, PC2, SM2)	
Varying Client Drivers (PM1, PM3, PM4, PM5, PM6, PM7, PM8)	

Lack of Experience (PM1, PM2, PM3, PM4, PM5, PM6, PM7, PC1, PC2, EM1)	
Lack of Trust (PM1, PM2, PM7, PM8, CL1, PC1)	
Unclarity Regarding Objectives (PM1, PM4, PM8)	
Technology Readiness Level Tool (SM1, PD1)	**Technology**
Team Flexibility (PM3)	
Mindset of Engineers (PM7)	
Highly Competitive & Pressured Environment (PM5)	
Skill Development (PM6, PD1)	
Involve Technology and Subject Matter Experts (PD1)	
Better Risk Sharing Mechanisms (PM4, CM1)	
Technology to Financial Feasibility Studies (PD1)	
Pilot Testing (PD1)	
Engaging Consultants (PM4)	
Subcontracting Portions of Technology Scope (PM4)	
Dual Pre-FEED Study (CM2)	
Early Engagement with Licensors and Innovation Partners (PM5, CM2, PC2, PD1, SM2)	
Strategic Groups (PD1, EM1, SM1)	
Expedited/Agile Estimation Process (PM5, PM9)	
Novel Technology (PM2, PM3, PM7, PM9, CM1, SOT1, SOT2, SM1)	
Evolving Technology (SM1, PM2, PM3, CM1)	
Lack of Clear Regulations (PM3, CM1)	
Interconnectedness Between Technologies (CM1, EM1)	
Integrate New Technology into Existing Facility (PM4, CM1)	
Variety of Technology Option (PM4, CM2)	
Lack of Ownership (PM1)	
External Funding Dependency (PM1, PM2, PM3, PM4, PM5, PM6, PM8, PM9, CM1, EM1, SM2, SM1)	**Financial**
Variety & Lack of Clarity Regarding Financial Requirements (PM3, CM1, SOT2)	
Dependency on Offtake Agreements (PM4, PM8)	
Adapting to Funding Sources Requirements (CM1, PM5)	
Funding Sources Dictating Requirements (PM3)	
Lack of Transparency (PM3)	
High Margins of Error (PM5)	
Loss of Control over Design (PM5)	
Inaccurate Estimate/Data Passed through Disciplines (PM2, PM5)	
Increased Certainty (PM3)	
Urge Clients to be More Transparent about Financial Requirements in Early Engagement (PM2, PM5)	
Securing Offtakers (PM6)	
Calculate CAPEX and OPEX (PM2)	
Direct Manufacturer-Client Partnership (CL1, CM1)	**Resources**
Reduced Quality/High Price of Bids (PM1, PM2)	
Risk of Remaining Idle (CM1)	

Unpredictability of Market Position for Long Term Strategy Development (PM3)	
Trust Building (PM3)	
Knowledge Transfer of Key Supply Chain Parties to Future Projects (PM3, PM6)	
Identify Genuinely Interested Parties (PM1)	
Gain Early Access to Crucial Information and Resources (PM5)	
Dynamic Resource Strategy (PM5)	
Adapting to the Supply Chain (PM4)	
Gain Early Feedback from Key Supply Chain Parties (PM4)	
Idle Time Compensation (CM1)	
Expanding Project Teams with Specialists (PM1, PM2, PM3, PM5)	
Standardizing Staffing Practices (PM5)	
Collaborative and Alliance Partnerships with Subcontractors (CM2)	
Early Engagement with Key Supply Chain Parties (PM1)	
Quicker Estimation with In-House Pricing (PM5)	
Accelerated Subcontracting Activities (CM1, PM3)	
Demand vs Capacity (PM3, PM6, PM7, CM1)	
Technological Requirements of Resources (CM1, PM5)	
Availability of Skilled Resources (PM1, PM2, PM4)	
Dynamic Supply Chain Market (PM1, PM3, PM5, PM7, CM1, SOT2	
Specialised Roles During Permitting Process (CL1)	**Legal & Regulations**
Lengthiness of Processes (CL1)	
Understanding the Permitting and Technology Requirements (CL1)	
Intense Subsidy Negotiations (PM4)	
Government Funding Reallocation Dynamics (CM1)	
Project Awarded 'Special Status' as Significant Contributor to Energy Transition (CL1)	
Clarify Roles and Responsibilities for Funding (PM8)	
Refine Project Definition Over Optimizing Financial Aspects (EM1)	
Need a Shift in the Policy Side (CM1)	
Policy Specialist (CL1, CM1)	
Continuous Engagement with Regulatory Bodies (CL1)	
Strong & Long-Term Relationships with External Authorities (CL1)	
Holistic Planning for Permitting (CL1)	
Engaging Consultants (CL1)	
Local Laws & Regulations (Permitting & Environmental Regulations) (CL1, SM2, CM2)	
Political Influence (PM3, PM4, CL1)	
Complex Regulatory Framework (PM8, CL1, SM2)	

Variability in Securing Subsidies (PM3, PM4, CM1, EM1)	
Interdependencies Between Tasks & Phases (PM1, PM5)	**Project management & Execution methods**
Variety & Interdependencies Between Business Verticals (PM1)	
Variety in Work Approach & Terminology (PM1, PM3, PM4)	
Agile Approach (PM9)	
Clients Have Specific Working Preferences (PM7)	
Scrutinize Contractor's Processes (PC1)	
Change as Source of Contention with Clients (PM8)	
High Level of Concurrency (PM5)	
Tools Overwhelming for Smaller Clients and Less Appreciation for Formality and Procedures (PD1)	
Catalyst for Positive Change (PM9)	
Knowledge Sharing (PM8, CL1)	
Advanced Data Change Management (PM5)	
More Checkpoints (PM8)	
Standardizing the Execution Plan for Energy Transition Projects (PM1)	
Robust Change Management (PM8, PM5)	
Baseline Centric Execution Approach (PM7)	