Mitigating Social and Institutional Factors in the Implementation of Photovoltaic Projects in Ghana

A Qualitative Case Study Conducted at the Kwame Nkrumah University of Science and Technology

Master thesis submitted to Delft University of Technology in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

Management of Technology

Faculty of Technology, Policy and Management
Delft University of Technology

Student name:	Barend Westra
Student number:	5174120
Thesis defence date:	25/08/2026
Version:	Final Version

First supervisor:	Ellen van Andel	TU Delft
Thesis committee:	Victor Scholten	TU Delft
	Fatima-Zahra Abou Eddahab-Burke	TU Delft

EXECUTIVE SUMMARY

The Ghanaian energy transition is progressing slowly. Despite considerable potential for renewable energy (RE), the share of RE in the national energy mix continues to fall short of the established goals. Existing literature mainly focuses on technical and financial factors, while social and institutional factors remain underexplored. This research addresses that knowledge gap by empirically exploring which stakeholders are involved and which social and institutional factors influence the implementation of PV initiatives in Ghana. Additionally, this research seeks ways to overcome the constraining effects of these social and institutional factors.

The research combines a literature review with a qualitative single case study at the Kwame Nkrumah University of Science and Technology (KNUST), where the size, geographical position and ongoing initiatives in the field of the energy transition offer an information rich case. Data was collected through 23 semi structured interviews with internal experts, external experts and end users, and supplemented by document analysis and site visits. The interviews were inductively coded and thematically analysed. The resulting factors were categorised into the circle of control, the circle of influence and the circle of concern, with the internal project team as the reference actor. This case is not representative of all Ghanaian PV initiatives, but does show in detail how social and institutional factors operate at the project level.

The stakeholder analysis shows a network of internal and external actors. Within KNUST, the University Council, the Directorate of Works and Physical Development and the Energy Consultant fulfil the most central roles, respectively determining the strategic direction, overseeing spatial integration and coordinating project implementation. The Procurement Office, Finance Office, internal experts, Maintenance Department and solar companies support the execution. At the national level, the Ministry of Energy, the Energy Commission, the EPA and the ECG determine the policy and infrastructural conditions.

The most frequently mentioned institutional barriers are bureaucratic procedures, cost prioritisation, unimplemented net metering, dependence on key actors and complex collaborations. These are counterbalanced by institutional enablers such as available project experience, internal expertise, centralised project governance, internal financing and supportive regulators. The most frequently mentioned social barriers are limited end user awareness, perceived limitations of PV, limited interest in sustainability, limited alignment with end user priorities and construction based nuisance. The main social enablers are perceived benefits of reliability, effective communication within the project team, institutional trust and perceived environmental benefits of PV.

The central analytical finding is that not all barriers should be treated in the same way. Factors in the circle of control are within the direct responsibility of the project team, factors in the circle of influence require indirect influencing through communication and collaboration, and factors in the circle of concern should be treated as external preconditions.

STAKEHOLDER RECOMMENDATIONS

University Council: Initiate the development of a campus wide PV plan and implement it in phases.
Directorate of Works and Physical Development: manage the lessons learned process and build preventive maintenance capacity.
Procurement Office: Digitalise procurement and communicate tender requirements to suppliers in advance.
Energy Consultant: Conduct and monitor project risk assessments throughout the project cycle, communicate system capabilities to end users, incorporate end user needs in the design.

ACKNOWLEDGEMENTS

I would like to express my gratitude to everyone who contributed to the realisation of this research.

Firstly, I would like to thank my supervisors at TU Delft: Ellen van Andel and Fatima-Zahra Abou Eddahab-Burke, for their guidance, feedback and support throughout the entire research process. I would also like to thank Victor Scholten for his role as chair of the graduation committee and for his valuable input to my research.

Furthermore, I would like to thank David Ato Quansah and Eugenia Anderson for their guidance and support during my time in Kumasi. Their local knowledge and network were of inestimable value to the fieldwork.

Finally, I would like to thank all respondents who participated in the interviews. Their willingness to share their experiences and perceptions made this research possible.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

1 INTRODUCTION

Climate change is a global problem caused by the increasing emissions of greenhouse gases and direct action is absolutely necessary (Cook et al., 2013). Numerous programs and research projects have been initiated to reduce these emissions and during the 2015 Climate Conference in Paris nearly all countries signed the Paris Agreement, aligning their views, intentions and targets. Moreover, a framework was created to transition from the traditional fossil fuels to renewable energy (RE) sources like solar photovoltaic (PV), wind power and hydropower (Opuni-Frimpong, 2025). This energy transition is not only relevant because of climate change, but also because of energy security, economic development and long-term infrastructure planning (Nyasapoh et al., 2022).

This global commitment is relevant for Ghana as well, a country in the global south where the energy sector is responsible for approximately 45.7% of total greenhouse gas emissions (Nyasapoh et al., 2025). At the same time, Ghana is vulnerable to the consequences of these greenhouse gas emissions. Over the last four decades the average temperature increased by approximately 1 degree Celsius, while in the same period rainfall decreased by circa 2.4 percent per decade. Climate projections even predict an increase of 2.3 to 5.3 degrees Celsius by the end of this century (Awuni et al., 2023). These changes in Ghana's climate will have significant consequences for Ghana's agriculture, energy security, critical infrastructure and safety (Odonkor et al., 2020). As a relatively large part of electricity is generated through hydropower which depends on natural rainfall, a decrease in rain would cause a direct impact to power production. This became evident during the dry period of 2014-2016 which resulted in large scale power rationing which caused the temporary closure of factories (Awuni et al., 2023).

Since the introduction of the Renewable Energy Act in 2011 the national policy has focused on increasing sustainability and reducing emissions in various sectors including the energy sector. The final goal is to achieve net-zero emissions in 2070 (Ministry of Energy, 2023). To achieve this goal the energy sector will have to transition to RE sources, for which Ghana is highly suitable. Due to the abundant opportunities such as high solar irradiation, and significant possibilities for wind and, as Ghana's potential for large hydropower has already been exploited, mini-hydropower the country holds a strong starting position to achieve these goals (Nyasapoh et al., 2022). As the high irradiation levels can be utilised on many different scales varying from small institutional installations to larger grid-connected systems, solar energy is particularly relevant in this transition (Nyasapoh et al., 2022).

Although Ghana's potential for the expansion of RE is considered to be significant, this goal remains far from being achieved. For the time being only 3 out of 124 provisional licences for RE projects have been successfully realized and the percentage of RE in the national energy mix, although increasing from 6.61TWh in 2000 to 10.08 TWh in 2024 in absolute terms, has decreased from 8.5% to 6.31% over the same period (Energy Commission Ghana, 2025). This decrease can be explained by the population growth, economic development and increasing electrification which have led Ghana's overall power production to grow significantly faster than its renewable energy capacity (Energy Commission Ghana, 2025). The target of 10% RE in 2020 has therefore been delayed to 2030 (Nyasapoh et al., 2025). This shows that the main challenge is not only in the presence of RE potential or policy ambition, but in the actual implementation of RE projects in practice.

A considerable amount of research has been conducted to explain what difficulties influence the fluency of this transition and multiple barriers have been identified (Mahama et al., 2021). Technical barriers such as lack of grid capacity, difficulty in getting spare parts and lack of infrastructure facilities; and economic barriers such as costs of financing, insufficient access to long term capital and insufficient incentives. Follow-up research like Sackey et al. (2023) then focuses on how to overcome these barriers through technology improvements such as battery storage, economic mechanisms such as financing schemes or policy interventions such as feed-in tariff policies. While research like this remains important, it does mainly explain the implementation of RE through technical, financial and policy conditions.

Barriers that receive significantly less attention are the socio-cultural and institutional barriers. They are often mentioned in passing, however they rarely get researched. This seems to imply their influence is considered to be less significant than their technical and economic counterparts. However, there is limited empirical evidence supporting this assumption. Interestingly research conducted in western contexts shows that social acceptance of RE almost never comes easy (Wüstenhagen et al., 2007). Moreover Afful-Dadzie et al. (2020) concluded that research into barriers to RE investments in the Global South are often not supported by concrete country-specific evidence. This means the current literature could be too general to explain how social and institutional factors actually manifest within specific Ghanaian implementation contexts.

This pattern is not only visible in the RE literature, but is confirmed by broader project management research in the Ghanaian context. Amoako-Gyampah et al. (2021) show that project success in Ghana is significantly influenced by social capital, especially trust and shared norms, through their effect on knowledge sharing and knowledge exploitation between project actors. This also suggests that project implementation in Ghana is not solely dependent on technical expertise or financial resources, but also on the quality of stakeholder relationships, shared understanding and organisational coordination. PV initiatives form no exception as they involve many actors, including policymakers, regulatory entities, project teams, contractors and end users, whose coordination, trust and shared understanding directly influence the implementation results.

Together, these observations indicate that the social and institutional dimensions of RE implementation are insufficiently understood in the Ghanaian context. Even though social acceptance does cause challenges in other contexts, research conducted in the global south is primarily focused on the financial and technological dimensions (Apfel et al., 2021). Therefore, the objective of this research is to explore the extent to which social and institutional factors influence the implementation, which in this research refers to both the initiation and the execution, of PV projects in Ghana.

Given the limited empirical insights at project level, context specific research is necessary to understand how these dimensions manifest in practice. Therefore, this research will be conducted through a case study at the KNUST campus. Even though RE in Ghana includes multiple technologies, this research will only focus on PV as the PV projects are the most common and practically relevant RE initiatives within the context of university campuses. KNUST is not used as a representative case for all Ghanaian PV projects, but as an information-rich institutional case in which multiple PV initiatives, stakeholder groups and organisational processes can be studied in detail. This research seeks to answer the following main research question:

1.1 MAIN RESEARCH QUESTION

How can the social and institutional barriers to the implementation of PV initiatives in Ghana be overcome?

1.2 SUB QUESTIONS

1 Who are the key stakeholders in Ghana’s energy systems?

2 Which social and institutional barriers and enablers emerge in the implementation of PV initiatives in Ghana?

3 How can the influence of the social and institutional barriers be mitigated when setting up future PV projects in Ghana?

This research objective is significant within the MSc Management of Technology (MOT) program, as the implementation of PV systems is approached as a topic where technology, organisation and institutional context all come together. The focus is not on the technical functioning of PV, but on the question of how social and institutional factors can function as barriers or enablers during the implementation of this technology.

Several courses from the MOT program are reflected in this research. Technology Dynamics (MOT113A) and Emerging and Breakthrough Technologies (MOT131A) approach the diffusion of technological change as a process shaped and influenced by actors, institutions, networks and existing systems. This connects to the idea of PV implementation as an element of a broader energy transition from conventional energy to renewable energy. Inter- and Intra-Organisational Decision-Making (MOT123A) is relevant for the analysis of the involved stakeholders and the attention to decision making processes involving several institutions with their own interests, responsibilities and degrees of power. Additionally, this course is relevant to reflect on the role of the researcher and to become aware of his positionality. Leadership and Technology Management (MOT121A) is relevant for the analysis of the project organisation, key figures, knowledge processes and the role of leadership in coordinating technology implementation. Finally, Research Methods (MOT141A) and Preparation for Master Thesis (MOT201A) support the methodological choices in this research including the qualitative case study approach, interview protocol and thematic analysis.

2 THEORETICAL BACKGROUND

This chapter establishes the theoretical basis for the analysis of the implementation of PV initiatives at KNUST. First, the central concepts used in the research are defined. Second, the broader Ghanaian RE context is outlined by discussing the country's RE potential, policy development and current implementation status. Third, this chapter discusses the social and institutional barriers that, according to the literature, are relevant to the implementation of RE projects, with particular attention to the Ghanaian context. Finally, the literature gap, conceptual model and circles of influence are introduced, which guide and structure the data collection and subsequent analysis.

2.1 KEY CONCEPTS AND DEFINITIONS

This section defines the central concepts used in this research to identify the project team and other relevant stakeholders, analyse social and institutional factors, and explore potential mitigation strategies.

Stakeholders are people, groups or organisations that, through their roles, interests or decision making power, can influence the development, execution or outcomes of a project, or are influenced by the project and its outcomes (Agyekum et al., 2017).

A **Project team** is a group of stakeholders with interdependent tasks who are collectively responsible for the project results and function as a recognisable unit within a broader organisational context (Fianko, 2019). Within this research the project team is the group of stakeholders within KNUST who are responsible for the implementation of PV initiatives.

Factors are contextual conditions which influence the implementation of a project. They are not inherently positive or negative, but can function as either constraining (barrier) or facilitating (enabler) depending on the specific context in which they occur. Barriers are conditions that obstruct or delay the implementation of RE technologies. Enablers are conditions that support, facilitate or accelerate the implementation of RE technologies (Damschroder et al., 2022). These conditions can be classified into different categories, such as technical, financial and economic, institutional and regulatory, and social and cultural conditions (Painuly, 2001).

Social factors are societal, cultural and behavioural conditions influencing the acceptance and implementation of RE projects. These factors may manifest at the socio-political, community and market levels and can either support or constrain RE implementation depending on the context in which they occur. Examples include public knowledge, public perceptions, community acceptance, trust and stakeholder participation (Amoako-Gyampah et al., 2021; Wüstenhagen et al., 2007).

Institutional factors are structural, organisational and procedural conditions within and between organisations, and policy and regulatory institutions which influence the implementation of RE projects. Depending on the context these factors can either support or constrain implementation processes. They often originate from deep-rooted rules, interests and decision-making practices that promote stability and continuity, but can also hinder innovation (Maswabi et al., 2021). Examples include administrative procedures, policy implementation and institutional capacity, responsibilities and coordination (Mahama et al., 2021).

Mitigation strategies are measures, actions or approaches applied to eliminate, limit or manage constraining factors to support the implementation of RE projects (Awuni et al., 2023).

2.2 THE GHANAIAN RENEWABLE ENERGY CONTEXT

The research of Nyasapoh et al. (2022) illustrates that the energy transition in Ghana is feasible both technically and economically. Ghana possesses a significant spectrum of opportunities such as a high level of irradiation (4.5 to 6.0 kWh per square meter per day), suitable windspeeds for electricity generation (5 to 9 m/s where windspeed above 5 m/s could be profitable) and largely unutilized hydro capacity (840MW). Moreover there are successful RE projects in each of these sectors already which could be expanded or used as an inspiration. As Ghana nowadays spends roughly 27% of their profits from export on importing fossil fuels there is an economic incentive as well. The possessed national sources of RE are considered to be an interesting and profitable alternative, which would increase energy independence as well. The long term profitability however could become even more stable with the right national policies in place to support the transition (Pueyo, 2018).

The political engagement with the energy sector has over the last decades evolved from a focus on electrification to decarbonization. The first national RE goals were developed in 2006 in the Strategic National Energy Plan. Among others this plan included a 10% RE target by 2020 (Nyasapoh et al., 2025). This goal was intensified in 2010 in the National Energy Policy where the Ghanian government explicitly stated its intention to diversify the energy mix, increase the access to energy and utilize RE sources such as PV, wind and hydro. This ambition was institutionalized by the Renewable Energy Act from 2011 which created a regulatory framework for investment incentives, licensing procedures and grid integration. In 2020 this Renewable Energy Act was amended where among other things the 10% target was extended to 2030 (Tettey et al., 2025). Finally in 2022 the National Energy Transition Framework set goals per decade with the final goal to become net zero in 2070 (Ministry of Energy, 2023). For now the 10% RE target remains far as the relatively slow growth of RE utilization has caused the percentage of RE in the energy mix to only go down (Energy Commission Ghana, 2025).

2.3 SOCIAL BARRIERS

Social barriers refer to the knowledge, perceptions, attitudes and relationships of actors involved in or affected by RE projects. They may arise among affected communities and other stakeholders, but also within project teams responsible for implementation. This section discusses four social barriers that are relevant to the implementation of RE: limited community acceptance, limited RE knowledge, negative perceptions and limited trust within project teams. Although these barriers are discussed separately, they may influence and reinforce one another.

2.3.1 Limited community acceptance

This barrier refers to the extent to which members of the public and affected communities are willing to adopt and support renewable energy systems (Agyekum et al., 2021). A limited public willingness to engage with the RE initiatives can create social risk and complicate project development (Mahama et al., 2021; Pueyo, 2018). This phenomenon can range from an unenthusiastic public opinion to active community opposition (Agyekum et al., 2021; Tettey et al., 2025). Low community acceptance can cause major delays in project development and is described as a fundamental obstacle to successful implementation of RE projects (Asante et al., 2022; Mahama et al., 2021). In practice, this can result in structural problems for Ghanaian RE initiative developers who report that limited public support adds an extra layer of complexity (Mahama et al., 2021). In several cases in Sub-Saharan Africa this increases development costs and investment risks which causes large scale projects to be blocked, interrupted and even terminated (Pueyo, 2018).

2.3.2 Limited RE knowledge

Limited RE knowledge refers to insufficient understanding of RE technologies among end users, communities and other non-technical stakeholders (Agyekum et al., 2021; Asante et al., 2020). This knowledge gap may concern how the technology functions, how electricity production varies, the role of energy storage, maintenance requirements and the practical responsibilities of users (Arthur et al., 2025; Tettey et al., 2025). In the Ghanaian literature, limited public awareness and insufficient dissemination of information are identified as important factors contributing to this barrier (Asante et al., 2020; Mahama et al., 2021). Without sufficient knowledge stakeholders may experience trouble to interpret system information, form realistic expectations and take part in conversations about its implementation and use (Agyekum et al., 2021; Tettey et al., 2025).

2.3.3 Negative perceptions

Negative perceptions refer to subjective, unfavourable assessments of RE technologies by end users, communities and other stakeholders. These assessments can arise from expectations, previous experiences and comparisons with familiar alternatives, and are mostly related to the affordability, reliability and practical value of RE. For example, PV may be perceived as an uncertain or supplementary energy source that is insufficiently suited to continuously meet daily energy demand, even when the actual technical performances may differ from this (Agyekum et al., 2021; Tettey et al., 2025). Previous project problems, limited visibility of successful applications and a lack of alignment with local needs can strengthen this barrier (Mahama et al., 2021). Familiarity with electricity from the national grid can also cause conventional energy sources to be perceived as more reliable and practical (Agyekum et al., 2021).

2.3.4 Limited trust within project teams

This barrier refers to limited trust among project team members and between collaborating project parties. In Ghanaian project environments, trust influences the way in which knowledge circulates within the team: trust facilitates knowledge acquisition and knowledge sharing, while knowledge sharing and knowledge exploitation mediate the relationship between trust and project management success (Amoako-Gyampah et al., 2021). When team members do not sufficiently trust one another, there is an increased risk that expertise, concerns and project problems are not shared or utilised timely, which complicates coordination and joint problem solving (Eyiah et al., 2025; Iddrisu & Mohammed, 2024). Moreover, in the Ghanaian construction sector, lack of trust gets empirically identified as a barrier for collaboration (Agyekum et al., 2017). This aligns with Ahiabu et al. (2024), who identified a significant positive relationship between coworker relationship quality and project performance.

2.4 INSTITUTIONAL BARRIERS

Institutional barriers refer to policies, procedures, organisational capacity and coordination mechanisms that influence the implementation of RE projects. They may arise within national policy and regulatory institutions, but also within and between organisations and stakeholders that are responsible for implementation. This section discusses six institutional barriers that are relevant to the implementation of RE: weak political commitment, weak operationalisation of RE policy, complex administrative procedures, insufficient institutional capacity, insufficient stakeholder participation, institutional coordination constraints. Although these barriers are discussed separately, they may influence and reinforce one another.

2.4.1 Weak political commitment

This barrier can be explained by RE in Ghana not being stably or consistently politically prioritised. The literature shows that RE is included in policies and objectives, but this ambition is not systematically translated into consistent political governance (Mahama et al., 2021; Tettey et al., 2025). The literature describes this in terms of *"inadequate political commitment"* and *"policy uncertainty due to political interference"* (Dokyi & Sharifi, 2024; Mahama et al., 2021). This creates uncertainty about the long term feasibility of RE projects among developers and other involved actors, which can cause them to hold back on their investments (Bukari et al., 2021; Pueyo, 2018).

2.4.2 Weak operationalisation of RE policy

Ghana possesses several policy frameworks and supporting instruments for the development of RE, including the National Energy Policy, the Renewable Energy Act, feed-in tariffs, net metering, tax incentives and the Renewable Energy Fund (Asante et al., 2020; Nyasapoh et al., 2022). The literature, however, shows that these policy ambitions are not consistently translated into effectively functioning instruments in practice (Afful-Dadzie et al., 2020; Asante et al., 2020). This is reflected in the limited operationalisation of the feed-in tariffs, net metering and the Renewable Energy Fund (Afful-Dadzie et al., 2020; Asante et al., 2020). Additionally the design of support mechanisms and contractual arrangements does not always provide developers with sufficient financial and long term certainty. Examples of this are: limited guarantee periods on tariffs, tariffs were denominated in local currency and investments were exposed to exchange rate risks (Pueyo, 2018). As a result, existing policy instruments do not consistently provide the practical and contractual conditions required to actually realise RE initiatives (Mahama et al., 2021; Nyasapoh et al., 2022; Pueyo, 2018).

2.4.3 Complex administrative procedures

This barrier refers to the challenges in administrative and bureaucratic procedures that are required for the implementation of RE projects. These "lengthy permitting procedures" (Dokyi & Sharifi, 2024), "complex administrative procedures" (Bukari et al., 2021) and "bureaucratic delays" (Pueyo, 2018) involve multiple steps and often require approvals from different agencies (Pueyo, 2018). As these procedures often lack transparency, the delays can be unpredictable, making it difficult for developers to establish reliable project schedules (Mahama et al., 2021). Even though these procedures are intended to ensure due diligence and regulatory compliance (Pueyo, 2018), in practice they cause significant delays and hinder the progress of RE projects (Dokyi & Sharifi, 2024).

2.4.4 Insufficient institutional capacity

The literature characterises this barrier as limitations in institutional capacity and available resources that affect the ability to implement RE projects (Arthur et al., 2025). This is reflected in a shortage of technical expertise required for the assessment, design and installation of RE systems, limited personnel capacity required for the operation and maintenance of RE systems, and insufficient financial and organisational resources (Bukari et al., 2021; Nyasapoh et al., 2025) These limitations reduce the ability of institutions to guide, support and monitor RE initiatives which reduces effectiveness of these projects (Mahama et al., 2021). Additionally, a lack of resources can lead to dependence on external expertise, which may complicate project development (Tindana, 2025).

2.4.5 Insufficient stakeholder participation

According to the Ghanaian literature, insufficient involvement of local stakeholders and communities during the planning phase can form a significant barrier in the development of RE projects (Bukari et al., 2021; Dokyi & Sharifi, 2024). When local participation is not timely and structurally embedded, this may lead to a top down project approach in which important design decisions are mainly made by policymakers and project developers (Dokyi & Sharifi, 2024). Consequently, local knowledge of user needs, preferences and financial capacity, as well as context specific practical and technical conditions, is insufficiently incorporated into the design (Bukari et al., 2021; Mahama et al., 2021). The project may therefore align only to a limited extent with the user context, which weakens its perceived relevance, local support (Agyekum et al., 2021) and prospects for sustainable implementation (Asante et al., 2022; Bukari et al., 2021).

2.4.6 Weak institutional coordination

Weak institutional coordination refers to insufficient alignment between government agencies, regulators, utility companies, developers and other institutions that are involved in the implementation of RE projects. In Ghana, this is mostly visible in fragmented responsibilities and unclear decision making authority, which creates uncertainty about which party has to coordinate and monitor progress (Mahama et al., 2021; Pueyo, 2018). Differences in institutional power, interests and priorities between actors can also hinder collaboration. A developer may, for example, want to quickly connect a project to the grid, while the utility company wants to ensure grid stability and may delay the connection. As the developer cannot continue on its own, the entire project may then be delayed (Agyekum et al., 2017; Pueyo, 2018). This causes decisions and activities to be insufficiently aligned, tasks to be delayed and project problems to remain unresolved. This then limits the continuity between planning, approval, implementation and maintenance (Bukari et al., 2021; Mahama et al., 2021).

2.5 Literature gap

Despite the significant relevance, possibilities and political intentions surrounding the energy transition in Ghana, only a limited number of projects have been successfully implemented (Nyasapoh et al., 2022). Current scientific research mostly focusses on technological limitations or economic dimensions to explain this trend. High investment costs, infrastructural challenges and technological availability have been identified as the main explanatory factors (Mahama et al., 2021). Social and institutional barriers are often being mentioned, but remain underexposed. Even though certain authors acknowledge the possibility of non technical barriers having significant influence on successful transitioning there hasn't been any systematic research on how these barriers manifest in Ghanaian context (Mahama et al., 2021). Moreover, as noted by Afful-Dadzie et al. (2020), "a number of authors often discuss the barriers to renewable energy investments in the Global South without presenting concrete evidence to buttress their claim, especially on a country-specific basis." This implies that existing research could be too generalised and study results might not apply in the Ghanaian context. The limited amount of research done into social and institutional barriers to RE projects in the global south could therefore be of limited relevance, which suggests new, context specific research is necessary to understand the manifestation of these factors in Ghana

2.6 FRAMEWORK FOR ANALYSIS

Figure 1 presents the conceptual model used to understand PV implementation in this research as an iterative process across successive projects. The model starts from the assumption that PV initiatives are not executed as isolated projects, but as part of a continuous sequence of projects in which earlier experiences can influence future decisions. Within every project the model should be read from left to right. The arrows indicate how each element influences the next.

Mitigation strategies are based on previous project experience and are positioned as responses to the perceived effects of social and institutional factors. They respond to these effects by limiting and managing the constraining effects, while enabling and strengthening the facilitating effects of the social and institutional factors. Social and institutional factors shape the conditions under which the project approach is developed and executed. These factors are not classified as enablers or barriers beforehand, but are analysed based on how their effects are perceived by stakeholders involved in PV implementation projects. The project approach then influences the implementation outcome through the way the project is organised and executed. The feedback loop from PV implementation outcomes to mitigation strategies does not represent a closed cycle within a single project, but reflects the iterative character of the model where outcomes from earlier projects can inform mitigation strategies in subsequent projects.

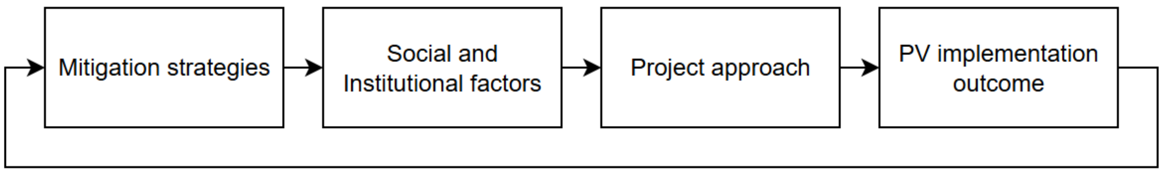

Figure 1: Conceptual model to analyse iterative PV implementation initiatives at KNUST in Ghana

To identify and analyse the factors influencing RE projects in Ghana, this research utilises the analytical framework of Painuly (2001). This model, which is developed within the UNEP Collaborating Centre on Energy and Environment, has been widely adopted in studies on RE diffusion and its barriers in varying economic contexts. An important aspect of the framework is the structured approach to barriers where a distinction is made between barrier categories, specific barriers and underlying elements. This enables not only identification, but also insight into their root causes and interrelations.

This research will not use the framework rigidly, but as a flexible frame of reference where the focus will be specifically on the social and institutional factors. Following Painuly's approach, which relies on stakeholder input and contextual data to identify barriers and possible measures, these factors will be analysed based on stakeholder interviews, document analysis and site visits. This way the application of

Painuly aligns well with the empirical research design, in which the experiences of involved actors are central for identifying factors, potential causes and possible mitigation strategies.

Next to the framework of Painuly, multiple frameworks for identifying barriers to RE projects do exist. The study of Asante et al. (2020) for example, provides a Ghana specific framework where barriers are grouped into different categories. Despite its relevance for understanding barriers, this framework is unable to explain how different barriers influence the implementation of RE projects. The Social Acceptance Model of Wüstenhagen et al. (2007) provides an excellent lens to examine the social dimension, but does not account for other types of barriers and how they relate to each other.

Painuly provides a structured approach, while leaving enough space for a practical, context specific hands on approach. Within this framework, barriers can not only be identified, but also analysed in terms of underlying causes, interactions and influence at the project level. This makes the framework particularly suitable for this research context, where multiple renewable energy projects have been initiated and executed within university campuses. The actors involved in these projects possess practical experience, from which valuable insights can be derived.

2.7 The Circles of Influence

This research uses the circles of influence to categorise the social and institutional factors to the degree the internal project team can act upon them. The circles are based on Covey (1989) who made a distinction between the circle of concern, which included all circumstances that were relevant to a specific actor, and the circle of influence, which only included the circumstances which this specific actor could influence. Additionally, he made a distinction between direct, indirect and no control. A variation of this distinction was applied by Breyer-Mayländer et al. (2024) to distinguish between independently influenceable subjects, subjects which can be influenced in collaboration with others and not influenceable external boundary conditions.

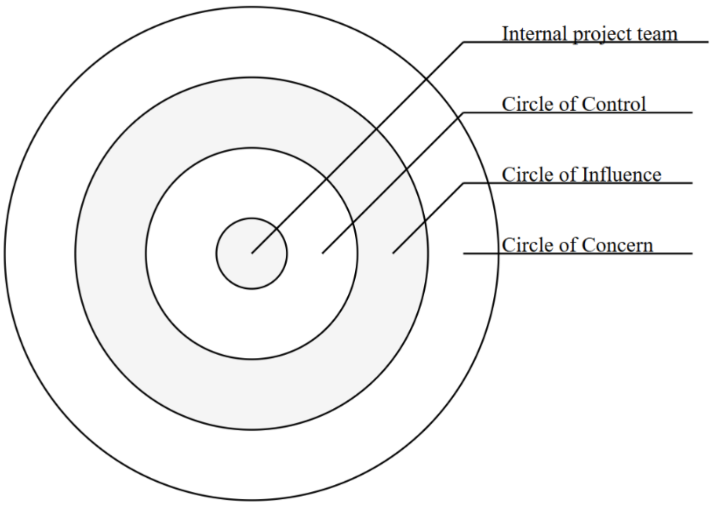

Figure 2: The three circles of influence from the perspective of the internal project team. Own illustration, adapted from Breyer-Mayländer et al. (2024)

Based on this, this research will use the following tripartite distinction: the circle of control, the circle of influence and the circle of concern. The first circle is the circle of control, which consists of the project specific factors within the direct responsibility and decision making authority of the internal project team. The second circle is the circle of influence, which consists of factors that cannot be controlled by the project team, but can be influenced indirectly through collaboration and/or communication. The third circle is the circle of concern, which consists of overarching external factors that influence the project, but cannot be meaningfully altered by the internal project team. A visualisation of the circles can be found in figure 2.

The layout is dependent on the chosen actor perspective. Breyer-Mayländer et al. (2024) show that subjects can be outside of an actors influence, while being inside of someone else's. The circles are therefore not talking about absolute possibilities. For this research the perspective of the internal project team will be chosen as central point.

The use of the tripartite distinction is in the connection between factors and realistic mitigation possibilities. As factors in the circle of control are independent from others this is where direct mitigation strategies will most likely be the most effective (Breyer-Mayländer et al., 2024). Secondly, factors in the circle of influence can be addressed through indirect mitigation, where collaboration, communication and coordination with others is necessary. Factors in the circle of concern cannot be mitigated, but should be kept as external preconditions in the design and execution as they can influence the projects implementation.

3 METHODOLOGY

This chapter describes the methodological approach used to examine how social and institutional factors influence the implementation of PV initiatives at KNUST and how the constraining effects of these factors could be mitigated. First, the research design and case selection are explained, followed by the sampling strategy and data collection. Then, the data processing and analysis are discussed, including the application of the circles of influence. Finally, the measures taken to strengthen the validity and reliability of the research are discussed.

3.1 RESEARCH DESIGN

This research is based on a qualitative, exploratory single case study approach (Yin, 2018). The choice for a case study is based on the goal of understanding how social and institutional barriers affect the execution of PV projects in Ghana. Such an approach enables an in depth analysis of the complex stakeholder and organisational processes through which the social and institutional factors manifest and influence PV implementation, rather than merely identifying individual factors.

For this research the Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi was selected as the case for analysis. This university forms a relevant object of study due to its size, geographical position and ongoing initiatives in the field of the energy transition. The university's large energy demand and complex organisational decision making structures represent an interesting institutional setting providing insight into the challenges that other Ghanaian projects might experience during the implementation of RE projects. The presence of multiple PV and other RE initiatives provided an interesting empirical context to analyse how social and institutional barriers in practice emerge during the implementation phase. Additionally, the ongoing collaboration between TU Delft and KNUST facilitated access to the university campus, relevant departments and current or former energy initiatives. The case study combines perspectives from internal institutional experts, external institutional experts and end users to analyse PV implementation from institutional and social perspectives.

The unit of analysis in this research was the implementation process of PV initiatives within KNUST. This process was examined by analysing organisational and institutional processes, interactions between stakeholders involved in the implementation and the perceptions and responses of end users. The research process consisted of three phases: Preparation, fieldwork and analysis. During the preparation phase the literature review was conducted and the provisional stakeholder analysis was developed, During the fieldwork phase the interviews were conducted and all relevant documents were collected. During the analysis phase the interviews were transcribed and systematically coded.

3.2 LITERATURE REVIEW

The theoretical background was developed through a narrative literature review of social and institutional factors that influence the implementation of RE projects, following the general principles described by Snyder (2019). The literature was primarily identified through google scholar using combinations of terms related to RE, solar PV, implementation barriers, challenges, constraints, social acceptance, stakeholder participation, institutional coordination project management and Ghana. Additional literature was identified through the reference lists of relevant studies. When insufficient Ghana specific literature was available, the search was broadened to Sub Saharan Africa. Circumstances that constrained, delayed or complicated the implementation were considered to be potential barriers, even if they were not explicitly described as such. Overlapping findings were then merged into four social and six institutional barriers, which formed the structure of the theoretical background.

3.3 SAMPLE STRATEGY

A purposive sampling strategy was used to select suitable candidates for the interviews. The primary objective of this sampling was not statistical representativeness, but analytical relevance. Respondents were selected based on their role in the implementation, decision-making, operation or experience with or exposure to PV initiatives at KNUST. Three groups of respondents were distinguished: internal institutional actors, external institutional actors and end users. During the preparation phase an initial list was created which was later extended by utilizing snowball sampling. Following this process the final sample consisted of 23 participants, seven internal institutional experts, six external institutional experts and ten end users.

The first group of respondents consisted of internal institutional experts who were actively involved in energy related decision making or implementation processes within KNUST. This group was selected because they could provide direct insight into the organisational structure of PV projects, the role of internal stakeholders, and the social and institutional factors that emerge during implementation. Their experience was therefore relevant for sub question 1, sub question 2 and sub question 3. The selection of respondents was based on their functional role within departments involved in: project design, finance, procurement, maintenance and operations. During the interviews the respondents were asked which other offices and departments were involved in the decision making and project implementation processes of the PV initiatives. This information was used to verify whether all relevant institutional actors had been included in the sample and to identify additional stakeholders when necessary. Table 1 presents an overview of the internal institutional actors included in the sample.

Table 1: Overview of the internal institutional actors

Participant ID	Role/Position	Type of organisation	Key areas of expertise
P1.1	Energy Consultant	University	Solar system design, team coordination, project implementation, system monitoring, battery storage, energy efficiency, RE policy
P1.2	Finance Office	University	Financial assessment, budgeting, payment and contract verification, financial risk analysis
P1.3	Procurement Office	University	Public procurement law, tendering processes, bid evaluation, supplier checks
P1.4	Development Office	University	Campus physical development, infrastructure planning, structural stability, construction supervision
P1.5	Electrical Engineering Consultant	University	Electrical network and PV systems, PV grid integration, load assessment, technical tender review, advisory support
P1.6	Researcher	University	GHG emissions assessment, decarbonisation technology research, project management
P1.7	Maintenance	University	Campus power supply, electrical maintenance, energy system operations

The second group of respondents consisted of external institutional experts who had experience in: PV research, regulation or implementation at KNUST or large scale PV initiatives in Ghana more generally. This group was selected because external actors could provide contextual insight into the broader regulatory and institutional conditions that shape PV implementation projects in Ghana, beyond the specific KNUST PV initiatives. Their perspectives helped to place the experiences of the internal group within the wider Ghanaian energy system and were particularly relevant for sub question 1 and sub question 2. Interviews were conducted until the most relevant stakeholders from outside the university had been represented. Table 2 presents an overview of the external institutional actors included in the sample.

Table 2: Overview of the external institutional actors

Participant ID	Role/Position	Type of organisation	Key areas of expertise
P2.1	RE Expert	Electricity Company	Grid integration of solar systems, network impact analysis, net metering, implementation regulations, customer advise
P2.2	Operational Staff member	Solar Com pany	Solar project logistics, commercial project support, technical design support, warranty
P2.3	Founder	Research Centre	RE research centre coordination, diverse RE research projects, project monitoring
P2.4	Head researcher	Research Centre	RE centre coordination, hybrid solar solutions, multi-partner consortium management, community engagement, project risk analysis
P2.5	Solar expert	Research Centre	Leading solar projects, donor-funded RE projects, institutional navigation
P2.6	Co-Director	RE NGO	Off-grid solar implementation, solar technician training, capacity building, community engagement

The third group of respondents consisted of end users of the energy system of KNUST who use the facilities connected to PV installations on a daily basis. These interviews were not conducted to gain insight into institutional decision making, but focused on awareness and user experience instead. While the unit of analysis was the organisational level, these interviews were included to get a better understanding of the social environment where the PV installations operate. This made this group primarily relevant for sub question 2. These respondents were approached on site at locations on campus where the PV installations were present. During the selection of suitable interview participants an effort was made to ensure variation in gender, age and role on campus. Table 3 presents an overview of the end users included in the sample.

Table 3: Overview of the end users

Participant ID	Role/Position	Type of organisation	Key areas of expertise
P3.1 – P3.10	Student, TA, Lecturer, Staff	University	awareness, perceived necessity, connection to daily life, attribution

3.4 DATA COLLECTION

The primary data collection method was semi structured interviews. This method adds to the exploratory character of the research as it enables addressing a fixed set of themes, while leaving the opportunity for respondents to share their experiences and perspectives thoroughly. During the interviews two interview protocols were utilized: one for the internal and external experts and one for the end users. Both consisted of an informed consent form and interview guide with open ended questions and can be found in appendix A and appendix B. All interviews were recorded with permission of the respondents.

The interviews conducted with the internal and external experts focused on their experiences with the design, implementation and operation of PV projects. During the interviews the respondents were asked about project organisation and structure, the involvement of different actors, constraining and facilitating factors that can emerge during implementation, and possible strategies to mitigate the constraining factors. The interview guide was informed by the theoretical background at the level of broad analytical topics, instead of directly asking respondents about specific factors that were identified in the literature. The questions focussed on project organisation, stakeholder involvement, constraining and facilitating conditions, and mitigation strategies, while the respondents were given space to describe their experiences in their own words. This reduced the risk of leading respondents towards literature based barriers and enabled additional factors to emerge inductively from the data. Factors from the literature were only used as optional follow up questions when they did not emerge spontaneously during the interview. The expert interviews on average took 45 to 60 minutes and were mainly conducted physically at a location of the participants preference.

In addition to the expert interviews, short interviews were conducted with the end users of the campus facilities where the PV installations were present. For these interviews a different interview guide was utilized with open questions on awareness, perceived necessity, connection to daily life and attribution. The interview guide for the end users was informed by the social factors discussed in the theoretical background and the four interview themes were developed as broad, non-directive categories. Awareness was used to gain insight into the knowledge of the participants, while perceived necessity and connection to daily life examined their attitude towards PV and its perceived relevance. Attribution focused on whether end users felt involved in the decision making process and perceived the initiatives as top down. By using these broad themes, the respondents were able to describe their experiences in their own words without being led towards predetermined social barriers. These interviews were conducted at the sites where the PV installations were present and took on average ten minutes.

Relevant documents and other publicly available information regarding the PV installations were also collected, and installation sites were visited to provide support and additional context to the information from the interviews.

3.5 DATA PROCESSING

After the data had been collected, it was transformed into an analysable dataset to facilitate further analysis. All 23 interviews were transcribed in full using automatic transcription software, after which each transcript was checked manually using the original recording. Transcription errors, incorrectly recognised terms and abbreviations, and unclear passages were corrected.

The transcripts were then lightly edited to improve readability. Repetitions, speech hiccups and obviously incorrect wording were, as far as, necessary adjusted. The substantive content of all statements remained unchanged. If sections remained unclear, the audio file was listened to again to enable further clarification. As all interviews were conducted in English, no translation was necessary.

Before the analysis the transcripts were pseudonymised. Names of interviewees and people who were referenced during the interview were removed, job titles and company details were generalised, and phone numbers and email addresses were removed. The participant codes were manually added at a later stage. The original data including the contact information were kept separately and were only accessible to the researcher.

3.6 DATA ANALYSIS

The collected data was analysed using an inductive thematic analysis inspired by Braun and Clarke (2006). This was done by systematically coding all interviews using the ATLAS.ti software.

The analysis started with open coding, where all relevant fragments from the data were coded without any pre-existing categories. This resulted in a large number of initial codes which remained close to the data. Using an iterative analysis process, these codes were refined, combined and improved (Belotto, 2018). This formed a codebook, which was developed throughout the process and can be found in appendix C.

In the next step, relationships between codes were established and codes were grouped into categories. Recurring themes, similarities and differences between respondents were examined and based on these categories, analytical themes were developed (Gibbs, 2012). These themes formed the structure of the social and institutional barriers surrounding the implementation of PV projects.

The interviews with institutional actors and end users were analysed in parallel. The institutional interviews mainly focused on implementation processes and barriers, while the interviews with end users provided insight into perceptions and experiences with PV installations in daily life.

To support the interpretation of the results, representative quotations were selected from the interviews. Additionally the interview findings were compared with the information from the collected documents and observations of the installation sites to contextualise and strengthen the results.

After the inductive coding process, the identified social and institutional factors were categorised using the three circles of influence introduced in section 2.7. The internal project team was used as the reference actor. Factors were assigned to the circle of control when they fell within the direct responsibility and decision making authority of the project team, to the circle of influence when they could be influenced indirectly through collaboration or communication, and to the circle of concern when they could not be meaningfully altered by the internal project team. The circles were therefore not used as predefined coding categories, but as a subsequent analytical framework to assess the project team's degree of influence over the identified factors and thereby clarify which barriers could be mitigated directly or indirectly.

3.7 VALIDITY AND RELIABILITY

Multiple methods were utilized to ensure validity and reliability:

1 Triangulation was applied by comparing the interview results with available internal documents and the literature review. Site visits to the campus, energy centre, engineering labs, technical facilities, and multiple project sites were also conducted to create a better contextual understanding that could be compared with the interview data. This ensured interpretations were not based on a single source and minimized methodological bias.

2 Member checks were done by sending the interview participants a document with the interview's main takeaways. Upon request the full transcription was made available as well. Where necessary, corrections and clarifications were made so that the transcription accurately reflected the interview participants perspectives. The initial summary was provided to increase clarity and accessibility.

3 Transparency, the coding process was documented in full detail. This includes the initial codes, the number of times each quote got mentioned and the clusters used to determine the final factors. This ensured the final interpretation remained traceable and transparent.

4 Pseudonymity was ensured for all participants as complete anonymity was impossible in this specific context. Removing participant names and replacing job titles with general descriptions however increased the credibility of their answers and reduced social desirability bias.

The researcher's external position might have influenced the participant's perceptions and responses. That’s why it was important to remain aware of potential cultural differences and social biases as they might have shaped the data in a way that had not been accounted for.

4 RESULTS

This chapter presents the empirical findings of the research. First, the stakeholders involved in the implementation of PV initiatives at KNUST are identified and analysed. Second, the social and institutional barriers and enablers emerging from the interview data are presented. Finally, the mitigation strategies identified by the respondents are discussed.

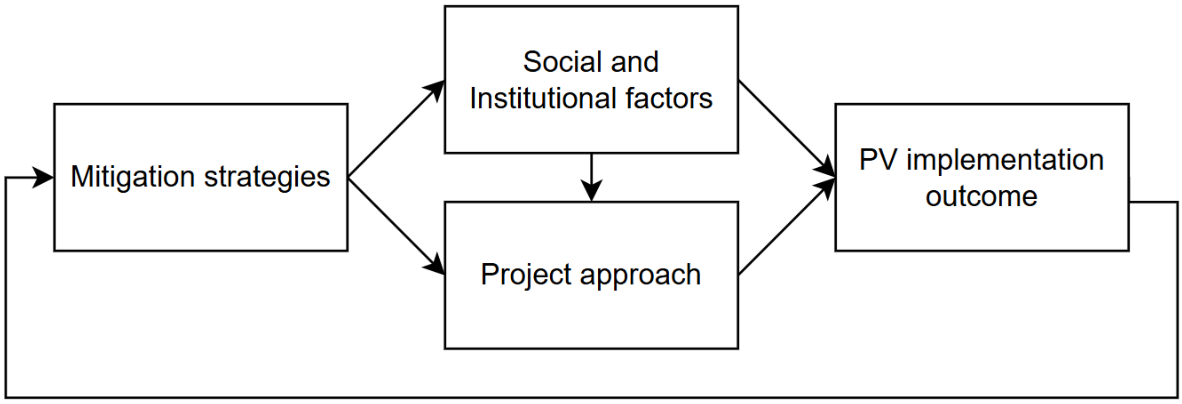

Figure 3: Updated analytical structure used to organise the results

Figure 3 presents the updated analytical structure used to organise the results. This structure builds on the conceptual model from the theoretical framework in Figure 1 by showing that PV implementation is more complex than a linear succession of mitigation strategies, social and institutional factors, project approach, and PV implementation outcome. Instead, the results show that social and institutional factors can influence both the project approach and the PV implementation outcome. Similarly, some of the mitigation strategies are focused on responding to the factors, while others focus on improving the project approach.

4.1 STAKEHOLDER ANALYSIS

In this section the stakeholders involved in the development and implementation of PV initiatives at KNUST are presented. First, the stakeholders are described, after which their relative positions are displayed in a power interest matrix.

4.1.1 Stakeholder descriptions

The stakeholder descriptions provide a concise overview of their roles, interests and involvement across the different phases of PV implementation. Together, they show how responsibilities and influence are distributed across the project network.

University Council

The university council functions as the highest decision making authority within the university and has a deciding role in the approval of large investments and strategic planning. The council has a strong interest in cost control, long term sustainability and institutional development. Through their formal decision power this stakeholder has a significant influence on the continuation of projects and adjustments in scope or budget. Their involvement is relatively low as they operate on the strategic level and are not actively involved in the daily operations.

Directorate of Works and Physical Development

The Directorate of Works and Physical Development is responsible for the spatial planning and physical infrastructure on campus and therefore plays a central role in the integration of PV systems in existing and new buildings. Their interest lies in the technical feasibility, safety and durability of the installations. The Directorate has a high influence as they are involved with both functional and structural design choices. Their involvement is highest during the planning and design phases, but remains significant during the actual implementation.

Energy Consultant
The Energy Consultant plays a central role in PV implementation projects at KNUST and functions as the key actor throughout the entire project. The primary interests of the Energy Consultant are ensuring robust functional design, system reliability and overall efficiency. The Energy Consultant is actively involved in multiple phases including functional design, procurement, implementation and operations. Furthermore this stakeholder functions as the primary point of contact, facilitating coordination and communication between all internal departments and external actors.

Procurement Office
The Procurement Office is responsible for the procurement process and the selection of external parties for the implementation of the PV projects. Their interests are mainly in transparency, following procurement law and cost control. This stakeholder's influence is significant as they select suitable candidates and advise the Energy Consultant on contractor selection, which gives them a strong influence on the final quality and implementation. Their involvement is mainly relevant in the early phases, particularly during procurement, and decreases during implementation and operation.

Finance Office
The Finance Office plays an important role in the assessment and approval of budgets and financial feasibility of projects. Their interests are in cost control, efficient use of resources and financial sustainability. Their influence is relatively high as financial approval is critical for project progress, but they are not directly involved in the design decisions. Their involvement is concentrated in the design and planning phases and decreases during implementation.

Internal Experts
Internal experts, such as technical consultants and academic staff, deliver substantive and technical input during the design phase of projects. Their interest lies in the development of effective and technically robust solutions. While their formal decision power is relatively low they still have a significant influence through their expertise driven advisory role, as they might influence other stakeholders' decisions. Their involvement is mainly relevant during the early phases of the project and decreases as the implementation phase starts.

Maintenance Department
The Maintenance Department is responsible for the basic operational maintenance and cleaning of the PV systems after installation. Their interest is in reliability and day to day functionality. The Maintenance Department only comes in after being called in by the Energy Consultant and does not perform routine checks independently. As specialists on the current energy system, the Maintenance Department sometimes gets involved in the design phase as well, but their role there remains limited and their main relevance lies in the operational phase.

End Users
End users, consisting of students, TAs, teachers and other staff, form the group that directly uses the energy systems on campus. Their interest is mainly in a reliable, continuous energy supply and lower costs. These stakeholders have no formal influence on the decision making, but are highly involved as they experience the direct consequences of the projects. Their feedback and experiences can indirectly influence future decisions and project adjustments.

Ministry of Energy Ghana (MoE)
The MoE is responsible for the development and implementation of national energy policy and plays a strategic role in the direction of RE projects. Their interest lies in increasing access to energy, improving national energy reliability and stimulating sustainable energy solutions. This stakeholder has a high degree of influence through its policy making role, which sets the frameworks within which projects are developed. Their involvement is relatively low as the MoE operates on national level and is not actively involved in the daily execution of individual projects.

Energy Commission Ghana (EC)
The EC is the governmental institution responsible for regulating, supervising activities within the Ghanaian energy sector and ensuring that all projects comply with national standards and regulations. Their interest are in regulatory compliance, system safety and the proper implementation of energy policy. This stakeholder has a high degree of influence as they establish and enforce technical and legal requirements. Their involvement is mainly concentrated at the approval and monitoring aspects of projects.

Environmental Protection Agency (EPA)
The EPA is responsible for ensuring that all projects comply with national environmental rules and regulations. Their interest lies in minimizing environmental impacts and promoting sustainable initiatives. This stakeholder has a moderate to high level of influence depending on the type of project. Environmental approval is often required for project implementation. Their involvement is mainly limited to the approval phase where environmental impacts are evaluated.

Electricity Company of Ghana (ECG)
The ECG is responsible for the management and maintenance of the grid and plays a crucial role in the integration of PV systems into the existing energy infrastructure. Their interest are in grid stability, system reliability and controlling the impact of decentralised energy generation. This stakeholder has a high level of influence, as connection to the grid depends on their technical judgement and capacity. Their involvement is mainly concentrated in the planning and design phases where they provide advice based on their experiences. If net metering and feeding electricity back to the grid are implemented in the future they will most likely also play a central role during the implementation phase.

Solar companies
Solar companies and contractors are responsible for the technical design details, delivery and installation of the PV systems. Their interests are project execution, profitability and delivering a system that complies to all contractual and technical demands. This stakeholder has a moderate to high influence, especially during the implementation phase, where they transform the design into an actual system. Their involvement is the highest during the implementation phase and decreases during the operational phase. If contractually agreed the company can also stay responsible for maintenance after installation.

Non-Government Organisations (NGOs)
NGOs can be involved in RE projects in different ways including education and awareness building, research & capacity building, and also by implementing their own RE projects. Their interests lie in promoting sustainable development, increasing energy access and improving local knowledge and capacity. The influence of these NGOs varies depending on their role, but would in general be moderate. Their involvement is often project specific and concentrated in the early phases, but can extend into the later phases as well.

External researchers
External researchers contribute to PV projects through knowledge, research and technical analysis. Their interests lie in generating new insights, testing innovative new solutions and developing scientific knowledge. Their influence is generally moderate as they only indirectly contribute to decision making and design choices. Their involvement is mainly present in the early stages of the projects, such as research, design and evaluation.

4.1.2 Power interest matrix
Figure 4 positions the identified stakeholders based on their power and interest in the implementation of PV initiatives at KNUST. Power refers to the ability of a specific stakeholder to influence project decisions, resources, approvals or implementation outcomes. Interest refers to the degree to which a specific stakeholder is concerned with, involved in or directly affected by the implementation and performance of the PV systems. Their positioning is based on their role descriptions, responsibilities and the experiences shared by the respondents.

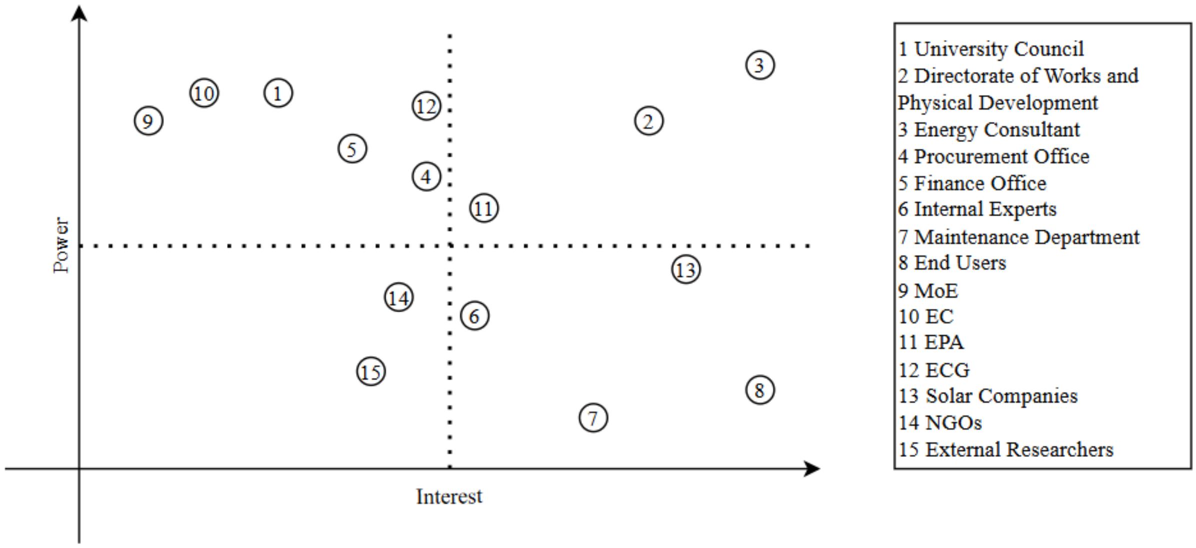

Figure 4: Power interest matrix of stakeholders involved in the implementation of PV initiatives at KNUST

The matrix shows that the decision making power is concentrated among a relatively small group of institutional and technical actors. The Energy Consultant and the Directorate of Works and Physical Development combine a high level of power with a high level of interest due to their continuous involvement in the planning, design and the implementation of PV projects. Other actors with high levels of power, such as the University Council, the Ministry of Energy, the Energy Commission, ECG, the Procurement Office and the Finance Office, are positioned in the quadrant with a high level of power and a low level of interest. These stakeholders can strongly influence projects through approval, regulation, procurement or financial decision making, but are generally less involved in the day to day implementation of individual PV projects.

In contrast, the end users, the Maintenance Department and solar companies have a relatively high level of interest in project outcomes, but a limited level of formal decision making power. They are directly affected by the system performance or are responsible for the operational and implementation activities, while strategic decisions are mainly taken by other actors. The EPA , NGOs and external researchers are positioned as stakeholders with relatively low levels of power and interest. However, their positions can differ significantly depending on their role in a specific project.

The positions within the matrix should not be interpreted as fixed, as the power and interest of several stakeholders can change across different project phases. Stakeholders such as the internal experts exert most of their influence during the design phase, while a contracted solar company exerts its greatest influence during the execution phase.

4.2 IDENTIFIED SOCIAL AND INSTITUTIONAL FACTORS

The analysis of the interview data resulted in a set of social and institutional factors that influence the implementation of PV initiatives at KNUST. These factors were inductively derived and categorised into four groups: institutional barriers, institutional enablers, social barriers and social enablers. Each category starts with a table that provides an overview. The factors in each table are ranked based on the total number of times they were mentioned, as presented in the column "Mentions". The column "Respondents" presents the total number of respondents that mentioned the factor at least once.

4.2.1 Institutional barriers

Institutional barriers are organisational, procedural, regulatory and political circumstances that constrain or complicate the implementation of PV initiatives. These barriers arise both within KNUST and in the broader Ghanaian institutional environment. The identified institutional barriers are presented in Table 4.

Table 4: Overview of the identified institutional barriers

Factor ID	Institutional Barrier	Mentions	Respondents
IB1	Bureaucratic procedures	41	9
IB2	Cost prioritisation	40	10
IB3	Unimplemented net metering	39	6
IB4	Dependence on key actors	28	8
IB5	Complex collaborations	22	8
IB6	Poor project team composition	21	8
IB7	Unreliable external environment	19	8
IB8	Regulatory constraints on grid access	16	6
IB9	Fragmented campus energy system	15	6
IB10	Top-down design	11	6
IB11	Stakeholder turnover	9	2
IB12	Environmental protection requirements	9	5
IB13	Bureaucratic procedures within KNUST	9	6
IB14	Political influence	8	4
IB15	Restrictive PPAs	6	1
IB16	Reactive maintenance	6	3
IB17	Conflict of interest	1	1
	Total	300	23

Bureaucratic procedures

RE projects in Ghana take place within an institutional context that operates both constraining as well as facilitating. Respondent **P1.2** explains that especially larger PV projects are impacted by this as they become dependent on "lengthy and bureaucratic" national governmental procurement procedures. This is highly relevant at KNUST as its PV initiatives often have high financial value, which means that they can exceed the governmental thresholds relatively quickly. Therefore, these projects often depend on external approvals, which can significantly increase the project duration. Respondent **P2.5** then emphasises that such delays are no incidental exceptions, but recurring and expected features of projects with governmental agencies.

> **P1.2:** *"The government has thresholds for the university and above that threshold we cannot do the project by ourself (...) right now it's about 100.000 GHS"*

> **P2.5:** *"Basically, if it's a government institution, you should expect these things"*

Cost prioritisation
This barrier refers to the way KNUST divides available resources across several institutional needs and decides how much of its budget is reserved for PV initiatives. Respondents **P1.1** and **P1.7** indicate that the long term cost of solar energy is significantly lower than the cost of conventional energy sources. Therefore, they consider PV as a financially attractive investment, despite the high upfront costs.

> **P1.1:** *"I did an analysis and I realised we are paying about 2.4 GHS / unit of electricity, while with solar it would be 1.1 or 1.2 GHS / unit of electricity, which means over 50% reduction."*

> **P1.7:** *"The decision to solar panels is because of the energy consumption. It's been huge and fuel prices are also high. It's higher than when we are using the solar panels to get the solar energy."*

This financial attractiveness does, however, not automatically lead to actual large scale investments, as PV projects have to compete with other institutional priorities and sufficient resources are not always available. As a result projects can be delayed, implemented only partly or remain limited to a reduced scale. Respondent **P1.4** illustrates the consequences of this approach and explains how this could cause more challenges later on.

> **P1.4:** *"if you reduce the scope, then this will happen [...] They will request for whatever has been taken out [...] during the implementation, then that thing will come in and then it will blow up the course. Wait, you have to have to go back through the various approval process."*

Unimplemented net metering
One of the most important bottlenecks in the implementation of PV projects is the lack of implemented net metering. Even though the net metering code was already passed in 2011, the implementation still has not started. As a result it is not possible to measure how much electricity is fed back into the grid or to receive compensation for this, which makes it difficult to recover the initial investment. Respondent **P1.1** explained this causes a lot of energy at KNUST to be wasted. When asked about this issue Respondent P2.1 suggested progress, but the timeline remains uncertain.

> **P1.1:** *"If we had net metering systems, we could push energy to the grid and get credit, but even though we know we have the net metering code, the law has been passed, the implementation has not taken effect. We lose a lot of solar [...] maybe during vacation or during holidays when there is peak generation. At 12 noon, and at that time, because the building is not being used, the demand is low a lot of the generated electricity goes to waste, which I have classified as redundant energy."*

> **P2.1:** *"We were having an issue with the tariffs. ECG and the PURC. (...) I believe by the second quarter this year we should be able to start installing them."*

Dependence on key actors
This barrier refers to the strong dependency of KNUST on a limited number of people with both relevant technical knowledge and project experience. Although these actors are present at the university, respondent **P2.3** indicates that their project experience often remains personal and is only limitedly captured or structurally transferred to others.

> **P2.3:** *"Well, unofficial communication is with the project lead. Unfortunately, the head, the current head of [Research Centre] was not on that project. So looks like the findings, the challenges, the lessons are limited to the members, those who are on the projects."*

As these key actors often also have many other responsibilities within the university, they are not always available to support projects for their entire duration. Respondent **P1.2** indicates that heavy workload can cause these key actors to delegate their activities to employees who may be less familiar with certain tasks.

P1.2: *"in actual sense the financial officer was supposed to be there, but due to the workload, he has nominated me to be there [...] So most of the meetings there is probably only 1 person that is on that committee that really understands probably, okay maybe 2, because the chairman and then the consultant or the technical person at that point. And then the rest of the people on it do not really understand what they are doing. [...] Without understanding it you will go to the meetings where others will be speaking, but you don't grasp the concept of it and then you'll be approving if it's a healthy investment or not. You don't understand it. You're just basing it on their technical expertise"*

Complex collaborations
Despite the relatively strong internal organisation, large and complex project structures continue to pose challenges. Respondents indicate that collaborations with many stakeholders can slow down decision making significantly, particularly when multiple stakeholders have different priorities. Respondent **P1.1** explains the process of getting approval from multiple parties as time consuming.

P1.1: *"This because they have their own activities. So they would have to find time for your activity and that could like extend the timelines."*

Poor project team composition
This barrier refers to the lack of timely and structured involvement of internal actors whose expertise is relevant to the planning, design, implementation and operation of the PV initiatives. Respondent **P1.5**, for example, indicated that he was not sufficiently involved in the design phase.

P1.5: *"Actually, I am supposed to be involved, but on a number of occasions I am not involved. [...] Right from the start, I should be involved in determining the capacity of the solar panels, the cabling design and other aspects. I should be involved in every bit of it."*

A similar complaint came from respondent **P1.7** who indicated he was only approached to provide some specific parameters and not involved in the project afterwards, even though the project data was also relevant to his responsibilities.

P1.7: *"It is only during the installation, when they need data or an assessment, that they involve us. But after the installation, they do not involve us anymore."*

Unreliable external environment
This barrier refers to the limited predictability of the implementation environment when project progress depends on external parties and the timely availability of essential project resources. The interview data shows that formal agreements are not able to completely overcome this dependency. Respondent **P2.4** illustrates this by giving an example of an external supplier, while respondent **P1.5** demonstrates how theft can disrupt project progress. Other instances involved long delivery times for imported goods and contractors who suspended their activities.

P2.4: *"Even though there was a contract signed [...] the subcontractors were not able to deliver within the time that we wanted the projects to be delivered. [...] We want to get this systems maybe within 3 months? Oh yeah we can. Before you realise 4 months have passed"*
P1.5*: "they've had to project in their college that suffered from thefts and the projects couldn't make their needed progress because key components were being stolen [...] Batteries, good batteries, invertors, yes people have stolen such."*

Regulatory constraints on grid access
Regulatory constraints on grid access limit the technical and economic possibilities of PV projects significantly. Respondents indicate that ECG's exclusive control over the sale of electricity, the maximum size of solar installations being 500 kW and licensing restrictions on microgrids supplying

electricity to multiple users are factors that significantly limit the scaling potential of KNUST's solar installations.

Fragmented campus energy system
The organisational structure of the university also influences the development of the energy system. The interviews reveal that colleges are responsible for their own energy use, budgets and PV initiatives. Furthermore, there are also solar panels installed that function as part of a research project rather than primarily for energy generation. This results in a fragmented system in which it proves challenging to implement new projects.

Top-down design
Top down design refers to the limited involvement of end users in the decision making processes concerning PV initiatives. The interviewed end users indicated that they were not involved in any decisions regarding the planning and design of the installations. Simultaneously, respondent **P1.3** emphasised the importance of involving the end users before the design phase, so that their needs and preferences could be included.

> **P1.3:** *"I think the users also have to be engaged before the design stage. The users, those who are going to use the power, have to be engaged because eventually they are going to be the beneficiaries. If they are not properly engaged, you might do something for them, but it might not be exactly what they need. So engagement before the project is designed is very key."*

Stakeholder turnover
The interview data suggest that the continuity of RE projects is sensitive to changes within political and regulatory structures. Respondents indicate that projects often depend on the support and priorities of the current government. Respondent **P1.1** explains that changes in governmental stakeholders therefore can be challenging.

> **P1.1:** *"If today you are doing a project with the director of the EC and tomorrow you see there has been a change of government which replaced that person then there is nothing you can do. You have to wait for the new director and pick it up with him. It is as simple as that. Because you cannot continue without him."*

This suggests that stakeholder turnover, for example following national elections, can have a significant influence on the project's continuity and timelines. Respondent **P1.7** indicates this can also occur within the institution where changes in leadership may alter the strategic direction and level of support.

> **P1.7:** *"If the next vice chancellor is not interested in it? You might propose it to the person and if he is not interested in it, it will be very difficult to push it to the council. Most of the projects always go through the vice chancellor to go to the board."*

Environmental protection requirements
This barrier refers to requirements in the field of environmental protection that can delay or disrupt the implementation of PV initiatives. If a proposed installation affects existing ecological conditions the project team first has to consult the responsible environmental protection agency to obtain permission. This may lead to additional assessments or adjustments to the original design. Respondent **P1.7** illustrates this with an example involving cutting down a tree on campus.

> **P1.7:** *"if you want to cut down a tree, you have to involve them before they clear the tree. Because where they wanted to instal there were trees around. […] for universities, it's no easy to cut down a tree. You are not supposed to cutting a tree."*

Bureaucratic procedures within KNUST

It stands out that bureaucratic delay is not only attributed to national governmental procedures, but also to the processes within KNUST itself. This barrier refers to delays that arise when project decisions, documents and administrative activities that have to go through several internal offices and levels of approval. Respondent **P1.6** emphasises that the university is supportive in principle and that the delays are not caused deliberately. The main challenge is the inertia of internal processes and the distribution of decision making authority across multiple offices.

> **P1.6:** *"University is very supportive, okay? Yeah, university administration is very supportive. It's slow. Bureaucratic but is supportive, it's not that people don't want to help you […] the process works very, very slow and that affects us."*

According to respondent **P2.2** the university's bureaucracy is not only visible, but even more prominently present compared to the industry regulators.

> **P2.2:** *"But how to get it run through the various offices faster? Yeah, it serves us a little Challenge. So the bureaucracy doesn't have to be with the regulators of the industry. […] But For institutions like KNUST yeah, that's where bureaucratic […] but for bureaucracy on the governmental regulations, no."*

Political influence

The interviews also indicate that political interference can play a role in the decision making of RE projects in Ghana, particularly in projects that are conducted outside of institutional settings such as KNUST. By allocating funds or giving out permits the government can influence which areas or projects get prioritised. Respondent **P2.6** suggests that RE energy projects are not only determined by technical and financial considerations, but might also depend on political agendas. In contrast, projects within institutions such as KNUST appear to be less influenced by these dynamics.

> **P2.6:** *"It's also political, whatever it is that you are doing must sit well with the government in power because they are going to use it for their campaign"*

Restrictive PPAs

Respondent **P2.6** suggested that the limited governmental attention to solar energy and net meter installation could be related to the power purchase agreements (PPAs) the Ghanaian government signed during the last energy crisis. These PPAs oblige the ECG to purchase a certain amount of conventional energy each year which, according to him, exceeds Ghana's total electricity demand. This reduces the ECG's incentive to promote additional energy sources such as PV. In addition, the electricity cannot be sold to any other party as only the ECG is permitted to sell electricity.

> **P2.6:** *"Because there was a capacity issue they signed all these long PPAs with like heavy fuel generator and diesel generators. And so now they have these like 20 year PPAs and can't get solar on board without breaching those contracts"*

Reactive maintenance

This barrier refers to the absence of a structural, preventive maintenance approach for the PV systems installed at KNUST. Respondents indicate a lack of routine inspections and repairs, and point out that maintenance activities are often initiated after components already have broken down. This is then aggravated by the lack of clear maintenance contracts and coordination between the responsible departments, which can prevent resources from being reserved in time. As a result, small defects may develop into bigger and more expensive replacement tasks.

Conflict of interest

This barrier refers to situations where personal relationships or preferences of individual decision makers can influence the objectivity of institutional decisions. Respondent **P1.2** illustrates this by giving an example of a procurement process where one of the committee members tried to shift the decision from professional and technical criteria to a preference for a particular company based on his relationships with its owners.

> **P1.2:** *"When we were taken the decision, we had feelings that one of us was trying to move towards a particular company. When it happened we tried to be professional and technical, and let the person know that we are not there to sabotage a particular company, but actually for the good of the whole university we want the quality. So there's not much, but 1 or 2 times it happened. […] the interest usually is like this: they have a relationship with the owners of the companies that are bidden for the contracts, and then they want their people to win the contracts"*

4.2.2 Institutional enablers

Institutional enablers are organisational, procedural, regulatory and political circumstances that support the implementation of PV initiatives. Within KNUST these factors mostly relate to available expertise, project experience, internal coordination and institutional support. The identified institutional enablers are presented in Table 5.

Table 5: Overview of the identified institutional enablers

Factor ID	Institutional Enabler	Mentions	Respondents
IE1	Availability of experience	25	7
IE2	Availability of technical expertise	18	5
IE3	Strategic institutional orientation	15	4
IE4	Supportive regulators	11	5
IE5	Availability of internal expertise	11	7
IE6	Centralised project governance	11	6
IE7	Project team structure	8	6
IE8	Internal project financing	5	5
IE9	Clear regulatory framework	4	2
	Total	108	23

Availability of experience

This enabler refers to the use of experiences from previous projects to recognise context specific implementation challenges and respond to them. Respondent **P2.2** emphasises that all projects are different and accumulated experiences might enable the project team to react to expectancies. Simultaneously, respondent **P1.2** indicates a potential downside, as previous project experience may lead to tunnel vision.

> **P2.2:** *"The projects are dynamic […] you cannot have a particular way of fixing all of them because the challenges we face on each site are different. So the only way to handle this is just broaden our knowledge."*

> **P1.2:** *"The user department have built trust with a particular supplier which has been supplying for quite some time, so the user department will want that particular company to supply for them, even though probably, when you're looking at those circumstances, he is not the best."*

Availability of technical expertise

This enabler refers to the availability of technically trained personnel for the installation, configuration and maintenance of the PV systems. Specialised activities are initially performed by the installer, while the university's maintenance team remains involved. Respondent **P1.5** explains that through this involvement, the responsibility can eventually be transferred to the university.

> **P1.5:** *"And because the new solar installation will eventually be maintained, they are brought onboard in the construction so that they get to understand the system [...] except that in most cases, the installer has a period within which to maintain before eventually handing it over to the university."*

Strategic institutional orientation
This enabler refers to the institutional anchoring of sustainability in the strategic direction of KNUST. As sustainability is treated as an institutional priority, PV initiatives can be included in the development plans and budgets, and resources can be allocated to them. Respondent **P1.4** describes how this ambition is shared across different organisational units of the university.

> **P1.4:** *"When you check our plans, you will see that sustainability is one of the key things that runs through every college, every unit and every department of the university [...] so the focus of the university is to make sure that, at least gradually, we move towards achieving a sustainable campus."*

Supportive regulators
This enabler refers to the constructive role of the regulatory bodies in the development of PV initiatives. According to respondent **P2.4**, their support is not limited to formal approval, but also includes guidance during the permitting process.

> **P2.4:** *"In my experience working with them so far, they are very open. When you approach them, they are willing to support you, making sure that you get the necessary permits to do your work."*

In addition, respondent **P2.1** shows that these bodies are willing to revise their institutional frameworks based on experiences from practise. This allows bottlenecks identified in ongoing projects to inform adjustments to existing regulations. This indicates an institutional context that, while rigid, actively attempts to accommodate and enable new RE initiatives.

> **P2.1: "***There is no need for new regulations. I think the existing regulations are sufficient. They just need to be amended to remove any barriers and speed up ongoing projects (...) and the regulations are getting updated constantly to make it a better fit to the projects"*

Availability of internal expertise
This enabler refers to the broad multidisciplinary base of specialist knowledge within KNUST. The development of PV initiatives requires expertise in technical system design, grid integration, structural and spatial assessment, financial feasibility, procurement and project organisation. As much of this knowledge is already present within the university, it can be mobilised across different project phases. As a result the university can undertake a substantial part of the project development internally. Simultaneously, this knowledge base decreases the university's dependence on external consultants, who could bring significant extra costs to the project.

Centralised project governance
By centralising the coordination of PV initiatives under the Energy Consultant, KNUST has one clear point of contact for internal departments and external parties. Although these actors retain their own responsibilities, overall project oversight and coordination between design, implementation contractual control and financial processing come together at one central point. As a result, successive project phases can be better aligned.

Project team structure
The structure of a project team forms an institutional enabler when the composition and leadership are adjusted to the specific requirements of each initiative. Respondents **P1.4** and **P1.2** explain that not every

project within KNUST uses the exact same team, but per initiative the team is specifically composed and its leader is selected based on the expertise needed in each project.

> **P1.4:** "There is a team, we form a team. Each project has its own team that we deliberately came up with during the briefing. If we don't agree, we have to have a debate."

> **P1.2:** "And notice it changes, it changes. You see usually we pick a chairman with knowledge in the particular contract we are buying. So in some instances the Energy Consultant can be the chairman. In some instances, we pick someone different. The electrical engineering consultant, an engineer from the department or a professor to be the chairman. So there's not one, it changes from time to time."

Internal project financing
This enabler refers to the capacity of the university to finance PV initiatives mainly from its own central and college level budgets. As a result, the implementation is less dependent on external subsidies and other sources of financing, whose availability and timing could be uncertain. Additionally the central university level could offer support when a college has insufficient funds during implementation. Internal financing therefore increases continuity and institutional control over project execution, without implying that the resources are unlimited.

Clear regulatory framework
A clear regulatory framework forms an institutional enabler as all project actors know which rules apply, what requirements they need to meet and which governmental authority is responsible. Respondents indicate that regulations concerning PV are clearly set out and that there is little to no confusion about the division of institutional responsibilities. As a result, project initiators have a clear starting point for the preparation and development of PV projects. Respondent **P2.4** emphasised that both the applicable regulations and the responsible authority were clear. This clarity reduces uncertainty about the applicable rules and responsible authorities, which enables project actors to prepare their initiatives more effectively.

> **P2.4:** *"Yeah, so I may, I may not know all the inconsistencies, but I think that That they're, the regulations are clearly set out. If it is solar, you know who you are dealing with. I mean, the energy commission is clearly in charge of that."*

4.2.3 Social barriers
Social barriers are related to the knowledge, perceptions, priorities and experiences of end users and other involved stakeholders. These factors can influence how PV initiatives are understood, valued and experienced. The identified social barriers are presented in Table 6.

Table 6: Overview of the identified social barriers

Factor ID	Social Barrier	Mentions	Respondents
SB1	Perceived limitations of PV	26	12
SB2	Limited user awareness	25	11
SB3	Limited interest in sustainability	19	9
SB4	Construction based nuisance	18	7
SB5	Limited alignment with user priorities	17	7
SB6	Concerns about future PV waste	1	1
	Total	106	23

Perceived limitations of PV
This barrier refers to the limited functional role and capacity that end users attribute to PV systems. During the interviews, PV was repeatedly described as a complementary, secondary or backup source

of energy alongside the grid, instead of an energy source that could replace the energy supply entirely. Respondents **P3.1** and **P3.4** emphasised this perception.

> **P3.1:** *"Energy from the sun can serve as a secondary backup for electricity anytime the power goes out, but not as the main source."*

> **P3.4:** *"It cannot take over. It will just be an add-on. [...] It would not fully replace the normal power supply."*

Other respondents connected this perceived limited role to the scale of the university and the level of the electricity demand. Respondents **P3.6** and **P3.7** did not consider a full transition feasible, as this would require, according to them, unrealistically large number of panels and the current solar systems were not capable of supplying high demand appliances.

> **P3.7:** *"Here, adding, not just fully replacing it. [...] Depending solely on solar panels would be a very large project because we would need a lot of solar panels to produce the required amount of energy."*

> **P3.6:** *"Hospitals use high power. They cannot rely on solar. [...] We do the same here, the solar does not power the ACs and the fans; it only powers the projectors."*

Limited user awareness

Limited awareness is reflected in end user's understanding of the functioning and configuration of the PV systems. The interview data shows that incorrect expectations may arise about the performance of the installations. Respondent **P1.7** explained that complaints may result from a lack of technical understanding.

> **P1.7:** *"When the grid goes off and it does not work for a while, they complain about why the solar panels are there and we do not have power, but they do not know that it is a grid-tied solar panel."*

Additionally, respondent **P2.2** indicated that minor technical issues may lead the end users to question the reliability of the systems. These findings show that limited awareness among end users can lead to complaints, negative perceptions and a decreased level of trust of the technology. This may reduce user trust and weaken support for further implementation and expansion

> **P2.2:** *"The moment you commission a system and there is a little issue, people that are not widely read come to feel like the PV systems do not work at all."*

Limited interest in sustainability

This barrier refers to the limited interest in the sustainability objectives of PV initiatives. During the end user interviews, the concept of sustainability was only mentioned occasionally as a motivation for supporting PV. Several institutional respondents also indicate that, when speaking to end users, the sustainable origin for the electricity was rarely a topic, let alone a priority. Respondent **P2.3** emphasises this once more, reducing the extent to which sustainability itself can generate a base of support for further PV expansion.

> **P2.3:** *"If they do have stable electricity, but the project is about making it more sustainable then they are not really interested in it"*

Construction based nuisance

The installation of PV systems may cause temporary disturbances for students, employees and other users of campus buildings. Respondents mainly referred to closed campus sections and noise disturbance. Although this nuisance is generally accepted, it still has to be taken into account in the implementation planning. To limit the consequences for end users, activities are often planned outside of working hours and during university holidays. Respondent **P1.5** explains that this factor is therefore not a major source of resistance, but can still be seen as a social barrier influencing the timing and organisation of the installation.

> **P1.5**: *"But the main thing would be the noise. Okay, we'll be hitting the roof and so on and so forth, so we try to do such works outside office hours. [...] A lot of it was done during the vacation."*

Limited alignment with user priorities
This barrier refers to situations where the intended benefits or design of a PV initiative insufficiently align with end user priorities. Within KNUST, this mainly manifests when end users acknowledge the potential benefits of PV, but simultaneously have different needs that they consider equally important. As PV initiatives use part of the available budget, respondent **P1.3** explains that their scope can be reduced in size to preserve funding for other activities.

> **P1.3:** *"But they are thinking we also need some other important things equally. So then let's do half of it. Let's do half of the building that will cost about 50000 okay. [...] And we will continue when we get the next allocation."*

Concerns about future PV waste
One respondent expressed concerns about what would happen with the solar panels and batteries when they reach the end of their lifespan. He indicated uncertainty about the storage, processing and recycling possibilities of these components and their potential future environmental and financial consequences of it. Although this concern has not yet caused any delay or resistance, this uncertainty could negatively affect the assessment of future installations by drawing attention to their full lifecycle impacts.

4.2.4 Social enablers

Social enablers are perceptions, relationships and communication processes that support the implementation of PV initiatives. Within KNUST they mostly relate to perceived benefits, effective communication and institutional trust. The identified social enablers are presented in Table 7.

Table 7: Overview of the identified social enablers

Factor ID	Social Enabler	Mentions	Respondents
SE1	Perceived reliability benefits of PV	27	15
SE2	Effective communication	22	8
SE3	Perceived environmental benefits of PV	9	5
SE4	Institutional trust	9	7
SE5	Perceived financial benefits of PV	8	6
SE6	Perceived societal relevance of PV	7	6
	Total	82	23

Perceived reliability benefits of PV

One of the most consistent findings from the end user interviews was that PV was mainly valued due to its attribution to a reliable and continuous electricity supply. Respondent **P3.1** described the PV as a welcome addition that prevented education, study and research related activities to come to a standstill entirely.

> **P3.1:** *"Ensure that there is always power supply, like 24-hour power supply, so that the class can go on even when electricity from the Electricity Company of Ghana is out. […] It has made it continuous. I can learn anytime, anywhere, with no problems related to electricity. […] I do not have to schedule because I know the light will be on."*

Respondent **P3.10** takes it one step further and indicates how the increased reliability is absolutely necessary for some people at the campus. This aligns with other respondents who spoke about the campus hospital and its need for continuous electricity.

> **P3.10:** *"When there are light-outs on campus, the solar panels are another source of energy. […] There are students doing research who need electricity to preserve their materials, such as chemistry students who have chemicals in storage."*

Effective communication

Effective communication is an important component of KNUST's project coordination. It refers to the timely, direct and solution based exchange of information between stakeholders involved in the decision making and implementation of the PV initiatives. Within KNUST this is realised by bringing together representatives from all relevant departments during the discussion of important proposals. Respondent **P1.2** illustrates this by giving an example of a recent procurement process.

> **P1.2**: *"So we go and sit down together, and then the companies will come so there will be a direct communication with the Procurement Officer, the Energy Consultant, and also the user department. […] that is where we will do all those analysis we're talking about, and then select one of them."*

Respondent **P1.3** explains the relevance of this method by emphasising how it enables the team to bring together different perspectives, identify problems quickly, and address them before they get out of hand. Effective communication is therefore not only relevant for knowledge sharing, but primary for the timely resolution of project problem.

> **P1.3**: *"You solve that problem, we solve the challenge. You know, when I am talking to you when you are talking to the finance person, you know and all that so that you know, you get a problem solved before they get out of hand."*

Perceived environmental benefits of PV
Although sustainability did not form a prominent theme in most of the interviews, respondent **P3.9** did indicate to value clean energy, emission reduction and broad sustainability objectives. This respondent not only saw PV as a practical solution to electricity challenges, but also as an environmentally friendly alternative to conventional forms of electricity generation.

> **P3.9**: *"The first thing that comes to my mind is there a good source of energy for like to replace all those negative forms, which we are being using for decades. So it's much more if we had cleaner way to use electricity. That's how I see solar panels."*

Although this environmentally oriented perspective was only mentioned by a relatively small number of respondents, the individuals who strongly value these aspects may play an important role in stimulating PV initiatives within the university. The role of the late professor Brew-Hammond forms a concrete example of this. According to respondent **P1.7**, approximately 15 years ago he developed a university wide ambition to gradually transition towards PV, which formed the base of the current PV objectives.

> **P1.7**: *"Because professor Brew Hammond wanted solar. The whole of the university to go on solar, that's what he proposed. And it was about to start."*

Institutional trust
Although the end users in general indicated that they had a relatively low degree of influence on the decision making process, they did not describe this as being problematic. Instead, they assumed that university made these decisions in favour of the entire campus community. The respondents expected that students, TAs, teachers, campus staff and others would benefit from the PV initiatives collectively. This indicates a level of institutional trust being present which appears to make the top down design process more acceptable to end users.

Perceived financial benefits of PV
The interview data shows that several end users are aware of the potential financial benefits of PV. They expect the use of solar energy to reduce the electricity costs and therefore deliver financial benefits to individual users, KNUST as an institute and the broad campus community. Although respondents' answers differed when asked who would benefit the most from the lower energy costs, the perceived financial attractiveness added to their positive assessment of the PV initiatives.

Perceived societal relevance of PV
Several end users consider PV not only relevant for KNUST, but also for Ghana as a whole. They connect the broad relevance to the high levels of sunshine, recurring power outages and the importance of using multiple energy sources. By seeing solar energy as an appropriate solution for national energy demands, the technology gets social legitimacy. This perception can contribute to a positive attitude against existing PV initiatives and support to further expansion. Respondent **P3.4**, for example, explicitly described solar panels as necessary for Ghana.

> **P3.4**: *"Ohh yes for a country like Ghana solar panels are really necessary and easier because of the weather and the part of the world where are it will be easier to put in place solar panels. It will help us as well as there are a lot of power breaks. It's a good thing I think."*

4.2.5 The circles of influence

In this section the previously identified social and institutional factors are ordered based on the degree of influence the project team can exercise over them. A distinction is made between factors that can be directly managed, factors that can be indirectly influenced and factors that should be seen as external preconditions. The ordering does not introduce any new factors, but forms an additional analytical layer that guides the discussion of potential mitigation strategies.

The circle of Control

The circle of control contains factors that fall within the direct responsibility and decision making authority of the internal project team. These factors can therefore be directly addressed through the organisation, coordination and execution of PV initiatives. Table 8 presents an overview of the factors assigned to this circle and the reasoning behind their placement.

Table 8: The circle of control

Code	Factor	Reason for circle choice
IE1	Availability of experience	The project team is self-organising and is therefore able to select people with relevant project experience.
SE2	Effective communication	The project team can organise discussions, communication lines and data transfers.
IB6	Poor project team composition	The project team is self-organising and is therefore able to adjust roles to match internal competencies.
IB10	Top-down design	The project team can decide how the design is organised and whose input is integrated.
IE6	Centralised project governance	The internal coordination structure is within the full responsibility of the project team.
IE7	Project team structure	The project team is self-organising and is therefore able to adjust roles to match competences internally.
IB16	Reactive maintenance	The project team can include maintenance planning and routine check-ups in PV initiatives.
IB17	Conflict of interest	Internal conflicts of interest can be addressed through transparent decision-making, clear roles and internal control.

The circle of Influence

The circle of influence contains factors that cannot be directly managed by the internal project team, but can be influenced indirectly. This can be achieved through communication, collaboration and the involvement of other stakeholders. Table 9 presents an overview of the factors assigned to this circle and the reasoning behind their placement.

Table 9: The circle of influence

Code	Factor	Reason for circle choice
IB2	Cost prioritisation	The project team can put forward arguments for prioritising a specific amount, but cannot make the final decision.
IB4	Dependence on key actors	The project team can transfer knowledge among its members, but cannot guarantee the continued availability of key actors.
SE1	Perceived reliability benefits of PV	The project team can present examples of system performance and reliability, but cannot determine how others value them.
SB1	Perceived limitations of PV	The project team can provide information and performance data, but cannot determine how end users assess the role and capacity of PV.
SB2	Limited user awareness	The project team can provide information and explanations, but cannot determine how others understand the systems.

IB5	Complex collaborations	The project team can improve roles, agreements and communication, but large-scale projects still require collaboration with stakeholders outside the university.
SB4	Construction based nuisance	The project team can try to plan around the busiest times, but the campus is always in use.
IE2	Availability of technical expertise	The internal project team cannot influence how many experts are available in the region.
IE3	Strategic institutional orientation	The internal project team can express its preferences, but the strategic orientation is decided higher up.
SB5	Limited alignment with user priorities	The internal project team can take account of different interests, but cannot change end-user priorities.
IE5	Availability of internal expertise	The internal project team can identify and involve internal experts, but cannot guarantee their availability
SE3	Perceived environmental benefits of PV	The internal project team can substantiate the environmental benefits, but cannot determine how end users value them.
SE4	Institutional trust	The project team can promote trust through transparency and consistency, but cannot determine whether trust is established.
IB9	Fragmented campus energy system	The internal project team can contribute to shaping the energy system, but cannot change it independently.
IB13	Bureaucratic procedures within KNUST	The internal project team can start early with the internal procedures to minimise impact, but cannot change these procedures.
SE5	Perceived financial benefits of PV	The internal project team can substantiate the financial benefits, but cannot determine how end users value them.
SE6	Perceived societal relevance of PV	The internal project team can substantiate the societal relevance of PV, but cannot determine how end users value it.
IE8	Internal project financing	The internal project team can develop financing proposals, but is not responsible for the final budget allocation.
SB6	Concerns about future PV waste	The project team can include provisions for recycling, but cannot eliminate stakeholders' concerns

The circle of Concern

The circle of concern contains external factors that influence the implementation of PV initiatives, but cannot be meaningfully influenced by the internal project team. These factors should be regarded as external preconditions to be considered during the design and execution of PV initiatives. Table 10 presents an overview of the factors assigned to this circle and the reasoning behind their placement.

Table 10: The circle of concern

Code	Factor	Reason for circle choice
IB1	Bureaucratic procedures	National permits and external administrative procedures are determined by government agencies and regulators.
IB3	Unimplemented net metering	The internal project team cannot realise the national introduction and implementation of net metering.
IB7	Unreliable external environment	Logistical and market uncertainty remains outside the internal project team's control.
IB8	Regulatory constraints on grid access	Rules and regulations concerning grid connection are outside of the project team's influence.
SB3	Limited interest in sustainability	The internal project team cannot influence people's underlying interests and personal value orientations.
IE4	Supportive regulators	The project team can maintain contact with regulators, but cannot determine whether they act supportively.
IB11	Stakeholder turnover	The project team cannot prevent key stakeholders from being replaced following national elections.

IB12	Environmental protection requirements	Environmental protection regulations are determined at the national level.
IB14	Political influence	National political influence and changing political interests are outside the project team's influence.
IB15	Restrictive PPAs	The conditions of the PPAs are set by public energy parties, regulators and contracting organisations.
IE9	Clear regulatory framework	The regulatory frameworks are developed at national level.

4.3 MITIGATION STRATEGIES

This section presents five mitigation strategies that are based on the experiences and recommendations of the respondents. The strategies are meant to prevent, limit or control the constraining effects of the identified factors. The strategies are not coupled one by one to the individual factors.

4.3.1 Phased implementation of a holistic approach

Respondent P1.2 indicates that a holistic approach should be adopted, in which, instead of individual projects, the entire campus is incorporated into a campus wide implementation plan. Central planning would enable the alignment of projects and collective procurement, instead of allowing each college to develop its own projects. This could reduce the fragmentation of the campus energy system. Additionally, project bundling may generate economies of scale, as design, procurement and implementation costs are spread across a larger programme, potentially reducing the cost per unit.

> **P1.2:** *"Everybody's doing their own projects at any point in time but we have wanted a situation where the university as a whole can plan. [...] So the expert or the technicians should look at that holistic approach, advise the university and then we apply for a contract for the whole university."*

To prevent institutional cost prioritisation from undermining this approach, phased implementation is mentioned by respondent P1.4 to facilitate large scale designs while working with limited financial resources. Instead of keeping projects small or removing essential components this approach would enable the university to retain the full long term design, while spreading the costs across over several budget years.

> **P1.4:** *"We have to still meet management and then make our things clear, that yes, if you don't want to do the full project now, don't skip things, but let's do it in phases. You see? Phasing out is as always the best, so that the project has the design that it needs. Then you phase it out, maybe we can do this floor for now. When we got money again, we will continue again all the way up to the end of the day. After completion, we will have achieved whatever we wanted."*

4.3.2 Efficient and digital procurement

Delays within the procurement process can be partly overcome by informing participating companies at an earlier stage about the required procedures and documentation. When companies know beforehand what certificates, statements and technical information are required and have ample time to prepare, they are more likely to timely submit complete and valid tenders. Consequently, this may prevent the need to request additional documents, repeat procedures or restart the entire procedure. Respondent P1.2 summarises this approach and calls it educating the companies.

> **P1.2:** *"Yeah, so one of the things is that education is very important with the companies. We have to educate a company on the procurement processes. That they have to go through, so that it becomes smoother, so you know, that's okay when any public institution is doing a tendering, I need this, that and that. So I get it before is ready so when there's anything I know I have my data complete."*

Additionally, respondent **P1.2** proposes digitalising the procurement process. A central platform could reduce the workload for both the university and companies and significantly speed up the process. Apart from saving time, digital submission could strengthen the traceability and verifiability of the process, as it would be clearer which documents were submitted, by whom and at what time. Digitalisation could therefore contribute to reducing delays due to bureaucratic procedures within KNUST.

> ***P1.2:*** *"And also, the submission process time we move away from manual submitting and do it digital. So even as a platform, why are somebody wants to tender? They just go in there and keep all those details and then they are done. They're going back-and-forth. Have to get documents. Sometimes you have to scan all those things bring in delay."*

4.3.3 Building Preventive Maintenance Capacity

The Maintenance Department should be involved more intensively throughout the entire project cycle. This would enable its staff to gain more insight into the configuration, operation and maintenance requirements of the new systems. As the number of solar installations increases, KNUST should also consider training or hiring personnel who are certified to work on the PV installations. This way the university will be ready for the eventual full takeover of maintenance activities by the internal maintenance team where respondent P1.5 refers towards.

> **P1.5:** *"And because the new solar installation will eventually be maintained. And so they should be brought onboard in the construction so that they get to understand the system here. So that they can help with the maintenance accept that in most cases, they installer has a period within which to maintain before eventually handing it over to the university to yeah."*

During procurement it should be clearly agreed to what extent maintenance and warranty services are incorporated into the contract. Warranty periods, the division of responsibilities, response times and conditions for retaining the warranty should be recorded. Respondent **P2.2** identifies the lack of such maintenance agreements as the most prominent indicator of later challenges. Establishing these arrangements can prevent uncertainty about who is responsible for defects, inspections and routine checkups after installation, as most challenges, according to him, originate from this not being done.

> **P2.2:** *"The only sign is that when we commission such a system and then the client or the people in charge fail to sign maintenance contracts with us or, you know, refuse to kind of involve us in any maintenance activities. Then they have caused challenges. Because solar components command understanding. They need to be maintained."*

When the responsibilities are clearly divided and sufficient internal or external expertise is available, KNUST should implement routine checkups and preventive maintenance. Dedicated maintenance schedules and budgets should be drawn up. The objective is to identify wear and tear early and prevent system failure instead of only organising resources and expertise after a system breaks down.

4.3.4 Proactive planning and risk assessment

Several challenges that arise during the implementation of PV initiatives at KNUST, can already be anticipated during the feasibility and design phase of the project. Among others, this applies for delays due to internal and external approval processes, long delivery and import times, limited availability of key actors, environmental requirements and potential disturbances to education and office activities. These risks should therefore systematically be identified before implementation and ordered based on their probability and potential consequences. Subsequently, fitting measures, responsibilities and time buffers should be included in the project plan. Respondent **P1.4** estimates that such an approach could take away a significant part of the future challenges.

> **P1.4**: *"If you want to reduce the challenges, then initially during the initial feasibility, you have to identify all the stakeholders with their challenges as predicted, and how we can mitigate those challenges that will have risks involved, you have to rank them. You have to*

rank them according to the degree of occurrences and then mitigate to do that. [...] So when we do that, then it means at least you have been able to do about 80 to 85% already."

The risk analysis should not only be executed for the internal project team. Suppliers and contractors possess practical knowledge of potential challenges in the availability of materials, transportation, installation and implementation. Respondent **P1.2** explains that by involving them from the start, KNUST can better estimate which external dependencies could cause delays and which measures could prevent this.

> **P1.2:** *"One approach that we use to bring down the challenges is we do an effective communication, then planning even before the project starts. [...] We communicate with the supplier, the contractor: okay, so what are some of the risk that we may face at this project? [...] The supplier gives us the kind of risk that we may face, and then we plan towards the risk."*

During the execution, the identified risks and associated measures need to be monitored regularly. By doing this, the project team will be able to recognise new delays or deviations early and, where necessary, adjust responsibilities, timelines or control measures. Proactive planning should therefore be seen as an ongoing process and not as a single activity before implementation

4.3.5 Clarifying PV Capabilities and User Needs

Before implementation the project team has to clearly inform the proposed end users about the specific functioning of the new PV system. For each building there must be an explanation to inform what is connected, if there are batteries present and what will happen when the national grid experiences a power outage. By doing this unrealistic expectations regarding the capacity and reliability of the system can be limited. According to respondent **P2.1** these explanations can be strengthened by using well-functioning PV installations as demonstration projects. The users will then be able to see the systems in practice, ask questions and learn more about the benefits.

> **P2.1**: *"And if become possible, sometimes we send the people to where it has been done before for them to go and have a look at what is there. And then it makes it easier for their understanding. [...] Where you have done it before, you can tell them, oh, we have done one at this place. You can go there and have a look at it and ask questions and how benefited it is."*

In addition, all technical information should be provided by trusted technical experts who can explain the benefits and limitations correctly, while department heads, facility staff, teachers or student representatives can spread the information further within their own departments and report questions back to the project team. Respondent **P1.3** emphasises that user engagement has to be initiated before the design phase so that their needs can still be incorporated into the design.

> **P1.3:** *"I think the users also have to be engaged before the design stage. The users, those who are going to use the power, have to be engaged because eventually they are going to be the beneficiaries. If they are not properly engaged, you might do something for them, but it might not be exactly what they need. So engagement before the project is designed is very key."*

5 DISCUSSION

5.1 SYNTHESIS OF FINDINGS AND LITERATURE

This research confirms the substantial role of social and institutional factors in the development and implementation of Ghanaian PV initiatives. Where other literature acknowledges their existence, the main focus is mostly on the impact and mitigation of technical and financial aspects. The data from this research however shows that these social and institutional factors are not only present, but heavily intertwined in concrete decision making procedures, project structures and final implementation results. These are not incidental disruptions, but structural patterns between different stakeholders and during every phase of the project cycle. This implies that research approaches that treat social and institutional factors as contextual details can create a distorted image which can complicate PV implementation within the Ghanaian context.

Simultaneously, the empirical analysis provided fewer distinct social factors than institutional factors. This should not be interpreted as evidence that social factors are inherently less important than institutional factors. A plausible explanation lies in the relatively homogeneous, and socially and institutionally bounded context of KNUST. Many of the involved actors operate in the same university environment, are confronted with similar problems concerning electricity reliability and are subject to the same decision making structures. As a result, diverse social and institutional interests and conflicts, such as land ownership, forced spatial adjustments or the division of costs and benefits between multiple communities are less prominently present than in other PV initiatives involving multiple communities, landowners and other socially distinct groups are involved. Demographic and identity related differences and similarities were not systematically examined and are therefore not used as an explanation.

One of the most notable findings is the level of influence of KNUST specific characteristics on the manifestation of both social and institutional factors. KNUST distinguishes itself in multiple dimensions which together create a favourable and facilitating implementation context.

Firstly the university has a substantial internal base of knowledge. The presence of technical consultants and academic experts largely eliminates the dependency on external consultants, which can increase cost and uncertainty in different Ghanaian contexts. This internal expertise lowers the costs of project development and raises quality of technical decision making within the project team. Secondly, the strategic positioning of sustainability within the university plays a facilitating role. Sustainability is explicitly anchored in the long term strategic plans of the university and runs through every college and department. This creates an institutional climate in which PV initiatives do not have to keep proving their legitimacy, but can build on existing organisational priorities. Thirdly, the internal financing makes the university less dependent on external flows of capital, which in the literature often get recognised as one of the main institutional bottlenecks. Although financial priorities remain relevant in KNUST's decision making, the acute vulnerability of external finance conditions remains limited. Fourthly, the accumulated project experience and strong team governance within KNUST significantly contribute to effective project execution. The presence of experienced key figures who are able to anticipate challenges, combined with the clear project structure considerably reduces execution risks.

A particularly interesting aspect is the acceptance of top down project structures by end users. As the literature consistently identifies top down implementation as a source of resistance and limited user engagement, it turns out this is barely perceived as problematic within KNUST. The data suggest this is not because of a limited critical consciousness among end users, but because of the trust those end users have in the institutional decision makers. The end users consider the university board to be a reliable actor which acts in the interest of the entire campus community. The trust appears to reduce the need for direct participation to create support. This suggests that the effects of top down structures are not universally negative, but strongly dependent on context and the level of institutional trust.

The data gives a nuanced image of the government as an institutional actor, which extends from how it is normally portrayed in the literature. Existing studies describe the Ghanaian government mainly in terms of weak operationalisation of existing policy frameworks, insufficient support for specific technologies and inconsistencies and instabilities in policy which cause unclear or even contradictory conditions for project development. The experiences of stakeholders within KNUST however give a more nuanced image. Governmental institutions are experienced as cooperative and constructive, regulations are actively adjusted based on practical problems and the involved agencies show willingness to think along with project developers. This combination can be explained when an analytical distinction is made between institutional intention and implementation capacity. The data suggests that the Ghanaian government at policy level shows a formal and supportive commitment to the energy transition, but that the conversion to concrete implementation structurally falls short. This distinction is not always made explicit in the existing literature which often treats policy and implementation as one, while this research suggests that they should be approached as two analytically separate dimensions. A government can be progressive policy wise and fragmented implementation wise at the same time, and this appears to characterise the context examined in this research.

The findings surrounding net metering and feeding electricity back to the grid form a telling example of this, as they most clearly illustrate the gap between policy intention and implementation capacity. The net metering code has existed since 2011, but has not been implemented yet. For individual households the peak supply and demand occur at different times of the day. The impossibility of feeding excess electricity back into the national grid in exchange for compensation therefore makes it almost impossible to earn back the initial investment. For large institutions such as KNUST this is less acute as long as the PV capacity remains relatively small compared to the total energy demand and generated energy can be directly used. The data, however, suggests that the situation becomes more vulnerable in the case of upscaling of PV systems or low occupancy, which would cause peak generation to exceed demand.

5.2 THEORETICAL IMPLICATION

This research contributes in multiple ways to the existing body of knowledge on social and institutional factors surrounding the implementation of PV initiatives.

Firstly, the findings confirm that social and institutional factors play a significant and autonomous role during the implementation of Ghanaian PV initiatives. This adds empirical weight to the statement that the predominant focus on technical and economic factors in the existing literature presents an incomplete picture of what hinders the implementation of PV projects in the Ghanaian context. Where studies such as Mahama et al. (2021) acknowledge the existence of social and institutional factors, they stop short of systematically analysing how these factors manifest in practice. This research addresses this knowledge gap by providing context specific empirical evidence at the project level.

Secondly, the research shows that social and institutional factors in the implementation of PV initiatives can get categorised not only according to their perceived effect, but also on the degree of influence project teams can exercise over them. Existing frameworks such as Painuly (2001) and Wüstenhagen et al. (2007) remain valuable for identifying and ordering barriers, but offer limited insight into how project teams should prioritise their responses. By implementing the circle of control, the circle of influence and the circle of concern, this research adds an action oriented dimension to the analysis of social and institutional factors in PV implementation. This contribution is therefore not in the development of a new framework, but in applying an existing analytical distinction to the context of PV implementation.

The value of this distinction lies in the coupling between factor identification and realistic scope of project based mitigation. Factors within the circle of concern usually cannot get mitigated by project teams and should therefore be anticipated for during the design and execution phase. Factors within the circle of influence require indirect mitigation through communication, coordination, collaboration and negotiation with other stakeholders. Factors within the circle of control form the most direct opportunity for mitigation as they can be controlled through project organisation, coordination and planning.

Additionally, this distinction shows that social and institutional factors differ in their degree of context dependency. Factors within the circle of concern, such as national regulations, political continuity and grid integration, may have broader relevance across Ghanaian PV implementation contexts. Factors within the circle of control and circle of influence, however, are heavily context dependent, as they are shaped by the executing organisation, team composition and local user context.

5.3 PRACTICAL IMPLICATIONS

The results show that substantial practical knowledge is already present within KNUST and the broader project network. Involved stakeholders are able to reflect in detail on earlier projects, the challenges that emerged during these projects and the choices that helped projects move forward. The interviews therefore demonstrate not only which social and institutional factors can have a constraining or facilitating effect, but also that many stakeholders have clear ideas about potential mitigation strategies that could be used to address these factors.

The conceptual model presents PV implementation at KNUST as an iterative process in which PV implementation outcomes feed back into mitigation strategies through the learning loop, thereby enabling new ideas and adjusted project approaches to be used in successive projects. The data, however, shows that this learning loop does not function automatically. KNUST has project experience, but this experience is still insufficiently converted into collective project knowledge. Many practical insights on stakeholder coordination, team selection, planning and risks remain centred around individuals or specific projects, instead of becoming part of a collective project approach. This explains why similar implementation challenges can reappear in successive projects even when possible mitigation strategies are already known. The main practical challenge, therefore, is not primarily to formulate new mitigation strategies, but to organise a process that systematically records existing experiences and enables their sharing and application in future PV initiatives.

This challenge does not stand on its own, but aligns with what is described in project management literature as the lessons learned process which is intended to capture the results and experiences from successes, failures, and near-misses, and absorb them into the organisational structure for future use (McClory et al., 2017). In practice, lessons often do get identified, but their capture, categorisation and application in successive projects remain limited (McClory et al., 2017). To address this, Eken et al. (2020) show that a more integrated process is required that actively collects lessons during the project instead of only through a concluding session after project completion. Lessons need to be captured in real time, continuously assessed, clearly structured and connected to project features to enable retrieval.

For KNUST, it is therefore important to treat the learning loop as an organised and structured process, instead of an automatic by product of project experience. This can be done by focussing on four concrete points of action: Assign responsibility for project learning, Capture lessons at fixed project moments, Maintain an accessible and up to date lessons learned repository, Activate lessons at the start of new PV projects.

Assign responsibility for project learning

The first point of action is to assign responsibility for the lessons learned process. Without a responsible actor, the learning remains dependent on the commitment of individual stakeholders and can easily disappear after project completion. A clear division of roles and responsibilities is therefore necessary to keep the lessons usable, especially because lessons need to be assessed, refined and made accessible to become valuable for other projects. At KNUST, this responsibility would most likely lie with the Directorate of Works and Physical Development as they are responsible for the project reporting which currently consists of information on project progress, technical performance, costs and the quantities of materials used. A mandatory lessons learned section could be added which specifically addresses project organisation and the implementation experiences gained.

Capture lessons at fixed project moments

The second point of action is to record lessons at fixed times during the project process. When lessons are only recorded afterwards or informally, they will depend on memory, availability and personal interpretation. To prevent this from happening, a short evaluation moment should take place after key project phases. This evaluation should not be too time consuming and should focus on practical questions: what went well, what was challenging, where did these challenges originate, what could be done differently or should be kept in mind during future projects? This information should then be translated into a complete and standardised lesson. A useful moment for this would be when the interim progress reports are prepared after each phase to determine what part of the project has been implemented and to approve the associated payments. As this is an already existing and formally anchored moment, it forms a suitable opportunity to also include the organisational lessons from each project phase.

Maintain an accessible and up to date lessons-learned repository

The third point of action is to keep recorded lessons accessible and usable. A lessons learned process does not only fail when lessons are missing, but also when they become fragmented across separate phase and final reports, emails or individual stakeholders. For KNUST, this does not require a complex IT system, but a shared folder managed by the directorate of Works and Physical Development, which project member can consult, should be sufficient. Duplicate lessons should be merged, incomplete lessons should be supplemented and outdated information should be removed. Additionally, the storage structure should be structured around recurring implementation themes, such as stakeholder coordination, procurement, planning, team selection and risk management, so that project members can easily find relevant lessons.

Activate lessons at the start of new PV projects

The fourth point of action is to activate relevant lessons at the start of each new PV project. The Directorate of Works and Physical Development has to guide the team through the lessons before the project approach is finalised, as this is the moment when project experience can still influence planning, role division, stakeholder coordination and risk management. If the lessons are only consulted at a later stage, the repository mainly functions as an archive rather than input for successive projects which limits its influence. For KNUST, this means that every PV initiative should start with a short review of relevant lessons from earlier projects during the initial project briefing, focussed on how previous experiences could be used to mitigate potential challenges during the next project.

5.4 LIMITATIONS

This research has a few methodological and contextual limitations that should be considered when interpreting the results. The choice for a single case study offers depth, but limits the generalisability. Additionally, KNUST forms an institutionally favourable context with relatively substantial internal expertise, strategic direction and financial autonomy. Factors that play important roles in different contexts could have been less visible here.

Moreover, the analysis is based on perceptions of stakeholders. Technical performance, energy output or actual project delays have not been measured and full project documentation has not been collected. Some of the conclusions therefore remain inherently interpretive in nature.

As a Western outsider the position of the researcher may have influenced the interpretation of the interview data. Cultural differences and possible socially desirable answers are relevant factors in this regard. The use of the English language as the sole interview language might also have led to nuance loss.

Furthermore, the research was conducted by a single coder, which prevented intercoder reliability from being established. The fieldwork that was conducted over a period of 6 weeks offers a valuable, but necessarily limited snapshot of a dynamic context in which policy and institutional relationships are continuously evolving.

5.5 Recommendations

This research offers an initial empirical exploration of the social and institutional factors involved in Ghanaian PV implementation initiatives, but also raises questions which justify further research.

Firstly it is recommended to conduct a comparative case study which includes multiple contexts, institutional as well as non-institutional. This to explore which results were influenced by KNUST's favourable conditions and which have a broader validity.

Secondly, further research into the structural causes behind the delay of the implementation of net metering is recommended. This research shows its impact, but was unable to fully explain the underlying institutional and political dynamics. Focused research into the decision making processes, including the possible role of the PPAs could provide valuable insights.

Thirdly, longitudinal research is recommended to analyse how social and institutional factors develop over time, especially during political transition moments such as the national elections and when a new university board gets installed.

For all these research directions it is recommended to involve local co researchers to decrease possible positionality bias and language barriers and improve upon the quality of interpreting.

6 CONCLUSION

Ghana possesses substantial potential for RE, but lags behind in actual implementation. The existing literature mainly explains this delay through technical and financial limitations, while social and institutional factors receive less systematic attention. This is striking, as previous research shows that such factors can significantly influence implementation processes and that their effects differ across contexts. This research therefore focuses on how social and institutional factors influence the implementation of Ghanaian PV initiatives and on how the constraining effects of these factors can be mitigated. To do so, the research aims to answer the following research question:

How can the social and institutional barriers to the implementation of PV initiatives in Ghana be overcome?

This question was answered based on the following three sub questions. The first sub question was:

"Who are the key stakeholders in Ghana's energy systems?"

The stakeholder analysis shows that the implementation of PV initiatives is influenced by a network of internal and external actors. Within KNUST, the most central actors are the University Council, the Directorate of Works and Physical Development and the Energy Consultant, as they respectively determine the strategic orientation, oversee the physical integration and coordinate the project. The Procurement Office, Finance Office, internal experts, Maintenance Department and solar companies support contractor selection, financial assessment, technical implementation and maintenance activities. At the national level the Ministry of Energy, the Energy Commission, the Environmental Protection Agency and the ECG determine the policy, regulatory, environmental and infrastructural conditions. End users, NGOs and external researchers have less formal power, but do contribute to acceptance, knowledge development and stakeholder involvement.

The second sub question was:

"Which social and institutional barriers and enablers emerge in the implementation of PV initiatives in Ghana?"

The results show that the implementation of PV initiatives is influenced by a combination of social and institutional barriers and enablers. The most important institutional barriers are bureaucratic procedures, cost prioritisation, unimplemented net metering, dependence on key actors, complex collaborations and regulatory constraints on grid access. These barriers are partly counterbalanced by institutional enablers such as the availability of experience, internal and technical expertise, centralised project governance, internal project financing and supportive regulators. The most dominant social barriers are limited end user awareness, perceived limitations of PV, limited interest in sustainability and limited alignment with user priorities. Simultaneously, perceived reliability benefits of PV, effective communication within project teams and institutional trust promote PV acceptance.

The third sub question was:

"How can the influence of the social and institutional barriers be mitigated when setting up future PV projects in Ghana?"

The findings show that the mitigation approach should align with the degree of influence the internal project team has over each factor. Factors within the circle of control can be addressed directly, factors within the circle of influence can only be influenced indirectly through communication, collaboration and coordination with other stakeholders, and factors within the circle of concern can only be anticipated by including them as external preconditions in the project planning. Concrete mitigation strategies identified in the research are: phased implementation of a holistic approach, efficient and digital procurement, building preventive maintenance capacity, proactive planning and risk assessment and clarifying PV capabilities and user needs.

To overcome the social and institutional barriers influencing the implementation of PV initiatives in Ghana, it is important to categorise the social and institutional factors according to the three circles of influence and use this distinction to determine an appropriate mitigation approach. The initial focus should be on the circle of control, as this circle offers the most immediate opportunities for improvement. In this circle targeted organisational improvements can directly strengthen how decisions, coordination and responsibilities are organised. Subsequently, the circle of influence should be addressed, as indirect mitigation measures can facilitate the implementation process. Finally, the circle of concern should be considered as the set of external preconditions that shape, but cannot be directly changed by, individual project teams. Within this circle, opportunities for direct mitigation by project teams are limited and these factors should therefore be treated as external preconditions under which the projects have to be developed.

Additionally, it remains important to facilitate organisational learning, as many insights and individual experiences from previous PV initiatives risk remaining project-specific if they are not systematically captured, shared and applied. If this is done effectively, these experiences can form a strong basis for the planning and implementation of future PV initiatives.

The findings should be interpreted in the light of several limitations. As this research is based on a single case study in a relatively favourable institutional context, the results cannot be directly generalised to all other Ghanaian PV initiatives. Additionally, the analysis is mainly based on stakeholder perceptions, while actual technical performance, energy yield and actual project delays have not been measured. The short fieldwork period, the use of a single researcher for coding and the position of the researcher as a Western outsider could also have influenced the interpretation of the data.

Follow up research should therefore compare PV implementation across multiple institutional and non-institutional contexts, to establish which findings are specific to KNUST and which findings have broader validity. In addition, further research is required into the structural and political causes of the delayed implementation of net metering. Longitudinal research could provide insight into the way social and institutional factors develop during periods of political transition and changes in university leadership. Involving local co-researchers could be of value to reduce positionality and language related limitations and strengthen the contextual interpretation of future findings.

From a Management of Technology perspective, this research shows that the implementation of PV requires more than the selection of a technically feasible system. Organisations must translate the technology into successful initiatives by making decisions on project governance, stakeholder coordination, expertise and procurement, while also taking the regulatory and institutional constraints into account. This research therefore contributes to Management of Technology by illustrating that the gap between technical potential and its actual implementation is partly shaped by how these decisions are made and how the social and institutional factors are managed.

References

Afful-Dadzie, A., Mallett, A., & Afful-Dadzie, E. (2020). The challenge of energy transition in the Global South: The case of electricity generation planning in Ghana. *Renewable and Sustainable Energy Reviews, 126*, 109830. https://doi.org/10.1016/j.rser.2020.109830

Agyekum, E. B., Ali, E. B., & Kumar, N. M. (2021). Clean energies for Ghana—An empirical study on the level of social acceptance of renewable energy development and utilization. *Sustainability, 13*(6), 3114. https://doi.org/10.3390/su13063114

Agyekum, K., Salgın, B., & Kwablah, N. M. (2017). Collaboration in the Ghanaian construction industry: Perceived barriers and benefits. *Eurasian Journal of Civil Engineering and Architecture, 1*(1), 1–12.

Ahiabu, M. K., Adzivor, E. K., Attipoe, J. A., Agyapong, J.-A. M., & Abiemo, M. K. (2024). Beyond bricks and mortar: Work-life balance and project performance of Ghana's construction professionals—Does co-worker relationship quality matter? *Social Sciences & Humanities Open, 10*, Article 100940. https://doi.org/10.1016/j.ssaho.2024.100940

Amoako-Gyampah, K., Acquaah, M., Adaku, E., & Famiyeh, S. (2021). *Social capital and project management success in a developing country environment: Mediating role of knowledge management*. Africa Journal of Management, **7**(3), 339–374. https://doi.org/10.1080/23322373.2021.1927450

Apfel, D., Haag, S., Herbes, C., & Voron, O. (2021). *Research agendas on renewable energies in the Global South: A systematic literature review*. Renewable and Sustainable Energy Reviews, 148, 111228. https://doi.org/10.1016/j.rser.2021.111228

Arthur, J. L., Kodiah, A. N., & Arthur, S. D. (2025). *Energy storage and renewable integration in Ghana: Socio-technical drivers, barriers, and policy implications for sustainability* [Preprint]. Research Square. https://doi.org/10.21203/rs.3.rs-6422986/v1

Asante, D., Ampah, J. D., Afrane, S., Adjei-Darko, P., Asante, B., Fosu, E., Dankwah, D. A., & Amoh, P. O. (2022). Prioritizing strategies to eliminate barriers to renewable energy adoption and development in Ghana: A CRITIC-fuzzy TOPSIS approach. *Renewable Energy, 195*, 47–65. https://doi.org/10.1016/j.renene.2022.06.040

Asante, D., He, Z., Adjei, N. O., & Asante, B. (2020). Exploring the barriers to renewable energy adoption utilising MULTIMOORA-EDAS method. *Energy Policy, 142*, 111479. https://doi.org/10.1016/j.enpol.2020.111479

Awuni, S., Adarkwah, F., Ofori, B. D., Purwestri, R. C., Huertas Bernal, D. C., & Hajek, M. (2023). Managing the challenges of climate change mitigation and adaptation strategies in Ghana. *Heliyon, 9*(4), e15491. https://doi.org/10.1016/j.heliyon.2023.e15491

Belotto, M. J. (2018). Data analysis methods for qualitative research: Managing the challenges of coding, interrater reliability, and thematic analysis. *The Qualitative Report, 23*(11), 2622–2633. https://nsuworks.nova.edu/tqr/vol23/iss11/2

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Breyer-Mayländer, T., Habann, F., Wehrstein, O., & Zerres, C. (2024). Auswirkung der Besonderheiten einer Organisation auf Change-Prozesse – die Integration interner Beratung am Beispiel von

„ekiba 2032“ der Evangelischen Landeskirche in Baden. *Organisationsberatung, Supervision, Coaching, 31*, 511–529. https://doi.org/10.1007/s11613-024-00900-3

Bukari, D., Kemausuor, F., Quansah, D. A., & Adaramola, M. S. (2021). Towards accelerating the deployment of decentralised renewable energy mini-grids in Ghana: Review and analysis of barriers. *Renewable and Sustainable Energy Reviews, 135*, 110408. https://doi.org/10.1016/j.rser.2020.110408

Cook, J., Nuccitelli, D., Green, S. A., Richardson, M., Winkler, B., Painting, R., Way, R., Jacobs, P., & Skuce, A. (2013). Quantifying the consensus on anthropogenic global warming in the scientific literature. *Environmental Research Letters, 8*(2), 024024. https://doi.org/10.1088/1748-9326/8/2/024024

Covey, S. R. (1989). *The 7 habits of highly effective people: Powerful lessons in personal change*. Free Press.

Damschroder, L. J., Reardon, C. M., Widerquist, M. A. O., & Lowery, J. (2022). *The updated Consolidated Framework for Implementation Research based on user feedback*. *Implementation Science, 17*(1), 75. https://doi.org/10.1186/s13012-022-01245-0

Dokyi, K. A., & Sharifi, A. (2024). Identification and analysis of barriers to the implementation of utility-scale solar photovoltaic technology in Ghana. *Energy for Sustainable Development, 83*, 101547. https://doi.org/10.1016/j.esd.2024.101547

Eken, G., Bilgin, G., Dikmen, I., & Birgonul, M. T. (2020). A lessons-learned tool for organizational learning in construction. *Automation in Construction, 110*, 102977. https://doi.org/10.1016/j.autcon.2019.102977

Energy Commission Ghana. (2025). *2025 national energy statistical bulletin*. https://www.energycom.gov.gh

Eyiah, A. K., Bondinuba, F. K., Adu-Gyamfi, L., & Liphadzi, M. (2025). Promoting effective management of cultural diversity in multinational construction project teams. *Buildings, 15*(5), Article 659. https://doi.org/10.3390/buildings15050659

Fianko, K. K. (2019). *Assessing the impact of teamwork on project success in the real estate industry in Ghana* [Master’s thesis, Kwame Nkrumah University of Science and Technology].

Gibbs, G. R. (2012). Thematic coding and categorizing. In *Analyzing qualitative data* (pp. 38–55). SAGE Publications. https://doi.org/10.4135/9781849208574.n4

Iddrisu, I., & Mohammed, B. (2024). Investigating the influence of employee voice on public sector performance: The mediating dynamics of organizational trust and culture. *Social Sciences & Humanities Open, 10*, Article 101096. https://doi.org/10.1016/j.ssaho.2024.101096

Mahama, M., Derkyi, N. S. A., & Nwabue, C. M. (2021). Challenges of renewable energy development and deployment in Ghana: Perspectives from developers. *GeoJournal, 86*(3), 1425–1439. https://doi.org/10.1007/s10708-019-10132-z

Maswabi, M. G., Chun, J., & Chung, S.-Y. (2021). Barriers to energy transition: A case of Botswana. *Energy Policy, 158*, 112514. https://doi.org/10.1016/j.enpol.2021.112514

McClory, S., Read, M., & Labib, A. (2017). Conceptualising the lessons-learned process in project management: Towards a triple-loop learning framework. *International Journal of Project Management, 35*(7), 1322–1335. https://doi.org/10.1016/j.ijproman.2017.05.006

Ministry of Energy. (2023). *Ghana's national energy transition framework (abridged version, 2022–2070)*. https://www.energymin.gov.gh

Nyasapoh, M. A., Elorm, M. D., & Agyemang Derkyi, N. S. (2022). The role of renewable energies in sustainable development of Ghana. *Scientific African, 16*, e01199. https://doi.org/10.1016/j.sciaf.2022.e01199

Nyasapoh, M. A., Gyamfi, S., Debrah, S. K., Gabbar, H. A., Agyemang Derkyi, N. S., Nassar, Y. F., Djimasbe, R., Gbinu, J., Odoi-Yorke, F., & El-Khozondar, H. J. (2025). Navigating renewable energy transition challenges for a sustainable energy future in Ghana. *Solar Energy and Sustainable Development, 14*(1), 237–252. https://doi.org/10.51646/jsesd.v14i1.479

Odonkor, S. T., Dei, E. N., & Sallar, A. M. (2020). Knowledge, attitude, and adaptation to climate change in Ghana. *The Scientific World Journal, 2020*, Article 3167317. https://doi.org/10.1155/2020/3167317

Opuni-Frimpong, J. (2025). Climate risk and financial stability in Africa: A comparative study before and during the Paris Agreement. *Sustainable Futures, 10*, 100908. https://doi.org/10.1016/j.sftr.2025.100908

Painuly, J. P. (2001). Barriers to renewable energy penetration: A framework for analysis. *Renewable Energy, 24*(1), 73–89. https://doi.org/10.1016/S0960-1481(00)00186-5

Pueyo, A. (2018). What constrains renewable energy investment in Sub-Saharan Africa? A comparison of Kenya and Ghana. *World Development, 109*, 85–100. https://doi.org/10.1016/j.worlddev.2018.04.008

Sackey, D. M., Amoah, M., Jehuri, A. B., Owusu-Manu, D.-G., & Acakpovi, A. (2023). Techno-economic analysis of a microgrid design for a commercial health facility in Ghana: Case study of Zipline Sefwi-Wiawso. *Scientific African, 19*, e01552. https://doi.org/10.1016/j.sciaf.2023.e01552

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research, 104*, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Tettey, G., Ansah, E. A., & Asante, W. (2025). The politics of renewable energy transition in Ghana: Issues, obstacles and prospects. *Energy Research & Social Science, 120*, 103939. https://doi.org/10.1016/j.erss.2025.103939

Tindana, P. (2025). *Scaling renewable energy in developing countries: Policy barriers and opportunities—A case study in Ghana* [Master's thesis, Weihenstephan-Triesdorf University of Applied Sciences].

Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy, 35*(5), 2683–2691. https://doi.org/10.1016/j.enpol.2006.12.001

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). SAGE Publications.

APPENDIX A: INTERVIEW PROTOCOL EXPERTS

A1 INFORMED CONSENT

CONSENT FORM

Dear participant,

You are being invited to participate in a research study titled Exploring Social and Institutional Dimensions in the Implementation of Ghanaian Renewable Energy Projects. The lead researcher of this study is Barend Westra from the TU Delft.

The purpose of this research is to explore the social and institutional dimensions of the implementation of renewable energy projects. Depending on your role and expertise you will be asked about your experiences, observations and professional insights regarding energy systems. You will be asked about barriers you have encountered yourself, barriers you have seen experienced by others, decision making processes, organizational challenges and your recommendations for improvement. You will not be asked any personal or sensitive questions and you will always be able to refuse an answer.

Within 4 weeks after the interview, we will send you the main takeaways of our conversation. If you have any concerns, you are welcome to suggest modifications. Upon request it would also be possible to receive the entire transcript of our interview.

All data collected during the interviews will be pseudonymized as quickly as possible. This pseudonymization will be done by deleting the original audio recordings after transcription and replacing identifiable information in these transcriptions with a general description. This pseudonymized research data will be preserved for up to 2 years at TU Delft. It will be used for the completion of this MSc thesis project and further scientific publication or educational activities on the topic of renewable energy. Only anonymous quotes and aggregated results will be presented in the MSc thesis and future research and education work. you will be anonymous in any and all outputs

Personal data (name, contact information, original recordings) will be preserved apart from the research data on a secure TU Delft institutional storage where it will only be accessible to members of the TU Delft research team. All personal data collected during this project will be handled according to European Privacy regulation (GDPR) and deleted after the completion of this research project.

Your participation in this study is entirely voluntary and you can withdraw at any time. If you request to be removed from the database all of your data will be removed within 1 week.

This interview will take you approximately 60 minutes to complete.

If you still have any questions feel free to ask.

I have read and understood the study information and I consent to participate and agree to the personal data processing described above.

Name	Date	Signature

Contact information of the lead researcher: B.P.Westra@student.tudelft.nl
Contact information on the supervisors: E.vanAndel@tudelft.nl F.AbouEddahab-1@tudelft.nl

TU Delft

A2 INTERVIEW GUIDE

Welcome and thank you for your time! I will start by introducing myself and telling something about my research.

Personal introduction
Then for the research project. I am currently studying renewable energy projects in Ghana where I focus on solar in particular. With this study I examine how social and institutional dimensions influence the implementation of these projects. My goal is to create a better understanding of how these factors might turn into barriers and how these barriers could be prevented or mitigated. To do this I am talking to experts in the field and asking them about their experiences and perspectives.

Do you have any question about my research?

If you have no more questions I would like ask you to sign this consent form (explain)

General questions
I have asked you for this interview because I have seen online that you have been involved in multiple solar energy projects. Could you describe your role in these projects?

- How many projects have you worked on?
- What are your responsibilities?
- How do your responsibilities differ from project to project?
- Are you working on a project now?

How are renewable energy projects in Ghana typically structured?

- Who initiates these projects?
- Who are involved in what phase?
- Who decides who are involved?

How are renewable energy projects usually received by the people who are affected by them?

- Do you feel like they are interested in these projects?
- To what extend are these people involved in the decision making process?
- Do the people generally understand why the project is initiated?
- What kind of reactions do you typically encounter? (skeptic, indifference, support, resistance)

Barriers/Enablers

Based on you experiences in renewable energy projects, could you describe early signs or indicators that the project might face challenges in a later stage?

- In what stage?
- How do you respond to this?
- How often are these correct?

In what phase of renewable energy projects do most challenges appear and how do they develop throughout the project?

- Can you describe these challenges?
- What challenges appear when?

Are the challenges unique or do you see the same challenges appear more often?

- What challenges keep occurring?
- Do similar challenges always have similar causes?
- Do certain contexts lead to certain challenges?

In your experience, how can interactions between actors within the project lead to challenges?

- What kind of interactions often create challenges?
- What actors are often involved in these interactions?
- Can you give an example of a serious challenge caused by someone inside of the project?

How can people or institutions from outside the project influence the development of challenges?

- What motivates these people to interfere with these projects?
- Are these people affected by the project?
- Can you give an example of a serious challenge caused by someone outside of the project?

Are there regulations or institutions that make renewable energy projects hard to execute?

- In what phase is this the most relevant?
- In what way do they hinder progress?
- Are these regulations in your opinion unnecessary?

When you compare multiple renewable energy projects you have worked on, is there any type of organization where you feel challenges appear more frequently?

- What kind of organization?
- Why do they appear there?

Have you ever experienced …?

- (Ask about desk research factor that has not been spoken about yet)
- How did you respond to this?

Mitigation
Based on your experience, what approaches have decreased the amount of challenges appearing in these kind of projects?

- Who were involved in this approach?
- Who initiated it?

What do you think is a common misconception when trying to decrease the amount of challenges appearing?

- Where does this misconception in your opinion come from?

Ending questions

- **What advice would you liked to get before starting this job?**
- **Is there anything we missed that you still want to share?**
- **Who do you think would be interesting to ask about …?**

Once again thank you for your time!
(Explain next steps)

APPENDIX B: INTERVIEW GUIDE END USERS

B1 INFORMED CONSENT

CONSENT FORM

Dear participant,

You are being invited to participate in a research study titled Exploring Social and Institutional Dimensions in the Implementation of Ghanaian Renewable Energy Projects. The lead researcher of this study is Barend Westra from the TU Delft.

The purpose of this research is to explore the social and institutional dimensions of the implementation of renewable energy projects. You will be asked about your experiences and views regarding solar energy projects on campus. You will not be asked any personal or sensitive questions and you will always be able to refuse an answer.

All data collected during the interviews will be pseudonymized as quickly as possible. This pseudonymization will be done by deleting the original audio recordings after transcription and replacing identifiable information in these transcriptions with a general description. This pseudonymized research data will be preserved for up to 2 years at TU Delft. It will be used for the completion of this MSc thesis project and further scientific publication or educational activities on the topic of renewable energy. Only anonymous quotes and aggregated results will be presented in the MSc thesis and future research and education work. you will be anonymous in any and all outputs

Personal data (name, contact information, original recordings) will be preserved apart from the research data on a secure TU Delft institutional storage where it will only be accessible to members of the TU Delft research team. All personal data collected during this project will be handled according to European Privacy regulation (GDPR) and deleted after the completion of this research project.

Your participation in this study is entirely voluntary and you can withdraw at any time. If you request to be removed from the database all of your data will be removed within 1 week.

This interview will take you approximately 15 minutes to complete.

If you still have any questions feel free to ask.

I have read and understood the study information and I consent to participate and agree to the personal data processing described above.

______________	______________	______________
Name	Date	Signature

Contact information of the lead researcher: B.P.Westra@student.tudelft.nl
Contact information on the supervisors: E.vanAndel@tudelft.nl F.AbouEddahab-1@tudelft.nl

KNUST KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

TU Delft

B2 Interview guide

Background interview

The goal of interviewing end users is not to talk about global problems or implementation processes, but gain insight into the personal experiences and perceptions of the people who are using the technology. This group of participants will not be asked to speak about barriers, but about personal perceptions using 4 analytical themes: Awareness, Perceived necessity, Connection to the daily life and Attribution. The interviews are intended to be relatively short (10 – 15 minutes) and the participants will be chosen based on whether or not they are affected by PV installations. The participants will be selected to achieve an even mixture of gender and age to reduce the impact of potential biases.

Introduction

Hi, thanks for your time! My name is Barend, and I'm a Master's student from the Netherlands. Right now I am doing research here at the university campus on solar energy projects. This is not a test of your knowledge, and there are no right or wrong answers. I am only interested in how students experience these kinds of projects. The questions will take approximately 10 to 15 minutes, your answers will be anonymous and you don't have to answer any question you don't want to.

Consent form

Before we start, this form just confirms that you're participating voluntarily and that you can stop the interview at any time.

Opening question

What comes to your mind when you are thinking about a solar panel?

Awareness (Is the reason for PV installation clear to the end user?):

Why do you think solar panels were installed here?
What problem do you think this project is trying to solve?
Had you heard anything about this solar project before it was installed?

Perceived necessity (Does the PV installation feel necessary or extra?):

Do you think installations like this are really needed here? Why or why not?
Do you feel like students ever experience electricity related problems?
If this solar system stopped working tomorrow, how would you feel about that?

Connection to daily life (Do the end users experience the impact of the project?):

Has this solar system changed anything in your daily study or living experience?
Do you personally notice when electricity comes from solar or not?
How dependent do you feel on reliable electricity in your daily student life?

Attribution (How do end users think of the actors behind the project?):

Do you know who decided to install this solar system?
Do you feel like the actual users had any influence on decisions like this?
Who do you think benefits from this project?

Ending question

Is there anything else about this solar project that you would like to add?
Based on your experience here, do you feel projects like this are relevant for Ghana in general?
Would you have liked to receive more information about this project?

APPENDIX C: CODEBOOK

This appendix contains the final codebook used for the thematic analysis. The codes are categorised and grouped into broader clusters and themes used to give structure to the results chapter. The different clusters of code are divided into four categories which form the structure of the results chapter:

SB, Social Barrier
SE, Social Enabler
IB, Institutional Barrier
IE, Institutional Enabler

Table 11: Codebook used to identify relevant social and institutional factors

Code	Mentioned	Factor	Clas Sifi cation
Unique contexts prevent standardized methods from being used	4	Availability of experience	IE
Re appearing challenges can be solved with experience	2	Availability of experience	IE
Energy company can give advice on how and where to instal solar	7	Availability of experience	IE
Experience in earlier PV projects helps decision making	6	Availability of experience	IE
Energy company gets involved early on	5	Availability of experience	IE
former collaborations can create tunnel vision	1	Availability of experience	IE
There is a lot of knowledge inside of KNUST	6	Availability of internal expertise	IE
Outside expertise can cost a lot of money	5	Availability of internal expertise	IE
maintenance has to be done by trained professionals	8	Availability of technical expertise	IE
Maintenance will be done by installer before handing it over to the university	6	Availability of technical expertise	IE
maintenance will help during installation	3	Availability of technical expertise	IE
The energy company is responsible to get the system working perfectly	1	Availability of technical expertise	IE
Bigger procurements have to go through national government	8	Bureaucratic procedures	IB
Lengthy mandatory procurement processes cause delays	10	Bureaucratic procedures	IB
It's impossible to design within procurement budget as price is dependent on companies	1	Bureaucratic procedures	IB
Bureaucratic procedures inside of the government	7	Bureaucratic procedures	IB

Companies sometimes miss the first tender due to timeframes	5	Bureaucratic procedures	IB
Limited contractor capacity and preparedness during tendering process	5	Bureaucratic procedures	IB
Failures during procurement process disrupt project progress	5	Bureaucratic procedures	IB
Bureaucratic procedures inside of KNUST	8	Bureaucratic procedures within KNUST	IB
planning a meeting took 2 weeks and caused delay	1	Bureaucratic procedures within KNUST	IB
Centralized project governance	11	Centralised project governance	IE
The ECG legally cannot stop you	2	Clear regulatory framework	IE
The rules for RE are clear	2	Clear regulatory framework	IE
fragmented approval	10	Complex collaborations	IB
complex collaborations can slow down projects	7	Complex collaborations	IB
Having different priorities can slow down projects	5	Complex collaborations	IB
Scared for RE waste in the future	1	Concerns about future PV waste	SB
conflict of interest during procurement	1	Conflict of interest	IB
cheaper energy out of range due to high upfront costs	5	Cost prioritisation	IB
cost reduction leads to reduced quality	5	Cost prioritisation	IB
Reducing the scope will cause more problems	2	Cost prioritisation	IB
Budget is limited	3	Cost prioritisation	IB
Costs are seen as the most important	25	Cost prioritisation	IB
Experiences of former projects are limited to the members of that project	1	Dependence on key actors	IB
Heavy workload can prevent experts to join conversations	2	Dependence on key actors	IB
Limited technical understanding within project team	11	Dependence on key actors	IB
Not involving all relevant people	14	Dependence on key actors	IB
End users might have different priorities	8	Limited alignment with user priorities	SB
It happens that the affected people care more about you giving them money you bring than about the project itself	6	Limited alignment with user priorities	SB
Physical group meetings are important for easy communication	8	Effective communication	SE
Solution oriented interactions prevent escalations	5	Effective communication	SE

Solving problems quickly can prevent them from growing	1	Effective communication	SE
Team meetings to reorganise can be really helpful	6	Effective communication	SE
When checking companies everyone comes together for a quick collaboration	2	Effective communication	SE
Environmental protection can cause delays	9	Environmental protection requirements	IB
increasing complexity of the energy system with growing RE integration	5	Fragmented campus energy system	IB
There is no holistic approach	5	Fragmented campus energy system	IB
Every college has its own bills and responsibilities	2	Fragmented campus energy system	IB
PV projects at KNUST are funded by the colleges	2	Fragmented campus energy system	IB
Some panels at KNUST are used for research instead of power	1	Fragmented campus energy system	IB
Most solar is installed by commercial/governmental institutions	1	Internal project financing	IE
Outside of KNUST it can be difficult to organise the finances	2	Internal project financing	IE
Most projects are funded by the university	2	Internal project financing	IE
Conflicting land use purposes	6	Construction based nuisance	SB
Construction related disturbances	5	Construction based nuisance	SB
Disturbance to the vicinity	4	Construction based nuisance	SB
Projects at KNUST are structured, but still experience outside complaints	2	Construction based nuisance	SB
Everyone from within the university can raise complains about the construction	1	Construction based nuisance	SB
People are interested with electrification and not so much with sustainability	1	Limited alignment with user priorities	SB
User perception, limited personal relevance of solar energy	2	Limited alignment with user priorities	SB
Limited knowledge can result in limited trust	6	Limited user awareness	SB
User perception, limited awareness and understanding of solar systems	4	Limited user awareness	SB
Limited technical knowledge among end users	15	Limited user awareness	SB
Positive reaction because PV brings down emissions	2	Perceived environmental benefits of PV	SE
User perception, solar perceived as environmentally beneficial	7	Perceived environmental benefits of PV	SE

PV brings down long term costs	2	Perceived financial benefits of PV	SE
User perception, solar perceived to reduce electricity costs	3	Perceived financial benefits of PV	SE
Staff is aware about differences in pricing	1	Perceived financial benefits of PV	SE
The end users pay the difference in energy price	1	Perceived financial benefits of PV	SE
The energy from the grid is perceived as expensive	1	Perceived financial benefits of PV	SE
Limited trust in PV	7	Perceived limitations of PV	SB
User perception, solar perceived as limited in capacity	2	Perceived limitations of PV	SB
User perception, solar is perceived as backup energy source	13	Perceived limitations of PV	SB
User perception, solar perceived as complementary energy source	4	Perceived limitations of PV	SB
Positive reactions due to increased reliability	10	Perceived reliability benefits of PV	SE
User perception, solar is perceived to improve electricity reliability	9	Perceived reliability benefits of PV	SE
User perception, solar perceived as solution to power outages	2	Perceived reliability benefits of PV	SE
For most people the main goal of PV is to ensure reliability	2	Limited interest in sustainability	SB
User perception, solar perceived to provide lighting	6	Perceived reliability benefits of PV	SE
User perception, solar perceived as necessary for Ghana	7	Perceived societal relevance of PV	SE
Projects can become political instruments	3	Political influence	IB
Strong government influence on project approval and decision-making	5	Political influence	IB
Authoritarian leadership	1	Poor project team composition	IB
Unclear division of responsibilities	11	Poor project team composition	IB
missing framework to distribute the financial gains	1	Poor project team composition	IB
Limited communication cause delays	2	Poor project team composition	IB
Project teams not following guidelines can cause delays	2	Poor project team composition	IB
Maintenance only gets involved when data is needed for the design	4	Poor project team composition	IB
Clear division of responsibilities prevents internal challenges	5	Project team structure	IE
project-specific team composition	3	Project team structure	IE

Maintenance does not check the solar panels	5	Reactive maintenance	IB
There is no communication structure for maintenance	1	Reactive maintenance	IB
Regulatory constraints limit technical options	5	Regulatory constraints on grid access	IB
regulatory restrictions on grid access due to safety and stability concerns	6	Regulatory constraints on grid access	IB
The end users only care about the energy being reliable	3	Limited interest in sustainability	SB
Generators do not function at night	1	Limited interest in sustainability	SB
Only critical loops are attached to batteries	5	Limited interest in sustainability	SB
User perception, continuous electricity perceived as essential for academic activities	3	Limited interest in sustainability	SB
User perception, frequent power outages perceived as disruptive	3	Limited interest in sustainability	SB
The grid remains unstable	2	Limited interest in sustainability	SB
PPAs prevent solar to be added to the energy mix	6	Restrictive PPAs	IB
Changes in stakeholders can lead to delays	5	Stakeholder turnover	IB
People falling away really impacts the projects continuity	2	Stakeholder turnover	IB
The vice chancellors term is 4 years	2	Stakeholder turnover	IB
strategic vision towards RE adoption facilitates implementation	13	Strategic institutional orientation	IE
There is an contingency buffer	1	Strategic institutional orientation	IE
There is some room for adjustments in the budget	1	Strategic institutional orientation	IE
Energy Commission adjusts regulations based on former experiences	4	Supportive regulators	IE
The government is perceived as supportive to RE	7	Supportive regulators	IE
Stakeholders do not get involved enough in the design phase	6	Top-down design	IB
top down design outside of KNUST can be problematic	1	Top-down design	IB
User perception, top down design is not a problem	5	Institutional trust	SE
It is hard to get 100% trust beforehand	3	Top-down design	IB
People will always keep asking questions	1	Top-down design	IB

User perception, solar perceived to benefit all campus users	4	Institutional trust	SE
Because there are no meters installed it is impossible to measure how much energy got feed back	1	Unimplemented net metering	IB
Net metering is not possible yet	12	Unimplemented net metering	IB
Surplus energy goes to waste when not connected to the grid	4	Unimplemented net metering	IB
There are big promises, but no net meter installation yet	6	Unimplemented net metering	IB
Only ECG can sell the energy	2	Regulatory constraints on grid access	IB
RE affects the conventional grid	3	Unimplemented net metering	IB
the solar panels are grid tied	4	Unimplemented net metering	IB
Low financial compensation for feeding energy into the grid	2	Unimplemented net metering	IB
you are not allowed to instal microgrids	3	Regulatory constraints on grid access	IB
KNUST only lowers consumption and does not feed into grid	2	Unimplemented net metering	IB
Tariff issues ECG and PURC have recently been solved	2	Unimplemented net metering	IB
ECG shows limited enthusiasm on RE	1	Unimplemented net metering	IB
Net meters would increase challenges for ECG	2	Unimplemented net metering	IB
Contractor stops or delays work because he did not get paid	2	Unreliable external environment	IB
External parties might neglect their duties	7	Unreliable external environment	IB
Theft of key components slows projects	4	Unreliable external environment	IB
Not everyone follows the rules	2	Unreliable external environment	IB
Shipping the equipment to Ghana causes major delays	4	Unreliable external environment	IB

APPENDIX D: REFLECTION ON THE USE OF AI

AI has been used to rephrase some sentences into a more academic style. This has improved readability and professionalism. Additionally, an AI tool has been used to keep order in the reference list.

During the field work AI has been used to support communication with different stakeholders and to create an initial transcription after the interview was conducted. This transcription was then completely checked for mistakes manually to ensure reliability. Furthermore AI helped to transform bulleted summaries of the interview results into the narrative summaries that have been used for member checks.