Integration of Sustainability into first of a kind projects: A Sustainable Project Management Approach

An explorative study into the tools/practices used in integration of sustainability in first of a kind projects.

MSc. Thesis

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By

Pranava Satish

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Author

Name:	Pranava Satish
Student number:	5239923

Graduation Committee

Chair:	*P*rof. dr. H.L.M. Bakker	T U Delft (CEG)
*F*irst Supervisor:	Dr. ir. M.G.C. Bosch-Rekveldt	T U Delft (CEG)
*S*econd supervisor	Dr. Martijn Leitjten	T U Delft (CEG)
Company supervisor	Wouter Gerwen van	Bilfinger Tebodin
Company supervisor	Diana Seijs	Bilfinger Tebodin

PREFACE:

Construction of first of a kind project is gaining momentum across the world from past few years with a strong motive to reduce the carbon dioxide emissions. However, due to the delays by new technology or methods involved, saving carbon dioxide emissions during the construction have been proved difficult. Hence the primary aim is to integrate sustainability in first of a kind project through sustainable project management approach to save the required civil dimensions and fulfil the sustainability criteria. Thus, I aimed to explore tools/practices to integrate sustainability in first of a kind project by pursuing a path in construction management and engineering. This report demonstrates my commitment to this mission. Thus, when I received a golden opportunity to pursue my thesis on sustainability, I knew it was a chance to increase my competency. The thesis topic, Integration of sustainability into first of a kind project: A sustainable project management approach; An explorative study into the tools and/or practices used in the integration of sustainability in first of a kind project, is a step in the right direction. The thesis suited my Master's in Construction Management and Engineering and provided me with a chance to appreciate consultancy and engineering while working at Bilfinger Tebodin.

I would not have achieved this without the guidance of my committee members. I will be forever grateful to my college supervisors Marian Bosch-Rekveldt and Martijn Leijten for their timely and priceless instructions. They sincerely supported me and ensured I had the resources necessary to complete this project. I would also like to thank Bilfinger Tebodin's supervisors, Wouter Van Gerwen, Diana Seijs, for their warm reception guidance throughout my association with the company. Last but certainly not least, I want to thank the committee chair, Hans Bakker, for precious instructions and guidance during the duration of the project. Thank you all.

The rest, thanks to friends and peers whose constructive criticism and encouragement were noted.

I hope you find this project a helpful, informative, and enjoyable learning experience.

Executive Summary:

Introduction and Ideology

Incorporating sustainable practices in projects through a project management approach has gained traction in recent years. The current definition of integrating sustainability in projects is ambiguous (Schipper, Sivius, & Nedeski, 2012) and stakeholders hold different perspectives on the topic. Integrating sustainability in projects has greatly shifted from the concept of reusing, recycling of materials in projects to reducing the delays in the projects to save the CO2 emissions and in increasing energy efficiencies in the projects (McPhee & Dias, 2020). Although, integrating sustainability into projects has gained traction in recent years, project management profession has faced difficulties in incorporating sustainability principles in large infrastructure projects especially in first of a kind project ("Progress of PM", 2022). This is because, technologies or methods to be employed in these projects are unknown and there is no precedent or project expertise to guide these projects. This has proven to be vulnerable to severe cost and schedule overruns and performance deficiencies. These projects are built with a strong motive to reduce the carbon dioxide emissions but, due to the delays by new technology or methods involved, saving carbon dioxide emissions during the construction have been proved difficult ("Progress of PM", 2022). The research is thus grounded by the gap of exploring tools/practices to reduce the delays in first of a kind project which will aid in saving the CO2 emissions and in meeting the energy efficiencies targets.

Research Objective & Question

The objective of this research is to explore tools/practices to improve integration of sustainability in first of a kind project. The research objective has been translated into the following main research question:

How to improve integration of sustainability in first of a kind project?

Research Methodology

The research applied qualitative research methods and was conducted in six phases which were literature review, data collection, cross case analysis, proposed solutions, expert validation, and final discussion/conclusions. Secondary research was adopted to extract data on existing body of literature on sustainable project management and the rationale for integrating sustainability in first of a kind projects. Tools/practices that project management professionals can use to integrate sustainability, and the challenges they come across while doing so were inventoried. In data collection, secondary data sources related to the projects like project reports were studied to understand the sustainability measures which were implemented as well as to collect the information about the stakeholders in each project. Project managers and Package unit managers in the projects were interviewed to gain insights on their perceived roles in implementing tools to integrate sustainability in such projects, more specifically about the tools requirements and how those sustainability assessment tools can help in choice of the right construction technology and methods. In cross analysis, challenges faced under few activities in common in the three first of a kind projects were discussed. Cross case analysis served as an anchor point in proposing solutions to the challenges faced in three first of a kind projects. In expert validation, people with knowledge in the field of project management, engineering and environmental studies evaluated my proposals. The key findings of the research was discussed in the last phase and conclusion was drawn by answering the sub questions and main research question of the research.

Case study

After thorough analyzation of a contemporary real-life issue with little control, a case study approach was chosen. Furthermore, the case study approach is well suited for answering a descriptive research question (Blaikie, 2009). A total of 3 first of kind projects were chosen as a part of case study. The company the author was working for had 6 potential projects out of which three were completed and the other three were in concept and design stage which means that the FEED phase was not started yet. So, the three first of a kind projects which were completed were chosen in this study. The interviews were analyzed qualitatively per case with an emphasis on the respondents' diverse opinions on sustainability and activities in the FEED phase. Case analysis was done per case in this phase to explore tools/practices used to integrate sustainability in three first of a kind projects in practice. In total, 9 interviews were conducted, and the interviewees were the project managers and package unit managers who were involved in these projects. The literature study and project documents which were studied resulted in the following themes for the interview: Managing the package unit vendors; Interface management; Research and development; Team integration; Value improving practices; Project scheduling; Lessons learned and project risks. The interviews mainly focused on collecting data on activities in FEED phase and in exploring tools/practices which were utilized to integrate sustainability under these activities.

Findings from Cross Case Analysis

Cross case analysis addressed the challenges that were faced in common in integrating sustainability under few activities in the three first of a kind projects chosen for the research. The Cross Case Analysis handled three aspects of CO_2 emission reduction impact:

1. Reaching the operational CO_2 emission reduction goal after project completion
2. Reaching the project completion goal, with resulting CO_2 emission reduction start, within planning
3. Minimizing construction related CO_2 emissions during the realization phase of the project

Managing package unit vendors, interface management, optimising value, research and development and project risk were among the activities that posed challenges to the CO_2 emission reduction targets. Main concern areas with respect to these activities were:

1. Dedicated attention per interface between key involved parties. In particular
   a) The production company R&D department
   b) The package unit supplier of key innovative technology
2. Overall and joint project risk management with clear ownership per issue
3. Overall and integrated project planning with clear freeze of parameters at interfaces and progress management.

The challenges resulted in project delays with consequential missed CO2 emission reduction during those delays and in meeting energy efficiency targets. Cross Case Analysis served as an anchor point for proposing solutions.

<u>Proposed Solutions to the practitioners</u>

The cross-case analysis showed the areas where the projects struggled in terms of integrating sustainability. The proposed solutions will have impact on all three main aspects on CO2 emission reduction targets mentioned in cross case analysis. The author has proposed solutions in the form of most significant tools/practices used to integrate sustainability in the FEED phase based on the scope of improvement in each project. The following are the tools/practices:

1. A four-step strategy to manage the package unit vendors and to avoid financial bankruptcy of the vendor
    a) Preselection of Technologies and Prequalification of Vendors
    b) Paying the prequalified vendor to do Basic Engineering
    c) Signing a risk sharing contract with the vendor
    d) Joint check agreement
2. Minimization, Optimization, Maximization and Constructability value engineering sessions as value improving practice to save the CO2 emissions and increase the energy efficiency targets.
3. A four-step strategy an appointed interface managing team should follow to manage the interfaces between design and engineering activities
    a) Re-ordering design activities
    b) Restructuring strategies.
    c) Anticipating the information on interfaces
    d) Overdesign
4. Stage gated project phasing to make sure stakeholders are committed and assigned to the project risk.
5. Commitment Action Risk Log to make sure stakeholders are committed and assigned to the project risk.
6. Appointing an external specialist in Research and Development phase.
7. Implementing a stage gated approach to manage the interfaces between research and development and the project organization.

The proposed solutions focus on promoting the overall alignment of interest and efforts. The alignment effort results in setting more realistic and reached sustainability targets like reduced CO2 emissions. On top of that, the stakeholder alignment most directly influences the realization time of the project. Faster project realization results in earlier coming to effect of the CO2 emission reduction measures. This results in a direct measurable connection between schedule effects and avoided emission per time increment. This measurement can support management of change decisions.

The proposed solutions will help in reducing the delays which will aid in saving the CO2 emissions and meeting the energy efficiency targets.

Expert Validation

Three experts were chosen for expert validation meeting. Expert 1 is heading the procurement department of Engineering and Consultants in Northwest European region. Expert 2 is the project Manager for the Engineering and consultants and expert 2 also leads the piping and mechanical department. Expert 3 is a project manager and a Line Manager for Engineering and Consultants. The experts were chosen based on their expertise they had in first of a kind projects and based on the years of experience they have working on such projects. The three experts who were working on integrating sustainability in the construction projects for a very long time. All the experts were happy with the proposed solutions. Furthermore, they suggested and put forth a few research papers to help validate and strengthen the research author's proposed solution. Expert 1 forwarded two research papers to strengthen the proposed solutions on managing the package unit vendors. Expert 2 forwarded research papers to strengthen the solutions on value improving practices. Expert 3 suggested the author to bring some of the requirements in proposed solutions to EU standards and regulations. Overall, these papers helped in validating the proposed solutions and made formulating and the structuring the proposed solutions easier.

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1 Introduction

The goal of this chapter is to introduce the concept of sustainable project management, sustainable project and First of a Kind project. Following that, a problem analysis is conducted, and the research objective is stated, from which research questions are framed. The chapter will also cover the contribution of research and finally go through the structure of report.

1.1 Background

Applying principles of sustainability to project management is one of the prominent problems faced by managers when sustainable construction is practiced. For a well sustainable yet balanced developmental, approach parameters like the people, environment and economics must be considered (A.J. Silvius, J. Van der Brink, & A. Kohler, 2015). The industries are trying to incorporate strategies and ideas into their process for attaining sustainability. Sustainability looks at a situation from a long-term perspective, seeking to integrate the project's societal, environmental, and economic components (Marcelino Sádabada, 2015). Project management is focused on the duration of the project, with the goal of meeting the project's schedule, budget, and performance targets.

Tasks like planning, managing, and analyzing the project; overseeing project implementation, associated support procedures as well as considering the environmental, social, and economic aspects of the project life cycle is included in sustainable project management (A.J. Silvius, 2015). With sustainable project management, it is very important that tasks should be carried out in transparent and ethical way for all stakeholders to be benefitted. It essential that the stakeholders and the project team play an actively participates in the programs produced for sustainability even if it is challenging (Marcelino Sádabada, 2015). Sustainable project management has greatly shifted when project management professionals acknowledged its importance in assisting project success, thus proving the relevance of sustainability (A.J. Silvius, 2015).

1.1.1 Sustainable Project

A project is considered sustainable when defects can be corrected, new requirements can be satisfied, future maintenance can be reduced, and the project can adapt to changing conditions readily (Wilkins, 2013).

Project sustainability is a common management technique for various projects, organizations, individuals, and entities that need to create, market, distribute, and provide products and services in an efficient and effective way (Martens & Carvalho, 2016). From projects conceptual phase to close out phase, sustainability in projects is measured through certain metrics. Most projects fail due to a lack of a good sustainability plan, which is a well-known fact (A.J. Silvius, 2015). As a result, for project execution, a full analysis of the social, economic, legal, cultural, educational, and political environments is required (Martens & Carvalho, 2016). The plan should transparently describe and state the project objective, mission, vision, values and goals.

1.1.2 First of a kind project

First of a Kind is abbreviated as FOAK. It's a term used in engineering economics to describe how the first item or generation of products adopting a new technology or design can be far more expensive than subsequent items or generations (Martens & Carvalho, 2016). There is no precedent or project expertise to guide these initiatives; as a result, first-of-a-kind projects have proven to be vulnerable to severe cost and schedule overruns and performance deficiencies. The tendency to measure the level of preparation (readiness to proceed) for these initiatives using the same criteria and metrics as similar projects that have previously been completed exacerbates the problem (Martens & Carvalho, 2016). The components of first of a kind projects are typically innovative, require scaling up of technological department and research and development. ("Progress of PM", 2022). Even if the constituent components are off-the-shelf, integrating them into a novel, high-performance system could be a first. When given the option of waiting until all technical uncertainties are resolved or going forward with project design and new technology development at the same time, senior management will often choose the speedier option. (Martens & Carvalho, 2016).

A first of a kind project may need to go on despite the risks, but these should be calculated risks. Unlike traditional projects, which often move in a linear fashion with no backtracking, the committee thinks that management in the first of a kind projects should make an informed choice based on an unbiased awareness of the risks involved and take proactive steps to reduce, mitigate, and manage these risks ("Progress of PM", 2022). Rework, recycling, and iteration must all be expressly considered and planned for in first of a kind project.

Construction of a new weapons processing plant, nuclear plants, carbon capture storage plants, ethanol plant, bio-diesel plant etc that could achieve scientific and technological leadership—all these endeavors, regardless of their purpose, share several characteristics. These projects are built with a motive to reduce the CO_2 emissions and other greenhouse emissions and in contributing to the three pillars of sustainability: environmental, economic, and social ("Progress of PM", 2022).

1.2 Introducing ECO

This study focuses on integration of sustainability in first of a kind project. This research is conducted in association with an ECO. It is a part of the civil and Industrial company, with a strong global network and experience in a variety of fields. They are dedicated to delivering superior quality projects within budget. Having the knowledge of markets and ambitions, they are clear on their vision about current developments. They collaborate with clients and foster innovation through integrated world-class consultation and engineering solutions, as well as expert project and construction management. With their worldwide presence and a large source of talented professionals, they provide their clients with solutions and practical expertise in a broad range of services.

1.2.1 Definition of Sustainability according to ECO

In recent years, sustainability into first of a kind project has grown more crucial. The present definition of sustainability is ambiguous (Schipper, Sivius, & Nedeski, 2012) and different stakeholders have differing viewpoints on the subject. ***Practitioners' opinion/definition of integrating sustainability into first-of-a-kind projects, according to the ECO, was to avoid delays in the projects, which will aid in saving CO_2 emissions and fulfilling the energy efficiency targets as planned.***

1.3 Problem Statement

Incorporating sustainable practices in projects through a project management approach has gained traction in recent years. Project management profession have faced difficulties in incorporating sustainability principles especially in large infrastructure projects.To achieve good project management, three important factors must be adopted: sustainability, efficiency, and effectiveness (Martens & Carvalho, 2016). The integration of economic, environmental, and social dimensions; the integration of short and long-term perspectives; and the consumption of income rather than capital are among the elements which contribute to sustainability, efficiency and effectiveness (van den Brink, Silvius, & Köhler, 2012). The triple bottom line concept, often known as the three pillars of sustainability, is the convergence of economic, environmental, and social goals (Martens & Carvalho, 2016). According to Gachie (2019), the economic pillar is seen as more essential than the other two. The three pillars are inextricably linked. As a result, progress in one dimension benefits the other two aspects. Social well-being and judicious use of natural resources, for example, have beneficial economic consequences. The economic pillar is particularly important because it protects and preserves the money invested in the project, which encourages the desire to maximize profit, minimize expenses, enhance revenue, profitability, and quality, and seek a return on investment (Salama, 2020).

Several research on incorporating sustainability into construction projects have been conducted. These findings shed light on the tools/practices utilized to integrate sustainability into projects, as well as how stakeholder engagement aids in this endeavor. Furthermore, these evaluations are conducted on projects where the technology or practices to be utilized to integrate sustainability have already been established. However, there has been little research done on integrating sustainability into first of a kind project where the technologies used are unknown. The research is thus grounded by the gap of exploring tools/practices to integrate sustainability in first of a kind project.

1.4 Research objective

The main aim of this research is to explore tools/practices to improve integration of sustainability in first of a kind projects.

1.5 Research question

The research objective has been translated into the following main research question:

How to improve integration of sustainability in first of a kind project?

Five sub-questions (SQ) have been framed to answer the main question. Answering them leads to the main question being answered.

SQ1: What are the tools/practices which could positively influence in integrating sustainability in first of a kind projects in theory?

SQ2: What are the limitations and challenges in implementing the tools/practices to integrate sustainability in first of a kind in theory?

SQ3: What are the tools/practices used in integrating sustainability in first of a kind projects in practice?

SQ4: What are the limitations and challenges to integrate sustainability in first of a kind projects in practice?

SQ5: What are the solutions that can be implemented to solve the challenges faced in first of a kind projects in practice?

1.6 Contribution of the Research

This research will explain the importance of different sustainability tools in first of a kind project. The research will present tools/practices to integrate sustainability in first of a kind project. The research will also add to the existing literature, the challenges encountered in integrating sustainability in first of a kind projects.

1.7 Structure of the Report

Chapter 1 introduces the concept of sustainable project management , sustainability according to the Engineering and Consultants , followed by definition of sustainable project and first of a kind project. The chapter also analyses the problem of the study and states the objective from which the research questions are framed.

Chapter 2 covers the research design which entails the different phases in which the research will be conducted.

Chapter 3 presents the findings of the literature study. First, the concept of sustainable project management is introduced. Tools/practices that are useful for integration of sustainability in first of a kind projects are introduced and explained as well as the challenges faced during integration of it.

Chapter 4 discusses the data obtained from one case study with three cases. The chapter also covers case analysis done per case to explore tools/practices used to integrate sustainability in each case.

Chapter 5 covers the cross-case analysis where knowledge from the cases is incorporated to help in the research. The purpose of this chapter is to mobilize and compare the case studies to produce new knowledge.

Chapter 6 proposes solutions to solve the investigated challenges explored from cross case analysis.

Chapter 7 covers the expert validation which compares the researched information from the project to informed individuals opinions with a track record in related fields of study..

Chapter 8 covers the discussion and conclusion of the project. The discussion section analyses the recommendations given by the author and interprets the significance of the findings. The chapter is finally concluded by answering the research questions.

2. Research Design

This research will apply qualitative research methods and will be conducted in six phases which are literature review, data collection, cross case analysis, proposed solutions, expert validation, and discussion /conclusion. Under literature review extracted data on existing body of literature on sustainable project management and how involving stakeholders in FEED will help in integrating sustainability in projects will be covered. In data collection secondary data sources related to the projects like project reports will be studied to understand the sustainability measures which were implemented as well as to collect the information about the stakeholders in each project. In cross case analysis, all the information from three project cases will be compared which will be the base in proposing the solutions for the challenges faced in projects. In expert validation, people with knowledge in the field of project management, engineering and environmental studies will evaluate the proposed solutions and finally conclusions will be drawn by answering the main research question and sub questions.

2.1 Phases for the research

Phase 1: Literature review

Secondary research was adopted to extract data on existing body of literature on sustainable project management and the rationale for integrating sustainability in projects (Stewart, 1993). Tools/practices that project management professionals can use to integrate sustainability, and the challenges they come across while doing so were inventoried. Sustainability measurement tools and assessment criteria for buildings and other infrastructure projects were gathered from existing literature. Keywords such as "Sustainable Project Management," "Sustainability Tools," "Sustainability Measurement tools," "Sustainability Assessment Tools" were used in relevant search engines including university research papers repositories and journal citation databases like Scopus. Sub-questions 1 and 2 were answered by this secondary research (Literature Review)

Phase 2: Data Collection

Three first of a kind project reports were studied to understand the sustainability measures which were implemented as well as to collect the information about the stakeholders in each project. Interviewing will be the primary data collection method in this phase. Project managers in the projects will be interviewed to gain insights on their perceived roles in implementing tools to integrate sustainability in such projects, more specifically those tools requirements and how those sustainability assessment tools can help in choice of the right construction technology and methods to produce reduced Greenhouse gas emission from construction activities (Sawalani, 2011). The interview will be semi structured to acquire as much information as possible from the participants. Because semi structured interviews engages a two-way conversation more efficiently, it would also provide in-depth information for the author about the projects. Case analysis was done per case in this phase to explore tools/practices used to integrate sustainability in first of a kind projects in practice which answered the SQ3.

Phase 3: Cross case Analysis

Cross case analysis was done based on the data collected from three project interviewees. Cross case analysis was chosen over other cumulative approach because it will be vital in comparing the similarities and differences in implementing tools/practices used to integrate sustainability in the three projects chosen for research. Cross case analysis will also be helpful in answering the SQ4.

Phase 4: Proposed solutions

Solutions will be proposed to the challenges faced in three first of a kind project chosen for research and cross case analysis will serve as an anchor point in proposing solutions. The proposed solutions will help in answering SQ5.

Phase 5: Expert validation

Experts from the field of project management, engineering and environmental studies will evaluate the proposed solution.

Phase 6: Discussion/conclusion

Conclusion is drawn by answering the main research question "***How to improve integration of sustainability in first of a kind project?"*** and the sub questions.

The phases of the research is presented in the form of a flow chart, (see figure 1).

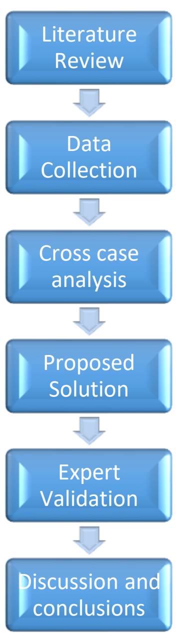

Figure 1: Research Design flowchart

2.2 Research Scope

This research will be conducted on first of a kind projects with an Engineering and Consultation firm and these projects' primary goal is to save the CO2 emission and to increase the energy efficiency. Integration of sustainability in first of a kind projects by project managers in their FEED stage will be evaluated. The existing sustainability assessment tools being used by these projects as benchmarks for saving the CO2 emissions and increasing energy efficiency will be explored including their influence on sustainable project management activities. Project managers usually face difficulties to integrate sustainability in these projects because they will not have clearly defined criteria for choosing the technologies/methods and to solve this challenge, the study will explore tools/practises that a project manager can use to integrate sustainability in these projects.

2.2.1 Case selection

The criteria used for selecting the projects for the case study are as follows:

1. The project should be first of a kind project (Carbon Capture Utilization and Storage, Nuclear Power plant, Biofuel plants) meaning it should involve new technologies or methods in the project.
2. The execution of the project happens over a period of time.
3. Construction phase of the project should be either underway or completed recently (which essentially means that at least the design phase should be completed).
4. The project should involve or have involved sustainability in project management, as it strikes a balance between the environmental, social, and economic components of project-based activity to meet stakeholders' current requirements without jeopardizing or overburdening future generations.

While choosing the projects for the case study, The company had 6 potential projects out of which three were completed and the other three were in concept and design stage which means that the FEED phase was not started yet .So, three first of a kind projects which were completed were chosen in this study because of the better accessibility to the project documents .Since these projects were already completed , sufficient information for the research could be gathered from the interviews.

Based on above criteria the following projects were selected, (see Table 1).

Type of the Project	Country	Phase	Project Code (to be used in this thesis)
Circular steam project	Netherlands	Completed	**A**
Carbon capture Utilization and Storage (CCUS)	Netherlands	Completed	**B**
Biofuel plant	Romania	Completed	**C**

Table 1: Basic Details of the projects

2.2.2 Interviewees Selection Criteria

To optimize the information acquired from the participants, a purposive sampling and selection rather than a random one will be conducted (APM, 2021). 2-3 participants in each project will be selected for an interview comprising a project manager, senior management member involved during front end development phase from the Engineering and Consultant firm and a package unit manager. Although the client representatives were contacted by the author, they were not willing to share the information through the interview due to the confidentiality agreement they had in their companies and the reason was the same for all the three projects from the client's perspective. Due to the above reasons only representatives from the company were selected and criteria for selection are as follows

1. The participant should hold a managerial position, overseeing single or multiple aspects of the project.
2. Should have been with the project since the start
3. Should be well versed with the proceedings of the project.

Based on the above characteristics the following interviewees were selected, (see table 2)

	Respondents	Position	Company
Project A: Circular Steam Project			
	Interviewee 1	Senior Project Manager	ECO
	Interviewee 2	Project Manager	ECO
	Interviewee 3	Package unit manager	ECO
Project B: Carbon capture and utilization storage project			
	Interviewee 1	Lead energy specialist	ECO
	Interviewee 2	Project Manager	ECO
Project C: Cellulosic Ethanol Project			
	Interviewee 1	Senior Project Manager	ECO
	Interviewee 2	Construction Manager	ECO
	Interviewee 3	Project Manager	ECO

Table2 : Overview of Interviewees

3 Literature Review

The aim of this chapter is present and elaborate the findings of literature. First, the concept of sustainable project management is introduced. Tools that are useful for integration of sustainability in first of kind projects are introduced and challenges to integrate these tools is explained as well. Sustainability measurement tools and assessment tools and criteria are then identified and explained by providing a framework for empirical work in chapter 4 and chapter 5

3.1 Background

The growing importance of balancing ecological, commercial, and societal factors in programs, the need to integrate sustainability into managing projects has gotten much attention in education with practitioners. Efforts to attain sustainability-related ambitions in project activities have been given crucial importance, suitable for complex first of a kind projects. The utilization of strategies for incorporating sustainability into the project management process of global climate projects is explored in this existing literature (Banihashemi et al., 2017). The core instrument of effective performance management, corporate sustainability planning, was introduced and evaluated to enable project leaders and supervisors to understand and implement it in these projects (Banihashemi et al., 2017). To characterize and ascertain the framework of sustainable program management, the subjective procedure relies on a literature review of participants' responses from project leaders working on science projects about climate (Armenia et al., 2019). Statistical approaches based on structural equation modeling statistical analysis of the data have been used (SPP). As a project planning approach, the findings show that SPP ought to be tridimensional, that is, administrative monitor, vulnerability assessments, and workforce collaboration which provides efficient resources which drive the project to success in global climate initiatives (Banihashemi et al., 2017). This review sheds light on academia and techniques related to the protracted managerial practices of project planning and the accomplishment of lengthy sustainability objectives in climate change initiatives.

3.2 Rationale for Integrating Sustainability in First of a Kind Projects

The expanding resource restrictions, the rising variety of stakeholders engaged, and the balancing necessity of ecological, commercial, and humanitarian objectives have all drawn attention to management in the context of projects. Sustainability with three factors (monetary, ecology, and societal sustainability) was previously suggested to be incorporated into project processes to tackle climate change and social difficulties, and financial aspects in doing business (Brzozowska et al., 2015). The necessity of sustainability will confront the work package and the project method of delivery, particularly for the project objective and the mechanism through which the work is accomplished. It necessitates maximizing resource allocation, adhering to a fixed timetable, and simultaneously attaining commitment purposes under various complex restrictions, particularly for significant climate change projects.

First of a kind projects, like all other turbulent and unpredictable projects, take a long time to complete, involve many stakeholders (– for example, authorities, subcontractors, developers, shareholders, service companies, and end consumers), and have significant societal implications

(Fathalizadeh et al., 2021). As a result, increasing partnerships among diverse participants, meeting a phase of achievable objectives, and ensuring top-tier sustainability becomes increasingly necessary projects.

Sustainable project management, defined as how resources are managed to ensure their sustainability objectives are met, has emerged as a viable area for pragmatic, sustainable construction (Lamers, 2002). Corporate sustainability leadership is associated with environmental, financial, and personal philosophies of the lifecycle of development's resources, procedures, milestones, and repercussions; corporate sustainability leadership focuses on planning, supervising, and managing building projects and supporting process to ensure that program is modified and suitable to encounter sustainability-related issues.

Even though SPP managing has been proposed to incorporate sustainability into product development, it remains an underappreciated and challenging field. Several studies looked examined how to include sustainability into first of a kind projects from the perspectives of sensitive prosperity attributes, range of projects mandating, and project monitoring, among other things. As a routine practice of the approach to managing process, project planning ought to be given greater attention in comparison to other techniques to achieve effective and successful project management throughout the project life cycle. Project scheduling was viewed as a frame of reference and arranging process connected to the program loop as one of the primary components of a durable plan approach (A. G. Silvius & Schipper, 2015). It directs the project delivery process to balance the numerous stakeholder expectations (Martens & Carvalho, 2017). Because first of a kind projects' sustainability-related objectives, such as cost, resource, schedule, and stakeholder satisfaction, are directly impacted. It is vital to incorporate durability into project approach procedures to guarantee that projects are executed sustainably. Even if scholars and managers in first of a kind projects recognize the importance of project planning, it is uncertain the effort that should be put into planning activities to achieve a high sustainability level (Rogers, Jalal, & Boyd, 2012). It is vital to establish and develop sustainable project planning to incorporate sustainability fundamentals and particulars into project planning practices and to maximize project planning's leading role.

Because there is no uniform definition or assessment of sustainable project planning, there is no practical and usable approach for incorporating sustainable features into projects. Project planning has been researched and accessible from several viewpoints in prior studies. Most of the research focused on its procedures, although it may be fundamentally evaluated by schedule, costing, and scope depending on planning elements. Despite focusing primarily on project quality and overall strategies, a category of maturity structures evaluates the comprehensive capabilities of project management processes connected to planning processes. Although the Project Management Body of Knowledge (PMBOK) recognizes 51% of project procedures relevant to project planning has limited redundancies and adaptability. Due to its comprehensiveness project Management Planning Quality (PMPQ), which consists of project know-how and organizational support processes, has received much attention (A. G. Silvius & Schipper, 2015). However, dealing with a progressive and reliable project environment is still difficult. Nevertheless, there is currently a shortage of appropriate structural study and assessment procedure for reliable project groundwork in first of a kind projects that explicitly describe how sustainability may be accomplished through good planning.

Schipper, Silvius, and Nedeski (2012) answered the question why sustainability should be integrated in engineering projects including first of a kind projects, the primary focus of this research. In their compelling argument, the recognition that the current ways of exploiting the earth natural resources in the attempt to develop societies and civilizations threaten resources depletion. Moreover, in the exploitation and use of earth's natural resources, pollution of the environment has been inevitable. This has unfortunately led to global warming and climate change which in turn threaten the very way of life and aspects of businesses. There is therefore the need to change the way natural, and other resources being produced and used. More obviously many organizations in other sectors are striving towards sustainable development and engineering – construction engineering - should be in the frontline, pioneering this change (Schipper, Sivius & Nedeski, 2012).

Moreover, Sustainability stresses on sparing use of resources and energy not only to minimize the risk of depletion but also to minimize waste and pollution (Silvius & Schipper, 2014). It advocates for the consideration of pollution impacts, hazardous substances and energy use of materials from production and through their entire life cycle. Materials that are durable, reusable and recyclable are recommended. Such kind of materials are less likely to promote increased Greenhouse gases emission in the construction industry, a factor that would aid in mitigation of climate change. Therefore, integration of sustainability in engineering projects, more so in first of a kind projects improves the chances of mitigating climate change.

3.3 Implementation of sustainability in first of a kind projects

The section covers activities used to integrate sustainability in the FEED phase of the project followed by the practices and tools used under certain activities which positively influence integrating sustainability in projects which answers SQ1.

3.3.1 Activities used to integrate sustainability in the FEED phase of the first of a kind project.

1. Managing the package unit vendors

Managers demonstrate their value in the project by effectively managing the supplier, contractors, and other external vendors through various phases of the project (Benton & McHenry, 2010). Through strong vendor relationship, organizations can fulfil the project's core mission with respect to sustainability goals. On the flip side, poor vendor relationship results in poor supply of project resources that could lead to project failure with subsequent setbacks with respect to the sustainability goals .The key to manage the package unit vendors starts by project managers building a relationship that prioritizes on trust and respect (Safa et al., 2017) that leads to knowledge transfer which can be used as critical success factor in integrating sustainability in projects.

2. Team integration

According to Baiden (2006), team integration is one of the effective concepts that have been used to foster alliances as a way of improving collaborative relationships between diverse organizations. The concept is achieved when parties from different companies connect properly with balanced disciplines and work in close collaboration to achieve clear targeted tasks of the project. The goal to achieve a sustainability in project, can only be achieved by an effective team integration (Baiden, 2006).

An effective team integration is built through trust, encouragement, accountability and transparency (Ibrahim, Costello, & Wilkinson, 2015). This in turn allows the team to engage which increases collaboration towards achieving the project's sustainability goals.

3. Interface Management

According to (Pavitt & Gibb, 2003) interface management is an important process, which helps in project development achieve sustainability by diving efforts among different teams. This process guarantees proper functioning of the project which is usually composed of many interfacing phases. Project managers use this process to ensure proper communication and transparency between multiple interfacing sub-systems (Shokri, et al., 2016). Failure to manage these interfaces will lead to delays in the projects thereby hampering the sustainability goals (Pavitt & Gibb, 2003).

4. Project Resourcing

This involves any resources needed to complete a project successfully and achieve sustainability. According to Raiden (2008), project resourcing is a key element of a project's planning phase and is centered on the identification of resource requirements and how they will be allocated. Proper project resource planning helps to keep the project running on schedule by ensuring that the targets in various phases are met in time while utilizing the resources from one phase to another.

Construction resource management is responsible for tracking down the resource availability, reallocating resources based on the project changes, ensuring that project teams have the right skills and experience, and identifying and resolving resource conflicts (Turner, Lingard, & Francis, 2009).

5. Research and development

Contractors perform this activity to enhance the efficiency and effectiveness of a sustainable project construction phases (Frederick, & Pijawka, 2014). Research and development are also essential when the projects require innovation and introduction of new technologies and methods that help the project thrive in the competitive market. It delivers this by providing a powerful knowledge and insights that leads to improvements of existing processes where efficiency can be increased, and costs is reduced.

3.3.2 Practices and Tools used under certain activities which positively influence integrating sustainability in first of a kind projects

McPhee & Dias (2020) present best practices and tools for integrating sustainability to engineering/construction projects. These practices and tools include:

1. Stakeholder Engagement – Stakeholder Engagement Plans (SEP)

Community opposition has seen to it many failures of projects to meet its scheduled milestones. The success of any projects is directly proportional to the level of support it receives from all its stakeholders including local communities. Some stakeholders in project include local and national governments, regulators, health agencies, contractors, suppliers, employees, shareholders and investors, customers and consumers, local communities, labour and trade associations, cultural associations, among others. A stakeholder engagement plan is an important tool/strategy for integrating sustainability in projects as it ensures smooth transition between project phases and can handle any unplanned changes like project delays harmoniously. Stakeholders can be engaged through town hall meetings, perception surveys, focus groups, formal working groups, design workshops, and site tours. Stakeholder engagement plan also informs team members on when to involve which stakeholder, the company and project's expectations as well as everyone's roles and responsibilities. It helps create a supportive environment between the external stakeholders and the project teams.

2. Sustainability Integration Framework

This document is a tool that provides project team members with the project's general approach, strategies and resources that are in place to facilitate achievement of the project's sustainability objectives. It embeds the concept of sustainability into the life of the project from planning, through design, procurement to construction phase. Therefore, it is applied over the entire life of the project. A developed framework should stipulate the deliverables of the key sustainability integration tasks including project delivery, environmental management and social responsibility. This will provide project teams with:

- A clearly defined methodology for integrating sustainability into the management of projects.
- An umbrella approach for all project tasks so the teams can make sense of interrelations between their roles and project's overall objectives.
- An understanding of the project's aims to integrate sustainability into the projects.

3. Managing Risks – Risk Management Plans

Sustainability risks are generally more complex and difficult to manage than conventional technical risk simply from the fact that they often entail external factors lying outside the project's perview and control. However, as McPhee & Dias (2020) assert, it's not a reason they should be left to run wild, they should be understood, managed and if possible, mitigated. For successful integration of sustainability into construction projects, the probable risks should be identified, the impact assessed, and their likelihood estimated. In infrastructure projects like first of a kind projects, environmental and social risk management is a major consideration to project management. Common Environmental risks include reduction of GHGs emissions or spillage which can be managed through design allowances.

Risk management action plans inform of the activities, designs, behaviours and processes to be modified to mitigate risks in the project. They are informative of who will 'own' the mitigation, when the mitigation measure will be implemented and how often the risk will be monitored (Yu et al., 2018).

4. *Managing Commitments – Commitment Action Logs*

During preliminary development of projects, commitments and promises are made by the organizations and projects teams to other stakeholders like the local community and regulatory bodies. These commitments include mitigating project impact on the environment and the societies, or community agreements, the project goals and objectives. A commitment action log lists all the promises the project has made to its stakeholders. The log keeps track of commitments made for example, for climate impact projects, these promises can be in environmental and social impact assessments to regulatory bodies. Commitment logs serve three primary purposes:

- Ensuring all promises of how to integrate sustainability are incorporated in the project's phases – planning, design and execution.
- Pinpoint critical path issues and impacts on project's phases including engineering design and construction.
- Risk that requires multi stakeholder attention are handled by commitment management team

Sr no	**Commitment Information**			**Project information**			**Commitment management**		
	Name	Description	Stakeholders	Department	Impact	Risk	Owner	Plan	Status
1									
2									
3									

Table 3: Simplified Commitment Log (McPhee & Dias, 2020).

5. Approvals and Permits

Approvals are permissions are required from governing bodies to allow projects like first of a kind to proceed entirely. On the other hand, permits are detailed permission for different components of the projects and are issued by regulatory bodies. In this context, approvals and permits are in reference to green engineering regulatory bodies such as BREEAM and environmental protection agencies. Approvals like environmental impact statements (EIS) provide benchmark for sustainability milestones by documenting the findings of the project's environmental and social impact assessments (McPhee & Dias, 2020).

6. Monitoring Sustainability Performance

Comprehensive projects like first of a kind require a long-term program to monitor the integration of sustainability and its performance. The project impact assessments usually establish a set of parameters that are used for baseline studies and that are in line with government standards. Integration of sustainability can be monitored against these parameters to measure the performance of the project regarding its sustainability goals.

7. The Last Planner System (LPS)

The Last Planner System (LPS) is a tool that increases worker productivity and accountability through tight scheduling and detailed group planning. The workflow method developed by the Lean Construction Institute which works on both small scale and large-scale projects (Ballard, 2000). For the large-scale project, Last Planner System is applied on each phase and works as managerial approach as it efficiently run the construction project (Porwal et al., 2010). The principle behind this method is to ensure that contractors in each department can manage their duties by being responsible towards their target goals.

3.4 Limitations and success factors to integrate sustainability in first of a kind projects

The section covers challenges in implementing tools/practices to integrate sustainability which answers SQ2, followed by the success factors in integration of sustainability in first of a kind project

3.4.1 Challenges in implementing the tools to integrate sustainability in first of a kind projects

The current definition of sustainability is very broad, and stakeholders hold different perspectives on the topic. The three-pillar approach and the integrated concept of sustainability are two approaches to explaining sustainability (Schipper, Sivius & Nedeski, 2012). In the impact assessment process, the former is the standard view of sustainability, which independently evaluates the environmental, social, and economic components. On the other hand, some advocates feel that there should be no trade-off between ecological assets and other socioeconomic goals and that sustainability should be founded on integrated and system-based thinking. The integrated principles of sustainability are also presented as a tool for assessing sustainability (*APM*, 2021).

According to Yu et al. (2018), interactive public engagement can influence established routines, attitudes, and perceptions. The foundation for facilitating the viewpoints mentioned above is interactive learning. The two most significant factors for integrating environmental thinking into policy planning are ongoing improvement of decision-making and learning at the individual and organizational levels (Martens & Carvalho, 2017). Organizational learning is based on the notion of double-loop learning. It refers to the reality that modifications to the governing aspects underlying the action will be made when mistakes have occurred. The culture or approach, for example, will be substantially altered. As a result, the learning process in projects is crucial for a drastic shift in institutional restrictions.

Although incorporating sustainability into first of a kind projects has gained traction, the question is of how much the project management profession has played a role in adopting tools/practices to integrate sustainability and what are the challenges faced in implementing these tools/practices in first of a kind projects remains unanswered (Yu et al., 2018). Several authors have presented the challenges faced in incorporating sustainability in first of a kind projects, (see table 4).

Number	Study reference	Challenge/barrier
1	Shen, Zhang & Long (2017)	Insufficient financial incentive and lack of evident return on investment.
2	Shen, Tam, Tam & Ji, (2010)	Lack of investment on sustainability
3	Broman & Robèrt, (2017)	Lack of systematic approaches to planning and execution of works in fulfilment of sustainability.
4	Broman & Robèrt, (2017)	Incomprehension of the potential benefits of proactivity in combating climate change and implementing sustainability, and the economic risks associated with lack thereof.
5	(Banihashemi, Hosseini, Golizadeh & Sankaran, 2017)	Inadequate studies and education on sustainable delivery of construction projects including first of a kind projects.
6	(Banihashemi, Hosseini, Golizadeh & Sankaran, 2017)	Lack of support from policy makers

Table 4: Challenges/barriers in integrating sustainability in construction projects** **Fathalizadeh et al., 2021).

3.4.2 Success factors in integration of sustainability in first of a kind projects

Integration of sustainability in the management of projects is a challenge (Silvius & Schipper ,2015). Some countries, companies and project management professionals are still lagging with respect to integrating sustainability in projects from a project management perspective. Banihashemi, Hosseini, Golizadeh & Sankaran (2017) identified the critical success factors which will help in integrating sustainability in engineering/construction projects. These success factors include:

1. Knowledge Transfer

The existence of knowledge about sustainability and sharing of that knowledge among team members was found to be a critical success factor in integrating sustainability in construction projects. In summary, establishment of constructive working relationship among all stakeholders in these projects is the bottom line. This tracks with the supposition of Silvius & Schipper (2015) that knowledge and stakeholder involvement play a crucial role in delivering sustainable projects. A team with distorted working relationship, and that which neglects to involve its stakeholders in the project management practices provides a great challenge to the integration of sustainability in construction projects.

2. Accountability and Transparency

As Silvius & Schipper (2015) presented, sustainability is all about transparency and accountability. Clients and influential stakeholders in first of a kind projects need to portray and ask for transparency and accountability. The organization/company also need to be open to accepting accountability and transparency. In their study of critical success factors of integrating sustainability in developing countries, Banihashemi, Hosseini, Golizadeh & Sankaran (2017) found the lack of transparency and accountability as key impeding factors to the integration of sustainability in construction projects.

3. Strategic Direction

Fierce competition in development and market gets in the way of implementing strategies, for example sustainability strategies. Therefore, crucial concepts of sustainability like accountability and transparency are overlooked. Therefore, the existence of strategic direction keeps integration of sustainability in construction projects on track and lack thereof brings up a challenge in integrating sustainability.

4. High Quality Workmanship

Experienced and well-trained workforce in first of a kind projects are pivotal to the success of integrating sustainability in such projects. First of a kind projects require execution of task that demand more technical skills than normal infrastructure projects. Quality and skilled workforce can be trained and licensed in accordance with the policies of governments and professional bodies

(Banihashemi, Hosseini, Golizadeh & Sankaran, 2017). Unskilled workforce impedes successful integration of sustainability in construction projects, including climate impact projects.

5. Project Manager's Knowledge, Skills and Abilities

More than often, project managers do not possess the necessary knowledge, skills and abilities, as well as experience to choose the right construction materials and methods and to utilize resources efficiently. In other times, as argued by Banihashemi, Hosseini, Golizadeh & Sankaran (2017), recruiters concentrate too much on the technical skills of project managers and neglect the soft skills required of a project manager. Development programs in professional bodies often either lack or are inefficient in equipping project managers with the necessary knowledge, skills and abilities. All these compounded make transitioning sustainability to construction projects all challenging.

3.5 Integrating sustainability in projects through stakeholder engagement

Several steps have also been identified to engage stakeholders during project's initial phases. These steps can be used as critical success factors in integrating sustainability in these projects.

- **Identification of key stakeholders**

The first step before engaging anyone is identifying the key stakeholders associated with a construction project. As Silvius & Schipper (2019) determined, although there are many stakeholders in a construction project depending on their size, there are only a handful of key stakeholders salient to integration of sustainability. Identification of key stakeholders is thus critical and its guided by their interests, power, and attitude – generally the potential they have towards achieving sustainability integration.

- **Relating Stakeholders to sustainability-related targets**

Silvius & Schipper (2019) further presented that different stakeholder possess different skills and knowledge and thus their ability to produce sustainability-related outcomes is different as well. Thus, relating stakeholders with different sustainability related targets as early as the front-end development phase is prudent. From their study, (Silvius & Schipper, 2019) concluded that key stakeholders should be made aware of the project's commitment and objectives towards sustainability from the beginning.

- **Stakeholders' prioritization**

As Bal, Bryde, Fearon & Ochieng (2013) provided all stakeholders in construction projects are important. However, their potential to impact the success of the project in regard to the achievement of sustainability-related targets differ. As a result, stakeholders should be prioritized based on their contribution to the achievement of sustainability-related outcomes, as well as their ability to influence, bring about and enforce integrity and legitimacy, and impart knowledge necessary to integrate sustainability. Prioritization can also be based on the stakeholder's contribution, economically, socially and environmentally, to the project's sustainability efforts, and on invested interest in seeing the project deliver sustainable outcomes.

- **Stakeholder management**

Management of stakeholders in construction projects implies fulfilling expectations of all that have interest, or influence on the projects, and those assuredly affected the project's deliverables (Bal, Bryde, Fearon & Ochieng, 2013). Stakeholder engagement and action plans are required from the beginning to maintain relationships and raise consciousness of the project among those that its success depends on.

3.6 Conclusion of literature exploration

The literature review provided information on sustainable project management, tools/practices used to integrate sustainability in first of a kind projects , challenges encountered in integrating sustainability and success factors for integrating sustainability. This chapter also aided in answering SQ1 and SQ2.

SQ1: What are the tools/practices which could positively influence in integrating sustainability in first of a kind projects in theory?

According to the literature, tools/practices which could positively influence in integrating sustainability in first of kind projects are listed below.

- Stakeholder Engagement – Stakeholder Engagement Plans (SEP)
- Sustainability Integration Framework
- Managing Risks – Risk Management Plans
- Managing Commitments – Commitment Risk Action Log
- Monitoring Sustainability Performance
- Approval and Permits
- Last Planner system (LSP)

SQ2: What are the limitations and challenges in implementing the tools/practices to integrate sustainability in first of a kind projects in theory?

Implementing tools/practices to integrate sustainability in first of a kind projects is always a challenge. What makes it even more challenging is that the current definition of sustainability is broad, and stakeholders hold differing perspectives on the topic (Yu et al., 2018). Although integrating sustainability into first of a kind project has quite gained some momentum, the question yet remains how much the project management profession has played a role in implementing tools/practices to integrate sustainability in projects (Yu et al., 2018). McPhee and Dias (2020) showed the best tools/practices used to integrate sustainability in first of a kind projects. Several studies also show the limitations/challenges in implementing these tools/practices to integrate sustainability in first of a kind projects and these are listed below.

- Insufficient financial incentive and lack of evident return on investment (Shen, Zhang & Long, 2017).

- Lack of investment on sustainability (Shen, Tam, Tam & Ji, 2010).
- Lack of systematic approaches to planning and execution of works in fulfilment of sustainability (Broman & Robèrt, 2017).
- Incomprehension of the potential benefits of proactivity in combating climate change and implementing sustainability, and the economic risks associated with it (Broman & Robèrt, 2017).
- Inadequate studies and education on sustainable delivery of construction projects including first of a kind projects (Banihashemi, Hosseini, Golizadeh & Sankaran, 2017).
- Lack of support from policy makers (Banihashemi, Hosseini, Golizadeh & Sankaran, 2017)

Furthermore, the literature review was used as a guide to select activities for the case study. Due to the limited research material available, other project documents were consulted. This greatly aided in the development of an organized format for the literature review and research. Management of package unit vendors, team integration, interface management, project resourcing, and research and development, as well as constraints and obstacles in applying tools to incorporate sustainability in first of a kind projects, are all mentioned. These techniques and practices mentioned in the literature will provide guidance for performing the case studies.

4 Case study

This chapter begins with the discussion on the data obtained from 3 first of a kind projects followed by analysis of the cases where the tools/practices used to integrate sustainability in three first of a kind projects is explored.

4.1 Methods

After thorough analyzation of a contemporary real-life issue with little control, a case study approach was chosen. Furthermore, the case study approach is well suited to answering a descriptive research question (Blaikie, 2009) like SQ3 in this research.

4.1.1 Case study protocol

The approach to achieve integration of sustainability in first of a kind projects required exploration of tools/practices under few activities. The protocol outlined the actions to follow. To eliminate bias, all participants received the same brief information on the interview goals. With a short mail, the anticipated participants were invited to participate in the interview. All the project professionals who were approached were eager to take part in the study. Project documentation, such as progress reports and close-out reports, were examined prior to conducting the interviews. As a result, prior to the interview, the interviewer was already familiar with the subject and the projects. The written data was also utilized to confirm and supplement the results of the interviews.

The interview meeting was recorded with the permission of interviewees. The interview was semi structured (William Adams, 2015) meaning there was room to ask additional questions based on the response's interviewees gave to the questions which were framed before. The interview questions were mainly focused on activities in FEED phase and its sustainability aspects next to the focal point resulting from the literature study (sections 3.3,3.4,3.5). Project documents were studied which resulted in the following additional themes for the interview: project scheduling, lessons learned, project risk and kick off meetings.

Recordings of the meeting were used to prepare the transcripts which were sent back to interviewees to cross-check and confirm if their answers matched the information from the meeting. A total of 22 questions under 9 different categories were framed. The categories and the interview questions which fall under each category are listed in Appendix 4.

4.1.2 Data Analysis

The interviews were analyzed qualitatively per case and by cross case analysis, with an emphasis on the respondents' diverse opinions on sustainability and activities in the FEED phase. The data was compiled into a single database, which included information on the participants backgrounds and project details.

All the three projects which were chosen were first sketched with a general overview of the project which is about half a page under each chosen case. Next actual analysis of the individual project activities took place showing how sustainability was perceived in each activity in the FEED phase of the project. Since the interviews were taken separately, they were not aware of the answers given by the other interviewees. In the next chapter, cross case analysis was conducted which focused on exploring trends on challenges faced in integrating sustainability in FEED phase of the first of a kind projects.

In subsequent sections of the case analysis, a brief description of the projects is introduced. Next, the project team, which was involved and new technologies/methods which were used are also described briefly. Subsequently, in each case different perspectives by interviewees on sustainability in FEED phase of the project were analyzed. Also, the activities which were most important to integrate sustainability were discussed. Next, the interviewees perception on tools/practices used to integrate sustainability under chosen activity was also discussed. More detailed description of interviewees response is shown in the below cases, complete description of interviewees response as well as tools/practices used to integrate sustainability under each activity are listed for project A, B and C respectively.

4.2 Case 1: Project A: Circular Steam Project

4.2.1 Brief Case Description

The Circular Steam Project (see figure 2), integrates cutting-edge technology into an existing manufacturing facility to transform wastewater into electricity. This project will improve the efficiency and sustainability of the site's existing production process, resulting in an annual reduction of approximately 140,000 metric tons of CO_2, 0.9 Petajoule of energy, and the avoidance of the release of 11 million kilograms of salt residue into surface water. The project being a first of a kind project is an important contribution to the CO_2 reduction target which is set by Dutch government. This project will result in annual CO_2 reductions equivalent to the removal of 31,000 automobiles of the road, as well as annual energy savings equivalent to the power consumption of Breda's 90,000 households. This is a step forward in the sustainable production. At the Maasvlakte site of LyondellBasell various caustic wastewater streams are generated. Currently these streams are sent to AVR for further treatment in the AVR Caustic Water treatment plant. LyondellBasell and AVR were engaged in negotiations for the extension of the contract, but a possible outcome was that the contract will be terminated by 2019.Anticipating on that situation, the client had initiated the wastewater treatment (WWT) project, which concerns the realization of a new treatment facility for the caustic wastewater streams at the Maasvlakte site of the client. Approximately 71 people were employed full-time during construction, with 11 full-time roles being created for operating the new facilities.

Figure 2: Circular steam project

4.2.2 Interview Results

Representatives Interviewed

Respondents	Position	Company
Interviewee 1	Senior Project Manager	Engineering and Consultants
Interviewee 2	Project Manager	Engineering and Consultants
Interviewee 3	Package unit manager	Engineering and Consultants

The following is an overview of the tools/practices used to integrate sustainability in FEED phase in first of a kind project (for a complete description, see Appendix 1):

General question

Each interviewee was asked a general question of their understanding of sustainability in the project context. Interviewee one defined the sustainability of this project as choosing the right technology and material for the reduction of carbon dioxide and other greenhouse gas emissions, while interviewee two and three emphasized that the main sustainability goal was to increase the energy efficiency, which was increased by 55%, from 30% to 85%.

1. Kick-off meeting

Interviewee two stated that all key members of the contractor team and all involved departments of the client were present at the kick-off meeting, where sustainability advantages were mentioned. Interviewee one emphasized on informing that the project started as a sustainability project. The project's main purpose was to improve the operating time for the plant by ending the contract with another contractor under the original name, wastewater treatment project. Later (during the EPCm phase), that was changed to the Circular Steam project. In ensuring the project's success, many studies had been executed in the past as the project officially started in 2008. For the past nine years (2008-2017), sufficient studies resulted in 20 alternatives regarding the sustainability goals, which proves that the project was very much focused on sustainability. Two additional years of study were used to design the technology through technical specifications set up, together with the technical engineering of the client. This aided in the collection of all the findings of the studies, and all of this were discussed in the kickoff meeting with the relevant stakeholders.

2. Managing the package unit vendors

Interviewee three explained that competitive biddings and hard negotiations were done, which aided in choosing the vendors for the necessary project materials/technology. Chosen vendors agreed and guaranteed values about the sustainability requirements and their responsibility to meet project goals, ensuring zero concessions during the design. There were delays in the project when the vendor went financially bankrupt in the conceptual phase, and the old situation, with lower energy efficiency, lasted longer. Adding to this, interviewee two stated that a package unit manager was appointed to manage the vendors and help them reach the targets as well as the sustainability requirement.

3. Team integration

Despite the delays caused by the vendors as noted by interviewee two, team integration played a key part in the success of this project through the planned meetings to come up with the requirements of sustainable standards and goals. By working closely together, client team members had a desk in the contractor office, and a few days in the week, they were present in the contractor office. The project's success led to Oschatz (vendor) winning the competitive tender during the FEED phase. Oschatz completed a new incinerator for a similar smaller service in China, client and contractor representatives made a study trip to get a good insight of the project which was useful in implementing few things in this project.

4. Lessons learnt and project risk.

Interviewee two stated that the lessons learned from a previous boiler project on the client site were reviewed. Sustainability was addressed mainly related to the energy efficiency and how to reduce greenhouse gas emissions. Common environmental risks like reduction of GHGs emissions or spillages were identified through EIA (Environmental impact assessment), which was a part of the permitting procedures. Design reviews were held, e.g. paving & drainage and further general identification of project risk done through RI&Es, specifically HSE oriented as well.

5. Interface Management

Interviewee three felt that the focus while addressing the sustainability in the interface management was through sustainable project planning (finishing the project on time and within budget to meet the CO_2 emission requirements which were planned before). This ended up failing due to many interfaces in the project, which consisted of new, unfamiliar technology. This led to the overall delay of the project, which affected sustainability.

6. Value Improving practises

The second interviewee felt that technology selection was one of the main tools which focused on the value improving practices to integrate sustainability in the early phases. This helped in the involvement of the stakeholders in various practices such as design to capacity, waste management, 3D designs, constructability, wherein a lot of money was saved, and there was no compromise regarding the sustainability objectives, in fact value improving practices helped achieve sustainability.

7. Project Resourcing

Management of resources was effectively done during the FEED phase of the project. However, interviewee one stated that there were a few problems regarding this, such as document control, which became a problem during the FEED phase of the project due to many documents from the suppliers that required review. There were only a few people from the integrated team who were looking into it. Adding to that, the team was also looking into their own design, which created more problems.

8. Project scheduling

There was a tight schedule in the FEED phase of the project, although it did not compromise the project's sustainability. However, interviewee two felt that there was a tight schedule and not having a realistic schedule in the project delayed the progress, which could have been done better by project planning. Adding more people to the integrated team would have done a better job according to interviewee two.

9. Research and Development

The main motive of this research area was to research technologies that were to be chosen to meet the sustainability requirements and choose the right suppliers/vendors after thorough research of their past projects and their experience. However, interviewee one felt that the research area was not only limited to the studies. There was also research going on the testing that has to be done to meet the sustainability criteria and how to reduce the GHG'S to the maximum extent by using the right technologies. Interviewee two said that the developments with respect to the research was done right and technologies were selected which would decrease to CO_2 emissions. He also stated that, there were 20 alternatives which were studied and set up before FEED phase and the best alternative for design was chosen which contributed very much to sustainable goals and to reduce the environmental risks.

4.2.3 Overall case conclusion

The main sustainability goal was to increase the energy efficiency from 30% to 85% but the energy efficiency was only increased to 60% because the project was delayed due to the vendor who failed in supplying technologies for this project. For the past nine years, sufficient studies resulted in 20 alternatives regarding the sustainability goals, which prove that the project was very much focused on sustainability. The focus while addressing the sustainability in the interface management was through sustainable project planning which required the finishing of the project on time and within budget to save the CO2 emissions and meeting the energy efficiency targets as planned initially. Furthermore, tight schedule delayed the project progress and the project could not save the CO2 emissions and meet the energy efficiency targets as planned. The main lesson learnt from this project was sustainability could have been achieved as planned if there was realistic schedule and if the package unit vendors were managed properly. Interviewee two also felt that having a large management team can help managing the package unit vendors which will not delay the project and also help in achieving the sustainability targets on time.

4.3 Case 2: Project B: Carbon capture and utilization storage- AVR

4.3.1 Brief case description:

Carbon Capture, Utilization, and Storage is a critical technology for achieving climate-neutral industry. Capturing and storing CO2 emissions minimizes the quantity of greenhouse gas emissions that are hazardous to the environment. The project utilized innovative technologies and not all partners had experience with involved. Approximately 15% of the carbon dioxide produced by the incineration of residual waste is re-cycled in this manner. This equates to a total yearly CO2 output of 60,000 tonnes, which may be boosted to 100,000 tones to satisfy rising demand. The contractor conducted the feasibility study for the client and provided conceptual, basic, and detail engineering, as well as project and construction management assistance to the client. The project team included 5 members from the contractor side and 5 members from the client side. The planned expenditure of the project was 20 million Euro. The project was completed in a short time span by cutting it into pieces, meaning when there was enough information about one piece of the project, it was started.

Figure 3: CCUS plant

4.3.2 Interview Results

Representatives Interviewed

Respondents	Position	Company
Interviewee 1	Lead energy specialist	Engineering and Consultants
Interviewee 2	Project Manager	Engineering and Consultants

General question

Each interviewee was asked a general question of their understanding of sustainability in the project context. While defining sustainability, interviewee one said that the project in itself is a sustainability project which captures 5000 tons of CO_2 per month. Further the goal was to upgrade the utilities, chemical storage, and wastewater disposal to meet the new environmental permit requirements and client standards. Main focus for this was loss of containment and allow emissions. Interviewee two stated that project scope was to implement Carbon Capture & Utilization (CCU) at AVR waste incineration plant reducing CO_2 emissions. This results in capturing 60 kton/year CO_2 and converting it into liquid CO_2 product to supply to green houses. This replaces grey CO_2 from fossil fuel (Natural gas) currently used.

1. **Kick-off meeting**

According to interviewee one, the project team from both the client/contractor side was present in each meeting, accompanied by important stakeholders from different departments. The purpose of the meeting was to share the importance of the project and its sustainability goals. Interviewee two stated that, the initial phase of this project was started by AVR-TNO in the FELI phase 1 year earlier, which targeted to assess the technology and capture efficiency targets. Contractor scope started at FELII till the final hand-over phase. FELII and beyond was for basic design and engineering of the capture plant and the integration/interface of utilities with the main waste to energy plant at the best possible overall energy efficiency.

2. **Managing the package unit vendors**

According to interviewee two, managing the package unit vendors was a key hurdle for this project but it did not have a substantial effect on the sustainability goals. Once the utility, consumables/chemicals & wastes were defined, the evaluation on "optional" scopes related to this flow was started in the early work, and actions that aimed to bring in additional or optional scope by design change were made possible.

3. **Team integration**

Team integration is achieved when parties from different companies connect properly with balanced disciplines and work in close collaboration to achieve clear targeted tasks of the project. Interviewee two stated that, a 3 D model and a well-managed communication corridor was set up in the project to achieve team integration.

4. **Lessons learned and project risk.**

Interviewee one pointed out that during the FEED phase, different learning sessions were conducted, aiming to assess risks encountered during the project. This helped both the client and the supplier. The client looked at the project risks while the supplier accessed the scope risks. Regarding sustainability, the focus was mainly on the lessons learned of the requirements from the environmental permit, meeting the industrial standard for loss of containment, and preventing emissions.

5. Interface Management

Interviewee one said that the basis for design in the interface management was a 3D model prepared by contractor based on conceptual information. During the project, all the different lots were exchanged by 3D models with the vendors. This way, the interfacing was possible, and clashes were managed. Interviewee two stated that , the main challenge was that there were interfaces between design and engineering activities which caused delays in the project and there were not able to save the CO_2 emissions and meet the energy efficiency targets as planned.

6. Value Improving practices

Interviewee one pointed out that, several options were identified as part of the contract. For example, in the end, the MEA storage (chemical to capture CO_2) was outsourced to another company because they were more experienced in certified double-wall tanks, which limits the possibility for loss of containment. In cases where sustainable options were chosen, they were determined based on proven technology, ALARP, and timing.

7. Project Resourcing

Interviewee one clarified that no specific tools were used to fulfil resource demands and effective management of resourcing. Resources were mainly outsourced, and it was the responsibility of the sub-contractors. This was essential as it encouraged the involvement of the sub-contractors as early as possible and limited the client project team to get involved very often.

8. Project scheduling

According to interviewee two, the project was well defined and prepared ,but delays were caused when the vendors were not able to supply the package units. All items were later addressed in good time before handover and final acceptance protocols.

9. Research and Development

Interviewee two said that the motive behind setting up a research area was to choose the right technologies/methods and the designs for these technologies which can help in saving the CO_2 emission and in increasing the energy efficiency during the FEED phase of the project. Interviewee one stated that there were also research going on the testing these technologies to meet the sustainability criteria in the project.

4.3.3 Overall case conclusion

The project in itself was a sustainable project which captured 60kton/year of CO_2. However, during the FEED phase managing the package unit vendors was a key hurdle which had substantial effect on sustainability goals. According to interviewee two, lesson learned session gave a good insight to stakeholders on failures of the vendors previous project and what really went wrong with respect to sustainability aspects which was used as critical success factor to integrate sustainability in the project. Interviewee one also stated that 3D model which was prepared by the contractor was really helpful because lot of information regarding the technology was exchanged with the vendors using the 3D model which helped them in achieving certain sustainability goals Interviewee two also stated that setting up a research area along with bringing in specialists from different companies helped them in choosing the right technology/methods which in turn helped them in achieving their sustainability targets . In addition to that, interviewee two stated that the focus was not only on the main topics such as contract scope, quality, planning and costs but also the review of the general technical requirements of the employer/owner.

4.4 Case 3: Project C: Clariant Cellulosic Ethanol Project

4.4.1 Brief case description

Clariant has built a Sun liquid® production facility in Podari, Dolj Romania, (see figure 4) . With this project, client wants to produce bioethanol with high purity from straw and has developed a new production process in which 1 ton bioethanol can be produced from 4-5 tons straw. The planned production capacity of the new facility in Romania is 50.000 tons/year. The bioethanol is intended for either mixing with fossil (Car) fuels or as base chemical. The project being first of kind will play an important contribution to the CO2 reduction targets which is set by the Romanian government. The project can save greenhouse gas emission especially the CO2 emissions by approximately 60% through its carbon capture technology.


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Figure 4: Clariant Romania plant

4.4.2 Interview Results

Representatives Interviewed

Respondents	Position	Company
Interviewee 1	Senior Project Manager	Engineering and Consultants
Interviewee 2	Project Manager	Engineering and Consultants
Interviewee 3	Construction Manager	Engineering and Consultants

General question

While defining sustainability interviewee one, two and three all stated that Clariant's sun liquid® is a highly innovative and sustainable technology that produces cellulosic ethanol and cellulosic sugars from agricultural residues such as cereal straw, corn stover, or sugarcane bagasse. Interviewee one and two also stated that if they would take carbon capture into consideration, the greenhouse gas savings could reach up to approximately 60%.

1. Kick off meeting

Interviewee one and two stated that the FEED itself was done by another company. However, due to the unfinished nature of the FEED (Basic Design package), contractor introduced a Basic Design Review phase and Basic Design Update phase to the project, before starting with the EPCm works. The Basic Design Review sessions were done at client's premises with all lead engineers and client counterparts involved. These meetings were held twice a week. Regarding sustainability, the project itself had its sustainable benefits. Next to that, savings on energy consumption and savings on water usage were defined during the kickoff meeting. In addition to that, quality criteria in choosing the technologies and methods were also discussed during the kickoff meeting.

2. Managing the package unit vendors

According to interviewee three, managing the package unit vendors was a key hurdle for this project because vendors were not able to supply the package units due to which planning was continuously jeopardized. The design however was done fully by the package unit vendors due to which sustainability was achieved based on expertise of the vendors. In case the vendor was able to deliver complete black boxes with a clear scope split, management was made easy. Unfortunately, that was not the case as a lot of vendors were not able to provide the complete black box and e.g. exclude civil works, automation or piping. This means that the number of interfaces was increased from a dozen of interfaces to hundreds of interfaces. And each interface needed to be correct, otherwise claims would follow.

3. Team integration

According to interviewee two, an integrated team stimulated sustainability by providing the flexibility to incorporate design improvements, even in such a complicated project with many dependencies. This also allowed for energy optimizations. (e.g. the number of fermentation tanks were reduced successively (6 → 4 tanks, number of yeast separators (4 → 2), etc.). Interviewee one said that engineering platforms (COMOS, E3D, Navisworks) were used as practices/tool to ensure the engagement of stakeholders from client and contractor in the project in defining requirements of materials and technologies and that they were open and available to the client daily. Furthermore, interview added that this was beneficial as they could contribute and optimize on a continuous basis which was imperative for the success of the project.

4. Lessons learned and project risk

According to interviewee one, there was a demo plant set up in Germany where the vendor and the whole team went to learn about its operation, risks and how sustainable was the plant working. During this lesson learned session, the main motive was regarding the sustainability goals and technologies that must be used in order to save the energy which was the plan and to increase the energy efficiency as well. There were no specific tools used during this stage though standard procedures such as EIA + HAZOPs +SIL were used as practices/tools to determine the mitigation actions such as environmental risk and how engaged the stakeholders were in identifying, assessing, and determining the mitigation actions of the risks.

5. Interface Management

According to interviewee two, there were lot of interfaces involved because the vendors could not deliver the black box on time which delayed the project during the FEED phase. So sustainable project planning was addressed in the interface management. Interviewee two stated that sustainable project planning is having realistic schedule, budget and having the right team to manage the interfaces. Interviewee three also stated that due to lesser number of people in the integrated team, managing these vendors became a challenge for them which delayed the project in FEED phase which means they could not save the energy as well as the CO_2 emissions as it was planned before.

6. Value Improving practises

According to interviewee three, issues of time and budget arose during construction which became a major challenge and left not much room for ideals and goals in terms of sustainability that had to be achieved. Interviewee two said that the client had internal value engineering sessions in which proposals were done to limit the CAPEX. Thereafter review of the proposed solutions and advise on whether and how to implement them was conducted during these sessions. Interview three also mentioned that limiting the CAPEX was one of their main sustainability objectives.

7. Project Resourcing

The practises used for fulfilment of resource demand and effective management of resources according to interviewee one was level three resource loaded schedule in combination with a physical task force team in one of the contractors' offices. Not only engineers from contractor side, but also the client was obliged to be present in the task force area at least two days a week. This helped us in effectively managing the resources which in turn in contributed to the sustainability goals of increasing the energy efficiencies in the project.

8. Research and Development

According to interviewee two, the main motive behind setting up the research area was choosing the right technologies / methods to integrate sustainability in the project. The research area was set up by the client who did a quite good amount of research on how to reach the sustainability goals by choosing the right technology. After their research, contractors started researching on the designs of these technologies and doing research on the vendors who were capable in supplying this package unit. Interviewee one stated that the contractors had planned to complete the research before the start of FEED phase, but it was extended till the execution stage which had led to more than 500 changes in design and other methodologies which in turn was challenging for client/contractor in choosing the vendors as well as bringing the project on the right track.

4.4.3 Overall case conclusion

During setting up of the project, team integration stimulated sustainability by playing a key role in the flexibility to incorporate design improvements, even in a complicated project with many dependencies. Managing the package vendors was a challenge since the vendors could not deliver the package units in time. To ensure that the project will run smoothly, the vendors and other team members did a prior assessment to a demo plant set up in Germany which offered lessons on the possible risks and solutions on how to run the project sustainably. The projects main motive behind setting up a research area was to achieve sustainability. This was supported by choosing the right technology and integration methods for the project after which contractors started researching on the designs of these technologies and doing research on the vendors who were capable in supplying this package unit. One of the main take away from this project was key to achieving sustainability in FEED phase of the project is by managing package unit vendors and to have in depth research done on the technologies to be used. But from the answers of the interviewees, research was prolonged till the execution stage which led to 500 major changes which in turn delayed the project affecting the sustainability goals.

4.5 Case Analysis

The themes selected for the case analysis were the same activities which were chosen for the interviews of three first of a kind project. The findings of tools/practices explored in all three first of a kind projects are listed under each activity and these tools/practices were explored from the interviews. Similarities and differences in implementing these tools/practices between the three projects are discussed in subsequent sections.

4.5.1 Findings on Managing the package unit vendors

In Project A, a package unit manager was assigned to oversee the vendors, ensuring that the vendors design process moves at a steady pace and that agreed-upon milestones are met on time, allowing the interconnection scope to be further developed. He also oversaw coordinating interfaces between the stakeholders, i.e., the vendors and the client/contractor. He was also responsible for the coordination of stakeholder information as well as the technical bid evaluation. He was also in charge of progress monitoring and follow-ups, using the techniques agreed upon by the stakeholders. Even though a package unit manager was assigned, the project was delayed because the vendor went bankrupt and began obtaining supplies from other players in the market, which did not affect the specifications but delayed the project and the projected energy efficiency objective could not be met.

In project B, package unit manager was not appointed because the integrated team believed that although managing package unit vendors was a key hurdle, it did not affect their sustainability goals/objectives since the objectives were established in the functional description created during the tendering phase and at the conclusion of the contract. This was part of the selection process. The contract was managed according to functional needs, and the vendors oversaw the rest. Vendors who failed to achieve the functional requirements were eliminated from the running.

Project C followed a similar approach as project A, a package unit manager oversaw the work done by the package unit vendors and ensuring that milestones were met on time. On top of it, client also set up a package unit managing team which comprised of four people to have an overview of the work done by the package unit manager. Weekly meetings with all vendors were held by the package unit manager and the package unit managing team to discuss progress, modifications made to the package unit, and follow ups and agreed methods given to them after consultation with stakeholders. Although a packager unit manager along with package unit managing team was assigned to manage the package unit vendors, project was delayed because the vendors could not deliver the complete package unit which created lot of interfaces. The only difference of this project when compared to project A although there was a delay project kept going, where in for project A it came to a standstill because the vendor went bankrupt.

4.5.2 Findings on Team Integration

In project A, an integrated team was set up to ensure collaboration between client and consultant parties to ensure that all the established requirements on sustainability objectives were met. The project team engineering meeting was held once a week using an escalation model to update all stakeholders on progress and to discuss issues that required separate meetings to resolve. A. This meeting was intended to ensure that all concerns, actions, and decisions made will be monitored, followed up on, and resolved as quickly as possible.

In project B, well established communication corridor along with a 3 D model was set up to ensure all sustainability objectives were met in the FEED phase of the project. Communication corridor was set up mainly to discuss all the sustainability challenges the project is facing with the stakeholders and come up with a sustainable solution to the challenge. 3 D model was an open platform created by the contractors to make the information more accessible to relevant stakeholders on a weekly basis. Collaboration took place between the vendors and the contractor/client through this model.

In project C, an integrated team was set up which stimulated sustainability by providing flexibilities to all the relevant stakeholders to incorporate design and for energy optimization through Engineering platforms like COMOS, E3D and Navisworks. These tools were open platforms and ensured engagement of stakeholders in choosing right technology and methods for the project.

4.5.3 Findings on Lessons learned

In project A, a lesson learned session with all relevant stakeholders was organized with the goal of gathering information and evaluating experience from past first of a kind projects completed by vendors and applying it to this project as critical success factors. Sustainability was mostly discussed in this session in terms of energy efficiency and ways to reduce greenhouse gas emissions.

Project B adopted a similar approach project A, but the only difference was lesson learning session with all the stakeholders was not done on vendors previous first of a kind project, but it was mainly done to assess the risks encountered during the project. Furthermore, there was also lesson learning session regarding sustainability that focused on achieving the industrial norm for loss of containment and reducing greenhouse gas emissions

Project C followed the same strategy as project A. The major goal of the lesson learned session in Project C was to select the appropriate technology for the project, based on lessons learned from the vendor's previous first of a kind project. One of the primary learning sessions in this project was when all relevant stakeholders visited the demo plant which was set up by the vendor to learn about the plant's operations, risks, and how sustainable the plant was in terms of the technologies used. A lot of stuff concerning energy optimizations, efficiency, and technologies to be used to reduce greenhouse gas emissions were also discussed in this lesson learned sessions.

4.5.4 Findings on Project Risk

In project A, a project risk assessment and evaluation workshop was organized, and all stakeholders were invited to learn about the project's threats and opportunities. When it came to risk mitigation, a small group of specialists from the integrated team was tasked with determining risk mitigation actions. The integrated team used tools like environmental impact assessment (EIA) to identify common environmental risks like greenhouse gas emissions or spillages.

In terms of project risk, there were two phases in project B, one in which the client investigated project risk and the other in which the supplier analyzed scope risk. Tools like EIA (Environmental Impact assessment) was used in this project to identify common environmental risk and gate reviews was done in assessing them and providing mitigating measures to the risk.

In project C, EIA, HAZOP and SIL were tools used to determine the mitigation actions for environmental risks like greenhouse gas emission as well for the spillages.

4.5.5 Findings on Interface Management

In project A, HAZOP and SIL sessions was organized with selected vendors to manage the interface between the units and the interconnecting scope which helped to achieve the sustainability objectives/goals.

In project B, a 3D model was developed that allowed for the exchange of information with vendors regarding interfaces as well as the management of clashes in the project due to the interfaces. When it came to sustainability, the focus was on reducing spillages and loss of containment at interfaces, which can result in increase of greenhouse gas emissions.

Project C adopted a similar approach like project B, a 3D model was set up to exchange the information with vendors regarding the interfaces in the project. On top it, to control the information which is exchanged on the 3D model an interface manager was appointed. He was also responsible to manage all the interface management on site as well. Project C also stressed on sustainable project planning, to keep the project on track whenever there was a delay due to interfaces.

4.5.6 Findings on Value Improving Practices

In project A, value engineering workshop/sessions was conducted with all the stakeholders to address sustainability goals. These sessions were also held to identify the opportunities to save money without comprising to sustainability objectives / goals of the project. An external specialist was mainly called to address sustainability goals especially on the subjects related to the reduction of greenhouse gas emissions, energy efficiency and spillages.

Project B used ALARP sessions as one of the tools for value improving practices especially when sustainability objectives involved. Unlike project A there was no value engineering workshop/ sessions because most of technologies/methods which involved value improving practices were outsourced to different companies.

Project C took the same approach as project A. To address the sustainability goals, an internal value engineering workshop was held with all stakeholders. Limiting CAPEX, which was regarded as one of the sustainable goals of the project, was one of the key concerns addressed at the value engineering session.

4.5.7 Findings on Project Scheduling

In project A, interactive sessions were set up with the integrated team and selected vendors for the project to develop consistent planning which will ensure that all stakeholders commit to the project objectives which includes the sustainability goals as well. The scope of work for the package unit vendor was included in this agreed-upon planning schedule by all the stakeholders. In addition, a clear level 3 biweekly meeting was held, as well as coordination meetings, to ensure that the team is kept up to date on project milestones and that their input is provided.

Project B did not have any interactive meetings or level 3 biweekly meeting as such. Basic project scheduling tools such as S curve were employed, and the project status was updated every two weeks using the status line in the project schedule, giving stakeholders a clear picture of the situation.

Project C followed a similar approach like project B. Basic tools like S curve were employed to give the stakeholders a clear picture of project status every two weeks.

4.5.8 Findings on Research and Development

In project A, a research area was set up to research on the technologies that were to be chosen to meet the sustainability requirements and to choose the right vendors after thorough research of their past projects and their experiences.

Project B followed a similar approach as that of project A.

Project C adopted a similar approach like project A, a research and development area were set up in close collaboration with the client and all the stakeholders in the FEED phase of the project which mainly focused on the long lead items and Package Units inquired on a budget level. Along with this, brainstorming sessions were held thrice a week with the relevant stakeholders to bring the best ideas and knowledge regarding the technologies and methods to be used in the project.

4.5.9 Findings on Project Resourcing

Project A and B did not have any specific tools which were used for effective management of resources. Resources were mainly outsourced, and it was the responsibility of the sub-contractors. This was essential as it encouraged the involvement of the sub-contractors as early as possible so that they can understand the sustainability goals better and contribute to the sustainability objectives in the early stages of the projects itself.

Project C followed a completely different approach when compared to project A and B. Lead engineers from the central engineering team oversaw project resource planning, which was delegated by line management. A line manager was also appointed to perform various functions which revolved around the project resourcing.

4.6 Summary of tools /practices:

A summary of tools/practices used in the three projects under each activity to stimulate sustainability is explained , (see table 5):

	Activities	Project A	Project B	Project C
1.	Managing the package unit vendors	A package unit manager was assigned to oversee the vendors, ensuring that the vendors design process moves at a steady pace and that agreed-upon milestones are met on time	No package unit manager was appointed	Package unit managing team was set up by the client which comprised of four people to have an overview of the work done by the package unit manager
2.	Team Integration	Escalation model was set up by the contractor to ensure all the sustainability goals in the project are met	Communication corridor along with a 3 D model was set up to ensure all sustainability objectives were met in the FEED phase of the project	Engineering platforms like COMOS, E3D and Navisworks which stimulated sustainability by providing flexibilities to all the relevant stakeholders to incorporate design and for energy optimization

3.	Lessons learnt	Lesson learning session with all relevant stakeholders was organized with the goal of gathering information and evaluating experience from past first-of-its-kind projects completed by vendors and applying it to this project as critical success factors. tools like environmental impact assessment.	Lesson learning session was set up regarding sustainability that focused on achieving the industrial norm for loss of containment and reducing greenhouse gas emissions.	Project C followed a similar approach like project A with respect to lesson learnt.
4.	Project Risk	Tools like EIA to identify common environmental risks like greenhouse gas emissions or spillages.	Tools like EIA (Environmental Impact assessment) was used in this project to identify common environmental risk and gate reviews was done in assessing them	EIA, HAZOP and SIL were tools used to determine the mitigation actions for environmental risks like greenhouse gas emission as well for the spillages.
5.	Interface Management	HAZOP and SIL sessions were organized with selected vendors to manage the interface between the units and the interconnecting scope which helped to achieve the sustainability objectives/goals	A 3D model was developed that allowed for the exchange of information with vendors regarding interfaces as well as the management of clashes in the project due to the interfaces	A similar approach like project B was followed but an interface manager was appointed to control the information exchanged on the 3D model
6.	Value improving practices	Value engineering workshop/sessions was conducted with all the stakeholders to address sustainability goals and to address these sustainability goals an external specialist was called to address these sustainability goals	ALARP sessions was used as one of the tools for value improving sessions especially when sustainability objectives involved	A similar approach like project A was followed in project C as well

7.	Project Scheduling	Interactive sessions were set up with the integrated team and selected vendors and a level 3 biweekly meeting was set up to discuss the sustainability goals of the project	Project scheduling tools like S curve was used to update the project status to the stakeholders twice a week	A similar approach like project B was followed in this project as well
8.	Research and Development	A research area was set up to research on the technologies that were to be chosen to meet the sustainability requirements	A similar approach was followed like project A	A similar approach was followed like project A but research also focused on the long lead items.
9.	Project Resourcing	No specific tools were used. Majority of the resources were outsourced to a third party	Same as project A	A line manager was appointed to perform functions revolving around project resourcing

Table 5: Tools/practices used under each activity to stimulate sustainability

4.7 Chapter Conclusion

The data gathered through the interviews with the project managers and package unit managers and the case analysis done on three first of a kind project will serve as a base for cross case analysis in Chapter 5 which will uncover the challenges faced to integrate sustainability under few activities in the FEED phase. The chapter also answered SQ3 of the research.

SQ3: What are the tools/practices used in integrating sustainability in first of a kind projects in practice?

The tools/practices used to integrate sustainability in first of a kind projects in practice are:

- Appointing a package unit manager to manage the package unit vendors
- Appointing a package unit managing team to manage the package unit vendors
- Use of engineering platforms like COMOS. E3D and Navisworks for team integration.
- Use of tools like EIA, HAZOP and SIL to manage the project risks.
- Use of a 3D model to manage the interfaces between the stakeholders.
- Appointing an interface manager to manage the interfaces between the stakeholders.
- HAZOP and SIL sessions with the vendors to manage the interfaces.
- Value engineering sessions to limit the CAPEX.
- Lesson learned sessions on vendors previous first of a kind projects used as critical success factors for these projects.
- Use of project scheduling tools like S curve to update the project status.
- Setting up of research area for research and development.

- Appointing a line manager to perform functions revolving around project resourcing.

While all these tools/practices were used in three first of a kind projects, The following were the best tools/practices because there were no challenges faced in implementing these tools/practices to integrate sustainability in three projects in practice.

- Use of engineering platforms like COMOS. E3D and Navisworks for team integration.
- Lesson learned sessions on vendors previous first of a kind projects used as critical success factors.
- Value engineering sessions to limit the CAPEX.
- Appointing a line manager to perform functions revolving around project resourcing.

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5. Cross Case Analysis

The goal of this chapter is to discuss the challenges faced under few activities in common in the three first of a kind projects based on the case analysis done per case in the previous chapter.

5.1 Added Complexity

A multi-disciplinary project is, in its basis, already a complex interaction of actions and involved parties.

Project management systems like PMBOK focus on a 'first time right' sequence of actions and freezing parameters.

All three projects mention, on top of this usual project dynamics, an added complexity of interfaces due to the 'first of a kind' character of the projects. This 'first of a kind character' resulted in insecurities in the basis of design. The two main areas of insecurities in all three projects were:

1. Production related operational parameters that were still under development by the Research and Development department of the production company during the project FEED phase and even during the project realization phase.
2. Conceptual technology related feasibility that was still under development by the package unit vendors during the FEED phase and the project realization phase.

In all three projects, this added complexity had impact on reaching CO2 reduction goals.

In the interviews, the main addressed general attention areas were the interfaces between contractual parties. From the perspective of the engineering contractor, this was the interface with the R&D department of the production company on the one side, and on the other side the interface with the package unit suppliers with innovative technology.

To analyze this further we look at three impact levels regarding reaching CO2 emission goals.

1. Reaching the operational CO2 emission reduction goal after project completion.
2. Reaching the project completion goal, with resulting CO2 emission reduction start, within planning.
3. Minimizing construction related CO2 emissions during the realization phase of the project.

<u>Reaching the operational CO2 emission reduction goal after project completion</u>

This goal has the most substantial impact and is closest connected with the justification of the investment. All the three projects had full focus on this goal and the project management gave priority on compensating setbacks with mitigating measures. On several occasions, this forced the project management to accept consequential delay in the project realization progress.

All three projects suffered from setbacks in the following areas:

1. The package unit suppliers with key innovative technology ran into trouble with delivering their 'black box' meeting functional performance requirements. In one of the occasions, this even led to bankruptcy of a package unit supplier.

2. All three projects reported that managing project risk and measuring progress should have been a more integrated effort. The chosen contract strategy with the package unit vendors hindered this co-creation approach.
3. The R&D department kept changing the operational parameters for the installation during the design and realization of the project.

Finally, in all three projects, the engineering contractor were not able to solve all issues and setbacks, resulting in an installation that did not meet the initial functional requirements regarding set CO_2 emission reduction goals.

Reaching the project completion goal, with resulting CO_2 emission reduction start within planning

Because of putting the fulfillment of predicted CO_2 emission reduction goals on top priority, the planning was suffering. This had a result on the CO_2 emission reduction during the planning delay.

During the planning delay, missed CO_2 emission reduction can be calculated by combining the length of the planning delay and the CO_2 emission reduction per time increment after completion.

Main project management related reasons for planning delay in the project realization are the incompetence of the package unit vendors to manage the functional performance of their delivery on one side and the failure to stop conceptual operational requirement changes form the operational R&D department.

In all three projects, the interviewed team members mentioned regarding planning management:

1. Surprises in risk management.
2. Too many changes in the conceptual parameters in R&D phase.
3. Lack of ownership in managing the interfaces and project risks.
4. Lack of coordination between the stakeholders.

Minimizing construction related CO_2 emissions during the realization phase of the project

In all three projects, the project management applied Value Engineering to optimize the overall investment, CAPEX.

It must be mentioned that these projects were realized with a goal to save the CO_2 emissions and meet the energy efficiency targets as planned.

In the ambition to reduce CO_2 emissions, none of the projects had focus on the own construction activities related CO_2 emissions. The focus was on the project impact after completion.

5.2 Interpretation of cross case analysis

5.2.1 Challenges that had an impact on reaching the CO2 emission reduction targets.

1. The package unit vendors handling the innovative technology were struggling to deliver their scope of work. This struggling resulted in:

- Financial Bankruptcy
- Not meeting performance targets. This resulted for the project not meeting overall sustainability targets.
- Delays in the availability of package unit related design information. This information was required to implement the package units in the overall project regarding utility supply, lay-out and operational procedures. Result was an overall project completion delay.

2. In all three projects, the main challenge was the interface management between contractual parties. In particular; the production company R&D department and the package unit supplier of key innovative technology.
3. In general, the communication with all stakeholders and commercial parties formed an extra complexity due to the first of a kind aspect of these projects. This complexity comprised of risk management, interdependency of design information and progress communication.
4. Before the project development and realization phase started, the production company had not been able for finalize its research and development regarding the implementation of the new technology into the management of operations. This resulted in over 500 R&D changes that influenced the basis of design after project development started. These changes continued in the project realization phase.
5. With respect to the value improving practices**,** value engineering sessions was setup in all the three projects, but it was just restricted to limiting the CAPEX and none of the projects had value engineering sessions on waste minimization or energy optimization which could have helped in integrating sustainability in the projects.
6. Overall and joint project risk management with clear ownership per issue was lacking in all three projects.

5.2.2 Tools/practices that influenced the CO2 emission reduction results

1. In all three projects, the following aspects have been mentioned as beneficial in the interviews: initial lessons learnt sessions, use of integrated engineering tools like 3D modeling and relational database connected engineering.
2. In terms of lessons learned, there were no challenges faced under this activity as lesson learned session was held on a selected vendor's previous first of a kind project before the start of all the three projects. This gave the project team a better idea of how to steer the current first of a kind projects in the right direction, so that mistakes made by the vendors in previous projects are not repeated and can be used as critical success factors in integrating sustainability in the projects.
3. Existing tools that could have been applied more are 3D model, COMOS and E3D model to improve the stakeholder communication and for planning to be more stage gated and realistic in the length of the activities. The impact of these tools was less direct clear and therefore not part of the project focus.

5.3 Chapter Conclusion

The chapter addressed the challenges that were faced in integrating sustainability under few activities in the three first of a kind project. **The challenges resulted in project delays with consequential missed CO_2 emission reduction during those delays and in meeting energy efficiency targets**. Managing package unit vendors, interface management, value improving practices, research and development and project risk were among the activities that posed challenges. Furthermore, the cross-case analysis will serve as an anchor point for proposing solutions in chapter 6 to solve the above-mentioned challenges. The chapter also helped to answer the SQ 4 of the research.

SQ4: What are the limitations and challenges to integrate sustainability in first of a kind climate impact projects in practice?

The following were the limitations and challenges faced to integrate sustainability in the three first of a kind projects chosen for this study:

- Financial bankruptcy of the vendor.
- Vendors were not able to deliver the black box.
- Value improving sessions was restricted only on limiting the capex.
- There were interfaces between Designs and engineering activities
- Overall and joint project risk management with clear ownership per issue was lacking
- Interfaces between contractual parties. In particular; the production company R&D department and the package unit supplier of key innovative technology.
- Inadequate studies on selection of technologies and its design.

6. Proposed Solutions

In chapter 4 and chapter 5, tools/practices were explored in three first of a kind project used in practice through interviews. Adding to that, the areas where these projects excelled and where they struggled in terms of integrating sustainability were also discussed in the cross-case analysis chapter. The cross-case analysis handled three aspects of CO_2 emission reduction impact:

1. Reaching the operational CO_2 emission reduction goal after project completion.
2. Reaching the project completion goal, with resulting CO_2 emission reduction start, within planning.
3. Minimizing construction related CO_2 emissions during the realization phase of the project.

The proposed solutions can have impact on all three main aspects mentioned. For the structured overview of the impact of the proposed solutions, the chapter starts by outlining the challenges faced under few activities followed by connecting per solution to all three impact areas if applicable. To place the proposed solution in a structured order, the proposed solutions aim to follow the project phases from start to finish. Most solutions have their main impact on the project planning and coordination of involved stakeholders and contractual parties. The proposed solutions were mainly extracted from the literature papers and PMBOK.

The challenges faced in few activities in all the three projects are presented in table 6

Sl no	Activities used to integrate sustainability in the FEED phase of the project	Challenges / barriers
1.	**Managing the package unit vendors**	1.Financial bankruptcy of the vendor 2. Vendors not able to deliver the black box
2.	**Optimizing Value**	There were only value improving sessions on limiting the capex but not on saving the CO2 emissions and to increase the energy efficiencies in the project
3.	**Interface Management**	Interfaces in Designs and engineering activities
4.	**Managing the Project Risks**	Stakeholders were not assigned and committed to the project risks
5.	**Implementing the Research and Development results**	1. Inadequate studies on selection of technologies and its design 2. Interfaces between research and development and project organization.

Table 6: Challenges faced under each activity

In line with the above-mentioned challenges in table 6, the main concern areas were:

1. Dedicated attention per interface between key involved parties. In particular ,the production company R&D department and the package unit supplier of key innovative technology
2. Overall and joint project risk management with clear ownership per issue
3. Overall and integrated project planning with clear freeze of parameters at interfaces and progress management.

The solutions proposed to the challenges mentioned in table 6 are explained in the subsequent sections.

6.1 Project start with target setting and structured ownership

At the start of the project, the production company sets the CO_2 reduction targets. The production company does this to justify the investment cost and to support the business case. The production company sets these targets in an early and initial stage of the project and it has to be clear that, similar to the accuracy of the planning and the investment cost estimate, this figure has a wide accuracy margin.

On top of that, in a first of a kind project, 'non proven' technological solutions are applied for some aspects. This 'non proven' aspect of applied technologies introduces insecurity that must be managed over all by the involved stakeholders and contractual parties.

In this initial phase, three solutions support the mitigation of these aspects:

- Structuring the stakeholders and contractual parties with their roles, responsibilities and tasks
- Managing project risk with clear ownership for each involved party or stakeholder
- Stage gated project phasing

6.1.1 Structuring the stakeholders and contractual parties with their roles, responsibilities, and tasks

Because of the expected complexity of the organization structure already present in this stage, the project organization must be set up. This will serve as a basis for interface management with every added contractual party in the project.

PMBOK uses a **RACI table** to give a responsibility summary per project aspect. RACI is the acronym for **Responsible, Accountable, Consulted, Informed**. Per subject, all involved stakeholders are connected to one of the RACI positions.

In CO_2 emission reduction projects, the interface with the Research and Development department of the production company and the interface with innovative key technology package unit suppliers requires specific attention. Both these interfaces are handled separately.

6.1.2 Managing the project risks with clear ownership for each involved party or stakeholder.

In a first of a kind project, the project risks are more diverse and complex to anticipate. Regarding the target setting and realization of CO_2 reduction goals, the project organization must give dedicated attention for project risk insecurities connected to CO_2 reduction. Commitment risk action log helps to solve the project risk insecurities and to manage the project risks with clear ownership. The proposed solution "Commitment risk action log "was inspired from the literature (McPhee & Dias, 2020).

According to McPhee and Dias (2020) commitment action risk logs has three main goals

- Risks that can be handled by a single contractual party of stakeholder has an explicit owner.

- Risks, that require multi stakeholder or multi contractual party attention, are clearly identified for dedicated attention throughout the project. This special attention aims for the moment that the remaining risk can be handled by one contractual party of stakeholder.
- Risk that requires multi stakeholder attention are handled by commitment management team

Sr no	Commitment Information			Project information			Commitment management		
	Name	Description	Stakeholders	Department	Impact	Risk	Owner	Plan	Status
1									
2									
3									

Table 7: Commitment action risk log

6.1.3 Stage gated project phasing

To involve, align and update stakeholders and contractual parties, a stage gated project phasing brings clarity and structure in the fixation of project parameters.

PMBOK mentions this approach under 'stage gate process'.

The stage gates cut the project in clear increments that can have its own character and bring focus on a specific aspect of the project development. A stage gate comprises a formal review of achieved results, parameters frozen, status of the risk register and revision of the RACI, Responsible, Accountable, Consulted, Informed register.

The more insecure the design basis in a certain project phase, the smaller the stage gate increments should be. In the Scrum methodology, a project is divided in Sprints that are in practice stage gated project increments. A sprint length can be two weeks and starts with a clear physical result scope. This can be a document. In the initial development stages of the project, the Sprints are used as a tool to align stakeholders about project decisions based upon both facts and assumptions. The sprint length is used to verify the assumptions that are critical for the decisions taken.

The fixation of parameter value is not possible from unfixed to fixed in one project stage for all project parameters. In the PMBOK description of stage gates is already a common practice for investment cost of project planning. Over the project stages PMBOK describes an approach to manage the accuracy of parameter fixation like investment cost and planning.

In the initial project phases, this accuracy management must be applied for the target setting of CO_2 reduction as well.

6.1.4 Impact of proposed solutions on reduction of CO2 emissions.

The proposed solutions create realistic and managed target setting. Also, the project ownership is defined better, both in generating project information as well as mitigating project risks. The impact on CO_2 emission reduction after completion is indirect. More realistic and managed target setting combined with more clear ownership for specific project aspects will result in a project realization that is closer to the theoretic maximum. This effect was calculated in one of the projects as a gap of 35% and this figure came out from the interviews.

The proposed solutions can also help to reveal which part of the missed target relates back to unrealistic target setting and which part is expected to be missed in the realization phase. It also creates a basis to minimize yield loss regarding the set targets in project planning during the project development phase. Delay in project completion directly connects to missed reduction of CO_2 emission. This effect is handled in the subsequent sections but is already influenced in a structured stakeholder ownership set up in this phase with clear tasks, responsibility and planning.

6.2 Project Development Phase

In the project development phase, the project management approach must focus on reaching the CO_2 emission reduction targets. These targets comprise both the targets that must be reached after project completion and the set timeline to reach this project completion.

From the interviews of all the three projects, it was seen that the project management approach had to cope with a more complex interface management. This complexity is driven by concurrent development of both the project requirements and the selected technology development.

The Research and Development department of the production company develops the input and output requirements and is in interaction with the package unit technology supplier that is developing innovative technology.

6.2.1 Interface between the Research and Development and the project organization

In all three ‘first of a kind’ projects, the interface with the Research and Development department of the production company resulted in realization delays. These delays are based on the concurrent approach between project development and operational technology development. This effect can be measured by the amount of conceptual design changes that influence the basis of design of the project development phase.

Two measures came out of the interviews that will bring improvement in relation to the analyzed projects:

1. The first measure relates to a stage gated project approach. PMBOK also asks attention for a clear technology transfer file at start of the design phase. For the ‘first of a kind’ projects, an optimization must be found between the schedule length due to the issue of the technology transfer package with a high completion percentage and the anticipated delays because of missing fixed data. To align all stakeholders and involved parties the stage gated project structure helps to fix key design basis information.

Because this optimization will result in a gap towards a complete technology transfer, a second solution advised to manage this gap during the project development phase.

2. PMBOK advises to manage important interfaces with one focal point of contact with a clear management of change procedure. This is common practice in project organizations. In the interviewed projects, this focal point was not clear at the Research and Development side of the interface. It can be expected that the Research and Development department was lacking a team member with ample project stage gate to function as focal point in the management of change procedure. So, the advice is to consider appointing an external specialist to fulfill this function. This external specialist must bridge the information gap between information development in the Research and Development department and the requirement for information in the project development organization. This specialist will work with a systematic way of managing the availability of frozen information in the overall project planning and a management of change procedure to manage the impact of change of already fixed information.

6.2.2 Interface between the package unit suppliers of innovative technology and the project organization

All the three projects suffered from the effect that the package unit vendors of innovative technology ran into financial problems and on one occasion, even went bankrupt. This resulted in delays in the project which had two major effects. First, the delivery of the package units was delayed resulting in construction delays. Second, the project development during the engineering phase was delayed. Reason for this delay was the key position of the innovative technology vendors in the generation of a multi-disciplinary design information.

According to the interviews, the basis of this problem was the risk management around the technological insecurities in the final performance of the package units. The core problem was that the project organization underestimated externalization of technology risks towards the package unit vendors by contractual terms. To solve this challenge, a **four-step** strategy is presented to solve the bankruptcy challenge and to ensure that vendors deliver the design for package unit on time which can help in reducing the delays in the projects. By reducing the delays, projects can save the CO_2 emissions and meet the energy efficiency targets as planned. The solution was inspired from the literature papers (Chunxia Yu & T.N. Wong, 2014) , (Ayman & Alaa Hosny , 2017) , (Ritesh & Samir, 2017) and (Scott Wolfe, 2020).

1. <u>Preselection of Technologies and Prequalification of Vendors</u>:

The solution for prequalification of vendor was inspired from the literature (Chunxia Yu & T.N. Wong, 2014). The first step involves client and the contractor preselecting the technologies without the involvement of the vendors. After preselecting the technology, prequalification of the best vendor should be done based on the following criteria's (Chunxia Yu & T.N. Wong, 2014). The author came up with the literature (Chunxia Yu & T.N. Wong, 2014) from the google scholar.

a) Vendor diversity: This refers to a vendor's capacity to provide multiple package units assess the production capacity and wide range of technology and patents the vendor holds.

b) Communication capability for multiple package units: This group assesses vendors communication capability for multi-package unit transactions, such as procedural compliances and numerous product information technologies.
c) General Characteristics: Production capability, technical competence, financial status, management and organization, and environmental performance are examples of generic qualities and capabilities directly related to suppliers.
d) History Performance: This group is concerned with the previous performance of suppliers in terms of quality, delivery, and service.

2. <u>Paying the prequalified vendor to do Basic Engineering</u>

The second step in the solution was inspired from the literature (Ayman & Alaa Hosny ,2017). In most of the projects, vendors are not involved in basic engineering phase and if they are involved also, they are not paid. According to (Ayman & Alaa Hosny ,2017) one of the benefits of paying the vendor to do the basic engineering especially in projects where in technologies/methods are not known is that knowledge from the vendor and the experience from the vendor previous first of a kind project can be transferred among team members which can be a critical success factor in integrating sustainability in construction projects. But the vendor will also not be willing to do the basic engineering even though the vendor is getting paid because the vendor will not be assured whether the projects contract will be given, and the vendor will not be willing to put the time and efforts to do the basic engineering even though the vendor is getting paid. This can be avoided by proper assurance and promises to the vendor that he is the primary source hence the project contract will be handed over to him. Furthermore, involving the vendor in the preliminary stages that is the basic engineering will help the vendor understand the design of the package units better that has to be used in the project.

3. <u>Signing a risk sharing contract with the vendor:</u>

The third step in the solution was inspired from the literature (Ritesh & Samir, 2017). This step involves signing a risk sharing contract with the vendor. According to Ritesh and Samir (2017) risk sharing contract outlines the guaranteed maximum price which means that the vendor should deliver the package unit within this price and this price is only decided after going through the specifications of the preselected technologies. Risk sharing contract is a non-traditional method of assigning value in the transaction. Hence the economic outcomes are agreed and measured prior to signing the contract which could be beneficial for the vendor and the client (Ritesh & Samir, 2017). It helps to mitigate the financial risk to the client where the contractor coordinates with the vendor to set up certain measures in a way that if there is no anticipated outcome, there will be a possibility of financial aid to the vendor without the client having a financial loss. Therefore, in situations where the contractor is struggling to meet the set outcome measures, the client can partner up with the vendor to increase the data sharing transparency thereby helping both the contractor and the client to improve on the given situation without either of them bearing a major loss which can gradually give an economic result.

4. **Joint check agreement:**

This is the last step to manage the package unit vendors. The solution was inspired by one of the articles (Scott Wolfe, 2020). Joint check agreements are a great tool which avoids financial bankruptcy of the package unit vendors which in turn prevents the delay in the projects (Scott Wolfe, 2020). By reducing the delays, the projects sustainability objective of saving the CO_2 emission or increasing the energy efficiency can be met.

The core idea of joint check agreement is that the contractor/ client enters an agreement with the package unit vendors and his subcontractors. Furthermore, all three parties agree that any payments made by the contractor/client for work performed by the vendor's subcontractors shall be written to the vendor and the vendor's subcontractors jointly, (see figure 5). With a joint check agreement in place, the vendor's subcontractors are safeguarded against the risk of the subcontractor failing to pay them, even after the contractor/client has paid them. The contractor/client is shielded against the risk of a mechanics lien being filed if the vendors subcontractors is not paid. The client/contractor should follow a two-step approach when the vendor goes bankrupt

1. Comply with the procedure and examine the joint check agreement: The first thing contractor/client should do is go over the conditions of the joint check agreement and check whether there was a violation and study the conditions to determine if there are any established methods for enforcing the commitments.
2. Think about overall point of view and keep the project running: The second step is to develop a bigger legal plan for dealing with vendor subcontractors disputes, delays, and contract breaches, while also not being naive about other minor disagreements. In addition to developing a legal plan, the client/contractor should continue paying the vendor's subcontractors after the vendor goes bankrupt to keep the project running and prevent the delays in the project, and this payment should be based on the joint check agreement that the client/contractor had previously signed with the vendor's subcontractors.

Figure 5: Joint check agreement

6.2.3 Interfaces between design and engineering activities

Interfaces between engineering information providing parties or stakeholders form a complexity. This complexity occurs when; it is difficult to develop an interface agreement between the parties, or to extract a requirement directly from the interface, or when the interface is labelled as high risk, or when there are interfaces between design and engineering activities. The project team must identify critical interfaces. Identified critical interfaces require careful management. Bogus, et al. (2006) and Ballard (2000) describe a four-step approach an interface managing team should follow to structure interface management.

1. Re-ordering design activities:

Ballard (2000) states that reordering design activities is the most useful way for interface team to manage the interfaces in the FEED phase of the project. The interface managing team should be responsible:

- To bring one of the designs ahead of the other so that the designs can be worked on at the same time, when the two interface designs is planned at distinct times.
- For moving high risk of failure interfaces ahead in the design phase, as is the case with components that must be completed sooner owing to construction restrictions. This approach will adjust the planning such that complicated designs with significant interface risks are planned at the same time, preferably in the same physical place, during the early stage of the design process and help to coordinate and transmit specialized information. Furthermore, by bringing the concerned design upfront, more time is saved for elaboration of that interface.
- For exploring the effects of moving the designs forward on predecessor and successor activities. Choosing a design solution may be dependent on assumptions, which may impose limits on the actions that came before it. However, possible delays and expenses might be avoided in the long run by detailing high-risk interfaces earlier in the design process. After the design has been frozen, changes can only be made when official change requests have been submitted to interface management team and all repercussions have been assessed by them. As a result, there will be fewer lesser design revisions.

2. Restructuring strategies:

Multidisciplinary sessions (see figure 6) should be organized by the interface managing team for restructuring strategies (Bogus et al., 2006). These sessions should focus restructuring strategies such as assembling cross-functional teams, leveraging team problem solving, and providing ranges of acceptable solutions to aid in the development of complicated interfaces (Bogus et al., 2006). These tactics emphasize working together to discover a solution and speed up the process which will in turn reduce the delays in the first of a kind project

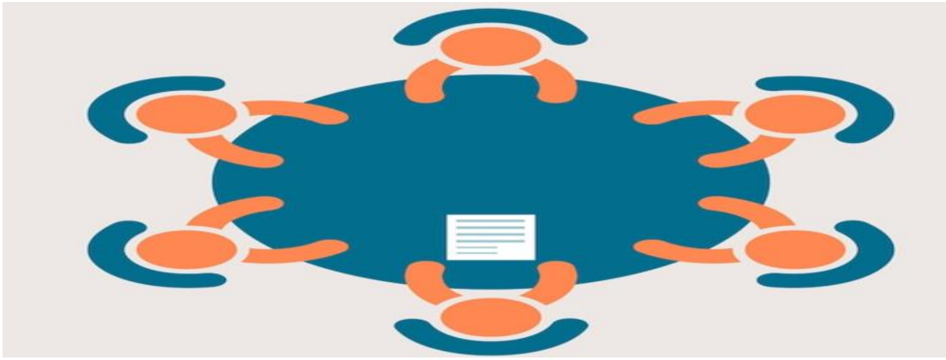

Figure 6: Multidisciplinary Sessions

3. <u>Anticipating the information on interfaces</u>:

The interface managing team should come up with other possible solutions if they cannot overlap the design the activities. When the interface information is not critical and can be easily anticipated, assumptions about the parameters can be made. The latter design team could make appropriate assumptions about the interface settings, allowing the previous team to complete their design (Ballard, 2000). The danger of forecasting this information should be carefully considered by the interface managing team. Delays may arise if the design team decides to wait and starting without this information is extremely dangerous. However, predicting interface information may introduce additional risk if the assumptions turn out to be incorrect. According to Ballard (2000) before making assumptions regarding interface information, the possible repercussions, in addition to the rate of sensitivity, development, and predictability of the information, should be thoroughly investigated. Assumptions that results in key decisions, should be validated on the shortest possible term to replace the assumption by a frozen parameter.

4. <u>Overdesign:</u>

Overdesign is the final strategy for managing the interfaces. When there are time restrictions and none of the above solutions are suitable, overdesign might be applied to proceed with successor tasks (Bogus et al., 2006). Overdesign might also be used to mitigate the hazards of possible rework when information is dependent on assumptions. Overdesign creates a buffer, making the correctness of the latter design team's expected parameters less important. Overdesign incurs more expenditures, but it has the potential to decrease or eliminate the need for rework in the long run. As a result, before implementing this method, the costs, advantages, and hazards of overdesign should be thoroughly investigated by the interface managing team (Bogus et al., 2006).

6.2.4 Impact of proposed solutions on reduction of CO2 emission

The above-mentioned solutions will have the clearest impact on efficiency in the project realization phase resulting in fewer delays with ultimately an earlier start of the CO2 emission reduction effect. This effect can be brought to the attention of the project organization by visualization of the final design target of the project, regarding emission reduction. For example, a nameplate design target of the installation of 365 Ton CO2 emission reduction per year results in a lost emission reduction effect of 1 Ton CO2 per day of schedule extension toward final completion. The project management organization has to implement such visual management structure of CO2 reduction target effect in first of a kind projects. From this experience, a project organization will get used to a CO_2 reduction awareness that can be expanded to project where sustainability goal is more secondary.

6.3 Minimizing construction related CO_2 emissions during the realization phase of the project:

Projects generate an impact on the environment during the project realization itself. In the focus on CO_2 emission reduction, there is a CO_2 emission generated by the project itself. This effect is lower in comparison to the generated emission reduction in dedicated CO_2 emission reduction projects but can be relatively more significant in projects where sustainability effects are secondary.

6.3.1 Application of Value improving practices

All the three projects had value improving practices on limiting the CAPEX. No attention was given to dedicated Value Improving Practices regarding Energy Optimization or Waste Minimization, constructability review and other value improving practices. It does not mean that in the design process the individual department did not apply optimization techniques. However, it is a missed opportunity not to have a multi stakeholder formal session in a Value Improving Practices approach. There are in total 14 value improving practices but according to Tian and Chen (2015) value improving practices on waste minimization, energy optimization, constructability session and maximization of end life production facility are the best practices to integrate sustainability in first of a kind project, (see figure 6). These value improving practices should be in the form of value enhancing sessions with a focus on CO_2 reduction and in increasing the energy efficiencies in the projects.

The waste minimization sessions should focus on a zero-waste plan for long-term sustainability, as well as value-adding strategies which will help in reducing the spillages (Tian & Chen ,2015). Furthermore, energy optimization sessions, as a value-enhancing approach, will help these projects achieving sustainability. Even though energy optimization was one of the key sustainability goals in all these projects, none of the project had sessions on it. These sessions should concentrate on building tools and technology for improving energy efficiency and assessing the present energy spending of in-service equipment by recognizing patterns, so eliminating costly operational expenditures and optimizing energy spending (Tian & Chen, 2015). Also, Value improving sessions on maximization of end life of production facility helps to integrate sustainability and this session should focus on designing the technologies in such a way that technologies used in this project could be used in the subsequent first of a kind projects as well. Value improving sessions should also focus on constructability review and these sessions should revolve around minimizing the impact on ongoing operational activities and should allow efficient execution of the activities during the FEED phase of the project (Waidyasekara & Harshini,2019). Furthermore, these sessions should also focus on optimizing the design of technology to minimize the impact on the existing facilities.

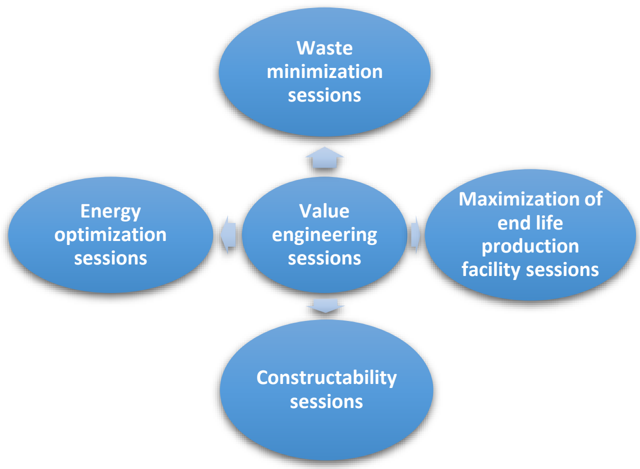

Figure 7: Value enhancing session

6.3.2 Impact of Value Engineering Sessions on CO_2 emission reduction.

The application of Value Engineering approach focuses on the required result, the need, and the resulting effort to reach this need, the cost and also the measurement of result .The effect on the cost side is lower in comparison to the reduction effects of planning reduction or target realization and is driven by the set ambition at the start of a formal Value Improving Practice cycle of Information Gathering, Functional analysis, Idea Generation, Idea Evaluation, Idea Ranking, Idea selection and Implementation. The above-mentioned value engineering sessions will help in saving the CO_2 emissions and in meeting the energy efficiency targets thereby achieving the sustainable objectives/goals.

6.4 Chapter Conclusion

In this chapter, proposed tools/practices addressed the challenges that were encountered in integrating sustainability in few activities in the three first of a kind projects chosen for the study. This resulted in project delays and the projects failed to meet energy efficiency targets and in saving CO_2 emissions as expected. The challenges were outlined at first in the chapter, followed by recommended solutions to the challenges. An overview of tools/practices to stimulate sustainability is mentioned in Table 8. The proposed solutions focus on promoting the overall alignment of interest and efforts. In general, the proposed solutions ask for more structured attention of existing project management tools. These recommended solutions ask attention for:

- A clarified and more explicit project organization with tasks and responsibilities.
- Overall integrated and stage-gated scheduling.
- Overall risk management with clear ownership.
- Management of change with aligned assumptions with short verification cycles.

The alignment effort results in setting more realistic and reached sustainability targets like reduced CO_2 emissions. On top of that, the stakeholder alignment most directly influences the realization time of the project. Faster project realization results in earlier coming to effect of the CO_2 emission reduction measures. This results in a direct measurable connection between schedule effects and avoided emission per time increment. This measurement can support management of change decisions. ***In general, the proposed solutions will help in reducing the delays in the project which will aid in saving the CO2 emissions and meeting the energy efficiency targets***. The chapter also helped in answering the SQ5.

SQ5: What are the solutions that can be implemented to solve the challenges faced in first of a kind project in practice?

The following are the solutions to the challenges faced in three first of a kind projects.

1. A four-step strategy to manage the package unit vendors and to avoid financial bankruptcy of the vendor
   e) Preselection of Technologies and Prequalification of Vendors
   f) Paying the prequalified vendor to do Basic Engineering
   g) Signing a risk sharing contract with the vendor
   h) Joint check agreement
2. Minimization, Optimization, Maximization and Constructability sessions as value improving practice to save the CO2 emissions and increase the energy efficiency targets.
3. A four-step strategy an appointed interface managing team should follow to manage the interfaces between design and engineering activities
   e) Re-ordering design activities
   f) Restructuring strategies.
   g) Anticipating the information on interfaces
   h) Overdesign
4. Stage gated project phasing to make sure stakeholders are committed and assigned to the project risk.
5. Commitment Action Risk Log to make sure stakeholders are committed and assigned to the project risk.
6. Appointing an external specialist in Research and Development phase.
7. Implementing a stage gated approach to manage the interfaces between research and development and the project organization.

8. Sl no	Activities used to integrate sustainability in the FEED phase of the project	Challenges / barriers	Tools/practices to solve challenges faced under these activities to integrate sustainability
1	**Managing the package unit vendors**	1.Financial bankruptcy of the vendor 2. Vendors not able to deliver the black box	4 step strategy: 1.Preselection of Technologies and Prequalification of Vendors 2. Paying the prequalified vendor to do Basic Engineering 3. Signing a risk sharing contract with the vendor 4. Joint check agreement
2	**Value improving practices**	There were only sessions on limiting the capex but not on saving the CO2 emissions and to increase the energy efficiencies in the project	Minimization, Optimization, Maximization and Constructability sessions as value improving practice to reduce CO2 emission and in meeting the energy efficiency target
3	**Interface management**	Interfaces in Designs and engineering activities	Appointing an interface managing team to manage the interfaces 4 step strategy: 1.Re-ordering design activities 2. Restructuring strategies. 3.Anticipating the information on interfaces 4. Overdesign
4	**Project Risks**	Stakeholders were not assigned and committed to the project risks	1. Commitment Action Risk Log to manage the project risk 2. Stage gated project phasing to make sure stakeholders are committed and assigned to the project risk.
5	**Research and Development**	1. Inadequate studies on selection of technologies and its design. 2.Interfaces between research and development and project organization	1. Appointing an external specialist in Research and Development phase 2. Implementing a stage gated approach to manage the interfaces between research and development and project organization

Table8: Overview of tool/practices to stimulate sustainability

7 Expert Meeting

*This chapter reflects on the comments and suggestions given by the experts on the proposed solutions (**chapter 6**).*

7.1 Expert Meeting Set Up

The purpose of this expert meeting was to understand the feasibility of the proposed solutions by experienced practitioners. An expert committee comprising of three experts was formed by the author's company supervisor and an expert meeting was held with the three experts whose details can be found in Appendix 5. Initially 8 experts were contacted by the author's supervisor but due to the busy schedule of few experts, only three experts agreed to join for the expert meeting. The experts were chosen based on the expertise they had in first of a kind projects and the vast knowledge they had in their respective fields. Furthermore, they were also chosen based on the years of experience they have working on such projects. The three experts who joined the expert meeting were also working on integrating sustainability in the construction projects for a very long time. The three experts who were a part of expert committee were not the same people who the author interviewed for three projects chosen for study. Expert 1 is heading the procurement department of Engineering and Consultants from past 3 years and oversees the entire procurement operation in Northwest European region. Expert 2 is the project Manager for the Engineering and Consultants with a work experience of more than 10 years and he also leads the piping and mechanical department. Expert 3 is a project manager and a Line Manager for Engineering and Consultants with 12 years of work experience. The meeting lasted for 90 minutes with a short introduction from the committee members and the brief introduction of the thesis topic by the author. In this brief introduction, first author explained about research questions, research gap, research objective and the three projects which were chosen for the research. Second, the activities which were chosen to integrate sustainability. Third, author explained about the tools/practices used in the three projects which was explored from case analysis. Fourth, author addressed the challenges faced in integrating sustainability in all the projects and last, the author proposed the solution to these challenges to the committee members.

7.2 Discussions on Proposed Solutions

Expert 1, a procurement specialist, stated that the proposed solution four step strategy to manage the package unit vendors and the interfaces might be incredibly beneficial and a game changer for the company. He went on to say that the four-step technique for managing package unit vendors was particularly intriguing. He emphasized notably on the second step, "Paying the vendors to do the basic engineering," and the fourth step, "Joint check agreement." He went on to say that most of his company's projects include vendors only after the contract has been signed, and that the company never pays them to undertake the basic engineering. He went on to say that this strategy will allow vendors to get involved early in the project, and that expertise transmitted from past projects and work experience will be extremely beneficial to the company. He also likes the idea of a joint check agreement; he believes that because of the joint check agreement with the vendor's subcontractors, the project can continue to run even if the vendor goes bankrupt. He also stated that these two strategies would reduce delays in the first of a kind project to a greater extent if the vendors went bankrupt and were unable to provide the black box, which would save CO2 emissions and help them meet their energy efficiency goals. In the FEED phase of the project, he also commented on the notion of interface management between stakeholders, stating that the four-step plan that the interface managing team should follow would be tremendously beneficial in minimizing the interfaces between stakeholders. He was very pleased with the other solutions proposed, but he believed that the project managers (Experts 2 and 3) would be better qualified to comment. Expert 1 also forwarded the author two research papers (Chunxia Yu & T.N. Wong, 2014) and (Scott Wolfe, 2020) to strengthen his solution on managing the package unit vendors. The author incorporated his suggestions and improved the proposed solutions, (see section 7.3).

Expert 2 was ecstatic with the solutions proposed. The tool "commitment risk action log" piqued his interest to better manage project risk. He further added, despite risk registers, tools like EIA, HAZOP, and SIL, there was no tool to ensure that stakeholders were committed to the project risk in all the company projects, and the proposed tool of commitment risk action log could be of great use to the company in ensuring that the stakeholders are committed to the project risks and in reporting the project risks. He also spoke about the interface management, which he believes is one of the most important activity to bring in sustainability to the projects . He was enthralled by the practice of appointing an interface management team to manage the interfaces between design and engineering activities, he went on to say that this may be particularly valuable in first of a kind construction projects which includes a lot of new technologies and innovations. He also commented on the value improving practices, stating that he believes the value improving practices recommended will be highly beneficial to the company, as the company currently solely concentrates on value improving practices that restrict CAPEX. He also forwarded author two research papers (Waidyasekara & Harshini, 2019) and (Tian & Chen, 2015) to strengthen the solution on value improving practices. The four-step strategies for managing package unit vendors and interfaces also pleased him. Furthermore, he stated that the tools/practices recommended would assist the company in meeting their energy efficiency goals and reducing CO2 emissions, allowing the projects to be more sustainable.

Expert 3 was quite pleased with the author's recommendations. The practice of bringing in external specialists throughout the research and development phase piqued his interest. He went on to say that he was involved in the research and development phase of two of the three projects the author was researching for his thesis, and that they had really struggled in the research and development phase in selecting the technologies and designs for it because none of the people involved in this phase were familiar with the new technologies or innovations that had to be chosen or designed, resulting in a lot of changes that had extended the R&D phase. He believed that bringing in an external specialist who had previously worked on various first of a kind projects would be beneficial to the company because of the knowledge and expertise that the external specialist would bring in. He was especially fascinated by the four-step strategies for managing suppliers and interfaces, and he proposed to the author that some requirements in the joint check agreement and risk sharing contract be changed to conform to EU standards and regulations. The author took his suggestions and brought the requirements within the rules and regulations of EU. Overall, he was quite satisfied with the solutions proposed by the author and further added that these solutions will make the project more sustainable by reducing delays which will in turn help in saving the CO_2 emissions and increasing or meeting the energy efficiency.

7.3 Interpretation of proposed solutions

Overall, all the experts were very happy with the solutions proposed by the author. The expert 1 forwarded research papers to the author to strengthen the proposed solution on four step strategy to manage the package unit vendors and while expert 2 forwarded research papers on value improving practices. The author had proposed a strategy of joint check agreement to manage the package unit vendors. The author had explained the core idea behind the joint check agreement and on how this agreement can reduce the delays in the project. The research papers forwarded by the expert 1 helped the author come up with a two-step approach client/contractor should follow when the vendor goes bankrupt

- Comply with the procedure and examine the joint check agreement
- Think about overall point of view and keep the project running

Furthermore, research papers forwarded by the expert 2 helped the author strengthen the proposed solution of value improving practices to integrate sustainability in first of a kind projects.

7.4 Chapter conclusion

The cross-case analysis and the data gathered from the interviews piqued the curiosity of all the experts. They agreed with all the solutions proposed by the author to solve the challenges faced in the projects in form tools/practices. Expert 1 and Expert 2 also forwarded literature papers to the author which helped to strengthen the solutions on managing the package unit vendors and value improving practices. The solutions proposed should be implemented in the company’s upcoming first of a kind projects to check how these tools/practices can improve integration of sustainability.

8 Discussion

This chapter begins with discussion on key findings of the research, followed by the implications of findings and the chapter is finally concluded by the limitations of the research.

8.1 Discussing the Findings.

The section begins with discussion on defining integration of sustainability in first of a kind projects according to the company the author worked for his thesis, followed by the discussions on themes which will be supported by the existing literature and section is concluded by implication on findings.

8.1.1 Discussion on "Sustainability"

Integrating sustainability into first of a kind projects has become more important in recent years. The current definition of sustainability is unclear (Schipper, Sivius, & Nedeski, 2012) and stakeholders hold different perspectives on the topic. The three-pillar approach and the integrated concept of sustainability are two approaches to explaining sustainability (Schipper, Sivius & Nedeski, 2012). According to the company the author is working on his thesis, practitioners' opinion/definition of integrating sustainability into first of a kind projects was to reduce the delays in the projects which will help in saving the CO_2 emissions and meeting the energy efficiency targets as planned. This opinion/definition by the practitioners is also supported by several existing research. McPhee and Dias (2020) states that sustainability should not just be restricted to usage of recycled and reusable materials in first of a kind projects to have less impact on environment, but it should also focus on exploring project management methods which can help in reducing the delays in first of a kind projects to meet the energy efficiency targets or even help in increasing the energy efficiencies in the projects. According to Morris (2017) sustainability can be integrated in first of a kind projects by reducing the delays and cost overruns. Morris (2017) also stated that to contribute to the three pillars of sustainability: environmental pillar, economic pillar, and social pillar, reducing the delays in the project can be major success factor in integrating sustainability in such projects.

8.1.2 Discussion on Managing the package unit vendors

Tools/practices

- Preselection of Technologies and Prequalification of Vendors
- Paying the prequalified vendor to do Basic Engineering
- Signing a risk sharing contract with the vendor
- Joint check agreement

The study found that managing package unit vendors is one of the important activities to integrate sustainability in first of a kind project. Furthermore, study also found that just appointing a package unit team /manager will not help in managing the package unit vendors, instead practitioners should come up with strategies the package unit managing team/ managers should follow to manage the vendors in structured way. It was also found that there are only limited vendors to supply the black box in first of a kind projects due to the new technologies/ methods employed in these projects. The research also found that there was no mutual trust between the contractors/vendors and the package unit vendors and there was lack of knowledge sharing between the parties which hampered the sustainability objectives/goals in the projects. The tools/practices explored to manage the package unit vendors ensures integration of sustainability in such projects. Prequalifying vendors based on preselected technologies helps in getting to know about the financial status of the vendors and vendors capacity to supply multiple package units. Paying the vendors to do basic engineering will involve the vendors at an early stage in the project which will bring in the knowledge and expertise of the vendor which can be used as critical success factors in integrating sustainability in such projects. Signing a risk sharing contract is a requirement because it helps to mitigate financial risk of the vendor and client as the economic outcomes are agreed and measured prior to signing the contract. Having joint check agreement ensures that vendors subcontractors are safeguarded against the risk of vendor going financially bankrupt which in turn will keep the project running, thereby preventing delays in the project.

A study by, Benton and McHenry (2010) supports that key to integrate sustainability in first of a kind project is by managing the package unit vendors effectively. Safa et al (2017) states that the key to manage the package unit vendors starts by project managers building a healthy personal relationship that prioritizes on trust, respect and by sharing knowledge. The study by (Chunxia Yu and T.N. Wong (2014) supports the findings of criteria's to be involved in prequalifying the vendors. Chunxia Yu and T.N. Wong (2014) mentions that vendor diversity and general characteristics should be investigated before prequalifying the vendors. According to Ayman and Alaa Hosny (2017) one of the benefits of paying the vendor to do the basic engineering especially in projects where in technologies/methods are not known is that knowledge from the vendor and the experience from the vendor previous first of a kind project can be transferred among team members which can be a critical success factor in integrating sustainability in first of a kind projects. Ritesh and Samir (2017) mentions that risk sharing contract outlines the guaranteed maximum price which means that the vendor should deliver the package unit within this price and this price is only decided after going through the specifications of the preselected technologies.

8.1.3 Discussion on Integrated Team

Tools /practices

- COMOS
- 3D model
- E3D model

The study found that integrated team plays a vital role in incorporating sustainability in first of a kind projects. The study also showed how an integrated team ensures collaboration between stakeholders to define the requirements of the project. Team integration was achieved using tools like COMOS, 3D model and escalation model in all the three projects. These tools could have been applied more to improve stakeholder communication and for the planning to be more stage gated and realistic in length of activities.

Study by Ibrahim, Costello, and Wilkinson (2015) shows that sustainability can be integrated in the projects by effective team integration which can be built through trust, communication, encouragement. According to Baiden (2006) team integration is one of the effective concepts that have been used to foster alliances as a way of improving collaborative relationships between the stakeholders. Sustainability can be integrated in construction projects when stakeholders connect properly with balanced disciplines and work in close collaboration to achieve clear targeted tasks of the project (Baiden, 2006).

8.1.4 Discussion on managing the interfaces

Tools/practices

- Appointing an interface managing team to manage the interfaces

4 step strategy

1.Re-ordering design activities

2. Restructuring strategies.

3.Anticipating the information on interfaces

4. Overdesign

The study showed that one of the key reasons in the delays of first of projects were due to interfaces not being managed properly in the FEED phase of the project. Stage gate process helps in defining the goals of the project; What will be engineered, and what will be left out; What will be the detail level of the engineering; What is the accuracy of the cost estimate / budget and are the contingencies properly defined; How to handle the non-defined items.Findings of the study showed that just using a 3D model to exchange information on the interfaces and appointing an interface manager to manage these information on 3D model will not help in integrating sustainability , instead appointing an interface managing team and making sure the four step strategy(for detailed explanation , see section 6.1.3) will be followed by interface managing team will help in managing the interfaces in a more structured way thereby reducing the delays in the projects which will in turn help in saving the CO2 emissions and meeting the energy efficiency targets as planned .

According to Pavitt and Gibb (2003) interface management is an important process, which helps in project development achieve sustainability by diving efforts among different teams. This process guarantees proper functioning of the project which is usually composed of many interfacing phases. The study by Shokri, et al. (2016) states that project managers should manage the interfaces to ensure proper communication and transparency between multiple interfacing sub-systems and failure to manage these interfaces may lead to delays thereby hindering the projects sustainability goals.

8.1.5 Discussions on research and development

Tools/practices:

- Appointing an external specialist in research and development phase
- Implementing a gated structure in research and development phase

The findings on the study showed that research and development was one of the key activities in integrating sustainability in first of a kind projects as it involves selecting the design for new technologies to be employed in these projects. Appointing an external specialist in research and development phase will bring in expertise and knowledge of external specialist for selection and designing new technologies to be employed. The external specialist ensures that there is efficient collaboration with the R&D department of the production company and with R&D and the engineering department from the research and development side. The findings from the study also showed that the first of kind projects always struggle with research and development phase due to which there are major delays in the projects hampering the sustainability goals.

According to Frederick and Pijawka (2014) research and development is an essential activity when the projects require innovation and introduction of new technologies and methods that help the project thrive in the competitive market and this innovation can be delivered by providing a powerful knowledge and insights that leads to improvements of existing processes where efficiency can be increased, and costs is reduced. The study by Turner, Lingard, and Francis (2009) shows that research and development will enhance the efficiency and effectiveness of a sustainable project construction phases while at the same time putting up competitiveness in the construction industry.

8.2 Implications of findings

8.2.1 The additional management complexity of first of a kind sustainability projects

The additional project management challenges in first of kind projects have a strong connection with the combination of two aspects.

First, the extended interfaces with interdependencies over contractual borders and stakeholder management in general. Second, the concurrent freezing of the Basis of Design (BOD) during the project development and realization phase. This results in a need for management of change to all involved parties that use the Basis of Design during the whole project development and realization phase.

This added complexity in project management is also clear in the new release of one of the leading project management methodologies, PMBOK. The latest version of PMBOK (7thEdition) has substantial addition in attention for interface management and management of change.

8.2.2 Focus on alignment between stakeholders and contractual parties

If both the operational requirements and the technological solutions have a substantial degree of insecurity, the reached level of alignment of overall ambitions and goals with parallel driving forces becomes a key success factor. The required alignment effort must involve all stakeholders. An extra complexity in this effort is the requirement to align commercial interest that cross a contractual border.

8.2.3 Specific findings at two key contractual interfaces

The findings bring specific attention to the interface between the project organization and two dependent contractual parties. At first the interface with the R&D department of the production company. Second, the interface with package unit suppliers of innovative technology. The specific findings regarding these interfaces are: In both interfaces, a single vocal point on both sides is required for structured interface coordination. All contractual parties must be involved in the project risk management and participate in the division of ownership for specific risks. For a first of a kind project, the project organization can only appoint some of the risks to one party after, considering per specific risk and initial mitigation period with involvement of multiple parties. Especially in the relation between the production company and the package unit suppliers, the contractual approach requires a new procurement strategy. This procurement strategy has to focus on co-creation and joint project result with management of risks that threaten this project result.

8.3 Limitations of the research

This section addresses the limitations/setbacks of this research that must be considered when elucidating its findings

8.3.1 Time Constraint

- Due to time constraints, the research only focused on integrating sustainability in the Front-End Engineering and Design phase (FEED). It did not focus on feasibility study phase, construction phase and close out phase.
- Due to time constraints and not having much first of a kind projects completed by the client/contractor or projects still being in the conceptual stage, only three first of a kind projects were studied.
- Due to time constraints, there was no extensive research on factors that will affect the proposed tools/practices in the first of a kind project.

8.3.2 Interviews

- Due to several people having tight schedule in their work, the sample size of number of people interviewed in each project was quite small. The author could just interview 10 people from all the three first of a kind of projects. A higher number of interviews would improve the generalizability of findings.
- The author could only interview people from the contractor side because the people from the client side were unwilling to provide project information because it violated their company's policies and regulations. The company's policies and regulations stated that the employees should not share the project management methods /tools/practices used in these projects to any third party because of the project being first of a kind.

8.3.3 Feasibility of proposed solutions

- Since the expert committee comprising of three experts was formed by the author's supervisor there could be influence of bias on feasibility of proposed solutions from the experienced practitioners.
- Some recommendations in chapter 7 like a 4-step strategy in managing the package unit vendors is best suited when there are limited package unit vendors supplying the black box. Adding to that tools/practice like overdesigning to manage the interfaces will require extra efforts, money, and time.

9. Conclusion

The objective of this research was to explore tools/practices to integrate sustainability in first of a kind projects. Conclusion is drawn in this chapter by answering the sub questions in section 9.1 and main research question in section 9.2. Following that thesis will be concluded by recommendations for future research and recommendation for practice.

9.1 Answering the sub questions

This section answers 5 sub questions that lead to the main research question being answered.

SQ1: What are the tools/practices which could positively influence in integrating sustainability in first of a kind projects in theory?

The following are the tools/practices to integrate sustainability in first of a kind projects in theory:

- Stakeholder Engagement Plans (SEP)
- Sustainability Integration Framework
- Risk Management Plans
- Commitment Risk Action Log
- Monitoring Sustainability Performance
- Approvals and Permits
- The Last Planner System (LPS)

SQ2: What are the limitations and challenges in implementing the tools/practices to integrate sustainability in first of a kind projects in theory?

The following are the limitations and challenges in implementing tools/practices to integrate sustainability in first of a kind projects in theory.

- Insufficient financial incentive and lack of evident return on investment.
- Lack of investment on sustainability in first of a kind projects .
- Lack of systematic approaches to planning and execution of works in fulfilment of sustainability.
- Inadequate studies and education on sustainable delivery of construction projects including first of a kind projects.
- Lack of support from policy makers.
- Incomprehension of the potential benefits of proactivity in combating climate change and implementing sustainability, and the economic risks associated with first of a kind projects.
- Stakeholders holding different perspectives on the sustainability goals/objectives and not being flexible to changes in these sustainable objectives/goals.

SQ3: What are the tools/practices used in integrating sustainability in first of a kind projects in practice?

This thesis looked at three first of a kind projects: Project A (Circular steam), Project B (Carbon Capture and Utilization and Storage), and Project C (Bioethanol Fuel). These projects showed that a diverse range of tools/practices were employed to incorporate sustainability into the projects. The following were the tools/practices that were utilized to integrate sustainability into these projects.

- Appointing a package unit manager to manage the package unit vendors
- Appointing a package unit managing team to manage the package unit vendors
- Use of engineering platforms like COMOS. E3D and Navisworks for team integration.
- Use of tools like EIA, HAZOP and SIL to manage the project risks.
- Use of a 3D model to manage the interfaces between the stakeholders.
- Appointing an interface manager to manage the interfaces between the stakeholders.
- HAZOP and SIL sessions with the vendors to manage the interfaces.
- Value engineering sessions to limit the CAPEX.
- Lesson learning sessions on vendors previous first of a kind projects used as critical success factors for these projects.
- Use of project scheduling tools like S curve to update the project status.
- Setting up of research area for research and development.
- Appointing a line manager to perform functions revolving around project resourcing.

SQ4: What are the limitations and challenges to integrate sustainability in first of a kind projects in practice?

The following were the limitations and challenges faced to integrate sustainability in the three first of a kind projects chosen for this study. All limitations mentioned below will be solved by the solutions proposed by the author which is mentioned under SQ5.

- Financial bankruptcy of the vendor.
- Vendors were not able to deliver the black box.
- Value improving sessions was restricted only on limiting the capex.
- There were interfaces in Designs and engineering activities
- Inadequate studies on selection of technologies and its design.
- Interfaces between contractual parties. In particular; the production company R&D department and the package unit supplier of key innovative technology.
- Overall and joint project risk management with clear ownership per issue was lacking.

SQ5: What are the solutions that can be implemented to solve the challenges faced in first of a kind projects in practice?

The solutions to the challenges faced in the first of kind projects are listed below. These solutions are the result of shortcomings identified in case studies of three projects. The solutions will aid in saving the CO_2 emissions and increase of the project's energy efficiency by reducing the delays in the first of a kind projects .

1. A four-step strategy to manage the package unit vendors and to avoid financial bankruptcy of the vendor
- Preselection of Technologies and Prequalification of Vendors
- Paying the prequalified vendor to do Basic Engineering
- Signing a risk sharing contract with the vendor
- Joint check agreement
2. Minimization, Optimization, Maximization and Constructability value engineering sessions as value improving practice to save the CO_2 emissions and increase the energy efficiency targets.

3. A four-step strategy an appointed interface managing team should follow to manage the interfaces between design and engineering activities
  - Re-ordering design activities
  - Restructuring strategies.
  - Anticipating the information on interfaces
  - Overdesign

4 Commitment Action Risk Log to make sure stakeholders are committed and assigned to the project

5 Stage gated project phasing to make sure stakeholders are committed and assigned to the project risk

6 Appointing an external specialist in Research and Development phase

7 Implementing a stage gated approach to manage the interfaces between research and development and the project organization

9.2 Answering the main research question

How to improve integration of sustainability in first of a kind project?

Implementing tools/practices to integrate sustainability in first of a kind projects has always been a challenge due to new technologies/methods involved. The following are the best tools/practices that can be used to integrate sustainability in first of a kind projects. The tools/practices were explored from the literature, projects studied as a part of case study and the solutions proposed to solved the challenges faced in the three projects.

From the literature

- ➢ Stakeholder Engagement Plans (SEP)
- ➢ Sustainability Integration Framework
- ➢ Risk Management Plans
- ➢ Commitment Risk Action Log
- ➢ Monitoring Sustainability Performance
- ➢ The Last Planner System (LPS)

In practice

- ➢ Use of engineering platforms like COMOS. E3D and Navisworks for team integration.
- ➢ Lesson learning sessions on vendors previous first of a kind projects used as critical success factors for these projects.
- ➢ Appointing a line manager to perform functions revolving around project resourcing.
- ➢ Value engineering sessions to limit the CAPEX.

Proposed tools/practices by the author

1. A four-step strategy to manage the package unit vendors and to avoid financial bankruptcy of the vendor

- ➢ Preselection of Technologies and Prequalification of Vendors
- ➢ Paying the prequalified vendor to do Basic Engineering
- ➢ Signing a risk sharing contract with the vendor
- ➢ Joint check agreement

2. Minimization, Optimization, Maximization and Constructability value engineering sessions as value improving practice to save the CO_2 emissions and increase the energy efficiency targets.
3. A four-step strategy an appointed interface managing team should follow to manage the interfaces between design and engineering activities

a) Re-ordering design activities
b) Restructuring strategies.
c) Anticipating the information on interfaces
d) Overdesign

4. Commitment Action Risk Log to make sure stakeholders are committed and assigned to the project
5. Stage gated project phasing to make sure stakeholders are committed and assigned to the project risk
6. Appointing an external specialist in Research and Development phase
7. Implementing a stage gated approach to manage the interfaces between research and development and the project organization

9.3 Recommendations for future research

Given the broad nature of sustainability and the possibility of more tools/practices being valuable to integrate sustainability in different stages of the first of a kind project, the following recommendations for further research are made, with the limits of the research described in section 8.3 serving as a springboard.

- As noted in section 7.2, the research was limited to the Front-End Engineering and Design phase (FEED). However, it is recommended to dive into other phases of first of a kind projects to see if the tools/practices employed in the FEED phase can be applied in these phases of the project and, if so, how effective they are. Furthermore, new tools/practices that can be used to integrate sustainability and guide project managers throughout the project's lifecycle should be investigated in subsequent phases of the project.
- It is recommended to interview more people and not just restrict to interviewing just project managers and package unit mangers but also take interviews of the package unit vendors, engineering manager and other stakeholders. One of the reasons is interviewees have their own perceptions and the information they share may differ from the rest of the interviewees. The other reason is to get a broader and more comprehensive perspectives on sustainability from different interviewees.
- The research explored tools/practices to integrate sustainability in first of a kind projects. It is recommended to carry out more research on what factors can influence the proposed tools/practices in integrating sustainability in first of a kind projects.
- It is recommended to explore this research in a quantitative approach so that the findings on the themes may be generalized more broadly and future results on using these tools/practices can be predicted more easily, hence boosting generalizability.
- The research was carried out on three first of a kind project projects from the European union. It is recommended to conduct the same research on different projects across developing countries such as India, the Middle East, and China, where many first of a kind projects are being built, and to see if the same tools/practices can be applied to these projects, as well as what challenges these countries might encounter to implement these tools/practices in their projects. This could lead to exploration of more tools/practices which can be helpful in integrating sustainability in such projects.

9.4 Recommendations for Practice.

The explorative findings of tools/practices in the research have been translated to recommendations to improve integration of sustainability in first of a kind projects. The recommendations proposed by the author are mentioned below.

- **Managing the package unit vendors**

It is recommended to use a four-step strategy: Preselection of Technologies and Prequalification of Vendors; Paying the prequalified vendor to do Basic Engineering; Signing a risk sharing contract with the vendor; Joint check agreement to prevent financial bankruptcy of the vendors and to make sure that vendors supply the black box within time.

- **Value improving practices**

It is recommended to have value enhancing sessions on waste minimization, energy optimization, maximization of end life production facility as value improving practices to save the CO_2 emissions and meet the energy efficiency targets as planned.

- **Managing the interfaces**

It is recommended that appointed interface managing team should follow a four-step strategy: Re-ordering design activities; Restructuring strategies; Anticipating the information on interfaces; Overdesign to manage the interfaces between the Design and Engineering activities in the FEED phase of project.

- **Project risks**

It is recommended to use a commitment risk action log to make sure that stakeholders are committed to project risk assigned to the stakeholders and that the stakeholders inform the commitment management team about the project risk and its implication on project progress on a regular basis.

To align all stakeholders and involved parties, it is recommended to apply the stage gated project structure which helps to fix key design basis information

- **Research and Development**

It is recommended to bring in external specialist in research and development phase to bring in expertise and knowledge of external specialist for selection and designing new technologies to be employed.

It is recommended to implement gated structure which can help to freeze the deciding parameters in facilitated sessions and these parameters can be: fixed; completely open for changes; fixed in an assumption that is still to be validated (but can be used for engineering).

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Appendices

Appendix 1: Project A (Detailed)

1. Managing the package unit vendors

The availability of the design of the Bioplant and Waste incineration will be the key hurdle for the FEED. The design of the package is expected to be completed only when the suppliers for these packages have been chosen and granted an order. The linking scope is determined by the design of the package unit suppliers and can only be completed once the package designs have been thoroughly defined. After the design of the package is completed, a stakeholder meeting will be held to discuss about the scope of design package.

A **package unit manager** will be in charged to manage the vendors and to ensure that the vendors design process will proceed at a constant pace and agreed upon milestones will be completed on time giving enough information for the interconnection scope to be developed further. He will also be in charged for interfacing coordination between the stakeholders that is between the vendors and Client/Contractor. The package unit manager will also look into coordination of received information from the stakeholders as well as the technical bid evaluation. He will be also responsible for progress monitoring and follow ups, based on the agreed methods from the stakeholders. The Package unit manager along with the key team members from the client side will visit the vendors' offices to kick off their works.

The consultant will draft a demand in order to get a lumpsum pricing from the vendors. This request must be as detailed as possible, and it must include not only the technical scope and guarantee values, but also the import design requirements for safeguarding and other Client-specific criteria.

Interviewee 2 felt that that managing the package unit vendors during the project was a key hurdle. This was after the delays which lowered the energy- efficiency from reaching the targeted 85%.

2. Organization structure.

The organization for this project was split into two structures. One was the client organization which involved all the specialist whose main function was to review the decision and give approval for the changes made in the project in all the phases. They were not involved in the decision-making process in all phases, but they visited the steering or integrated team in the task force area every twice a week. Second structure was the steering or the integrated team which consisted of 25 members mainly involved in the decision-making process in the project and for looking into day-to-day activities. The members from the steering or integrated team were from different fields of discipline like project manager, project engineer, package unit manager, process engineer, document control engineer etc. This team was also responsible for reporting the progress and decisions taken to the client as well as other stakeholders once in every two weeks. The integrated team also interacted with Client's organization regarding the information about the existing plant which needed to be made available, options and alternatives was discussed, operational and maintenance procedures was made clear to the project team, project requirements was further explained, and so on. The Clients organization project manager's job was to make the relationship between the client organization and the integrated team more efficient.

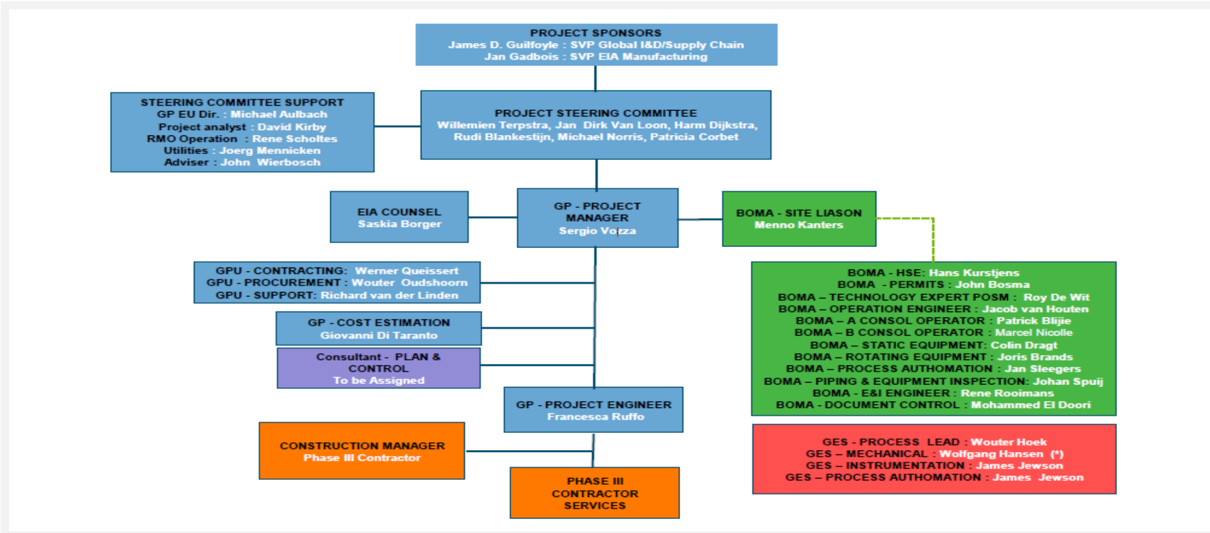


Figure 8: Client organization structure

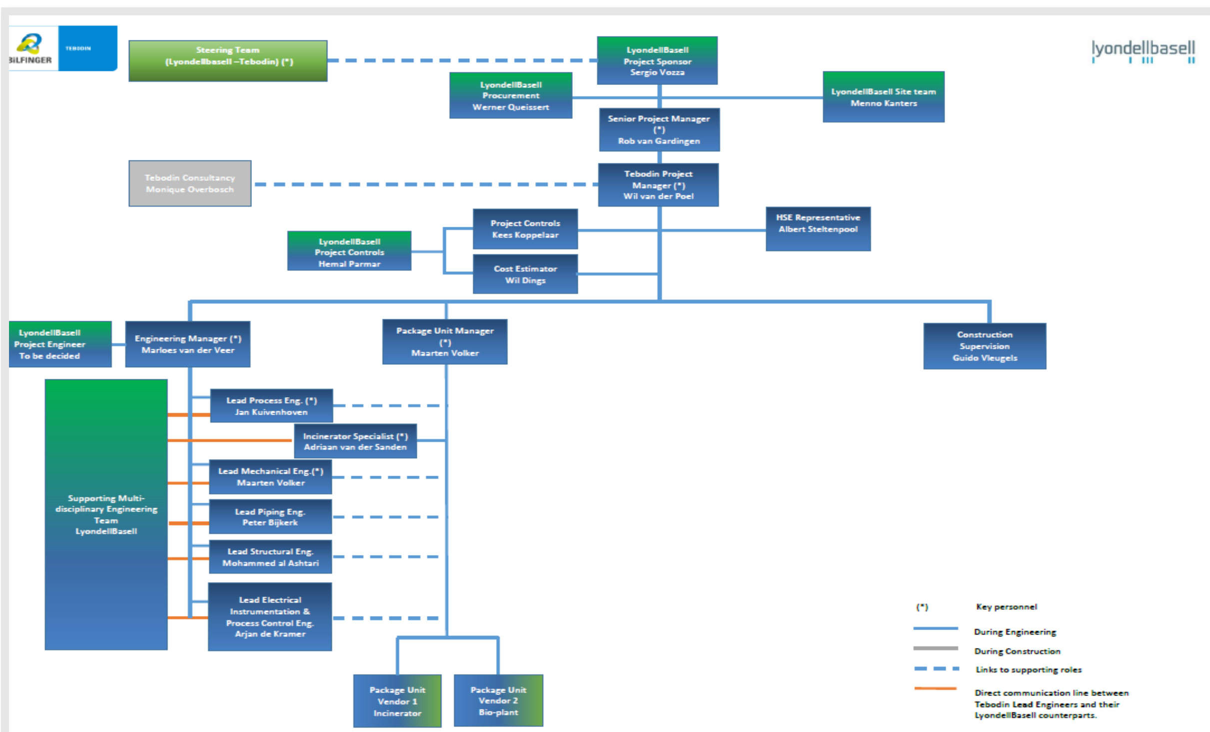


Figure 9: Steering team organization structure

3. Team Integration

An integrated team was set up to ensure collaboration between stakeholders of client and consultant to ensure that all the defined requirements will be complete. An escalation model was used to keep the project team engineering meeting once in a week to inform all the stakeholders about the progress and to address issues for which in separate meetings solutions had to be found. A project steering group was also formed to discuss about the project's validity in FEED with key participants and to solve the problems which could not be solved in team engineering meeting and this meeting is intended to check all the concerns, actions, and choices which were made will be monitored, followed up on, and resolved as quickly as possible. Extensive kick off meeting was held at the beginning to ensure intensive collaboration between all the stakeholders and to create a team work ethic. A task force area for integrated team was also set up. Execution of work in this area was done by consultants and few members from the client side. Adding to that, to overview of the work done by the integrated team specialist from the client side came to task force area once in a week.

According to **interviewee 2**, team work especially between the client and the contractor was evident during the FEED phase. The second interviewee felt that this relationship broke due to the delays caused by the vendors.

Function	Tebodin	LyondellBasell
Project management	Wil van der Poel /Rob van Gardingen	Sergio Vozza
Project engineering	Marloes van der Veer	Francesca Ruffo
Package units manager	Maarten Volker	Wouter Hoek, Menno Kanters
Civil, Steel & Architectural	Mohamed Al Ashtari	Kiran Bissumbhar
Mechanical	Maarten Volker	Colin Dragt / Wolfgang Hansen
Piping	P. Bijkerk	Khan Sharifullah / Wolfgang Hansen
Fire fighting	Ad Broeren	Peter Heijn
Process	Jan Kuivenhoven	Wouter Hoek
E&I	Arjan de Kramer	René Rooimans
Process	Arjan de kramer	Jan Sleegers
Document control	Danny van Zanen	Hamza El Doori
Cost estimating	Wil Dings	Giovanni Di Taranto
Project controls	Kees Koppelaar	Parmar Hemal
HSE	Albert Steltenpool	Hans Kurstjens

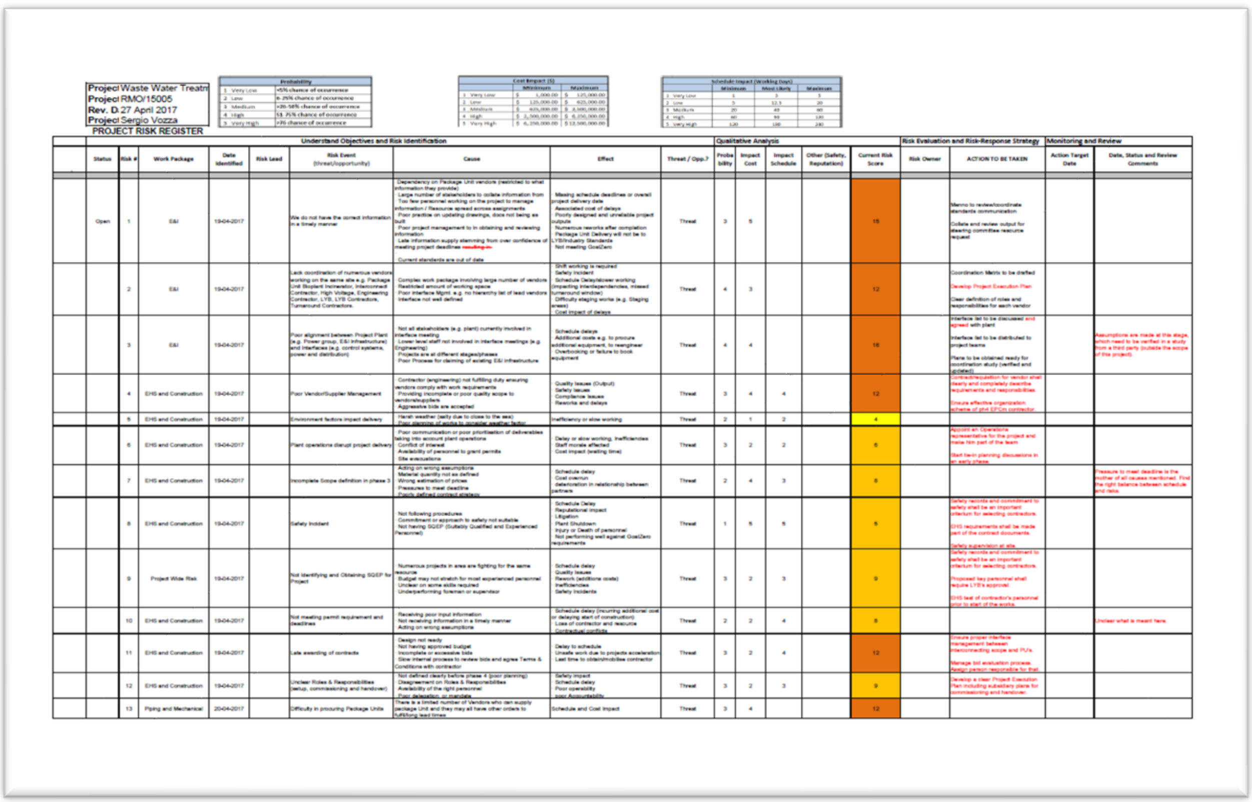
Table 9: Overview of integrated team

4. Lessons learned and Project Risks

One of the first things which was done in the FEED phase was to involve all the key stakeholders and key team members from both consultant as well as company side to have a lesson learned session from all the previous first kind of projects with the intention to gather and evaluate experiences from previous projects and use them as key success factors for this project.

Project risk identification and evaluation workshop was set up and the entire integrated team was present to identify risk, assess them as well as to rank them. Also, other stakeholders were invited to participate in this workshop to get a good knowledge about the threats and opportunities of this project. Adding to that, a smaller group of specialists from the integrated team was also set up for determining the mitigation action of the risks as well to identify the risk owners. To track the progress of mitigation actions by the small group of integrated team, regular follow up meetings was held weekly .Common areas of attention in this project were general risk(organizational aspects) ,EHS and permit risk , technical and executional risks , planning risk , financial and commercial risk.

The **third interviewee** stated that the lessons learned from the previous boiler project on the client site were reviewed. Sustainability was addressed mainly on the energy efficiency and effective ways to reduce the greenhouse gas emissions. In addition, lessons learned from a project in China.



Project Waste Water Treatm
Project RMO/15005
Rev. D 27 April 2017
Project Sergio Vozza
PROJECT RISK REGISTER

Probability	
1 Very Low	<5% chance of occurrence
2 Low	6-25% chance of occurrence
3 Medium	>26-50% chance of occurrence
4 High	51-75% chance of occurrence
5 Very High	>76 chance of occurrence

Cost Impact ($)	Minimum	Maximum
1 Very Low	$ 1,000.00	$ 125,000.00
2 Low	$ 125,000.00	$ 625,000.00
3 Medium	$ 625,000.00	$ 2,500,000.00
4 High	$ 2,500,000.00	$ 6,250,000.00
5 Very High	$ 6,250,000.00	$ 12,500,000.00

Schedule Impact (Working Days)	Minimum	Most Likely	Maximum
1 Very Low	1	3	5
2 Low	5	12.5	20
3 Medium	20	40	60
4 High	60	90	120
5 Very High	120	180	240

Understand Objectives and Risk Identification								Qualitative Analysis						Risk Evaluation and Risk-Response Strategy		Monitoring and Review	
Status	Risk #	Work Package	Date Identified	Risk Lead	Risk Event (threat/opportunity)	Cause	Effect	Threat / Opp.?	Probability	Impact Cost	Impact Schedule	Other (Safety, Reputation)	Current Risk Score	Risk Owner	ACTION TO BE TAKEN	Action Target Date	Date, Status and Review Comments
Open	1	E&I	19-04-2017		We do not have the correct information in a timely manner	Dependency on Package Unit vendors (restricted to what information they provide) Large number of stakeholders to collate information from Too few personnel working on the project to manage information / Resource spread across assignments Poor practice on updating drawings, docs not being as built Poor project management to in obtaining and reviewing information Late information supply stemming from over confidence of meeting project deadlines ~~resulting in~~ Current standards are out of date	Missing schedule deadlines or overall project delivery date Associated cost of delays Poorly designed and unreliable project outputs Numerous reworks after completion Package Unit Delivery will not be to LYB/Industry Standards Not meeting GoalZero	Threat	3	5			15		Memo to review/coordinate standards communication Collate and review output for steering committee resource request		
	2	E&I	19-04-2017		Lack coordination of numerous vendors working on the same site e.g. Package Unit Bioplant Incinerator, Interconnect Contractor, High Voltage, Engineering Contractor, LYB, LYB Contractors, Turnaround Contractors.	Complex work package involving large number of vendors Restricted amount of working space Poor interface Mgmt. e.g. no hierarchy list of lead vendors Interface not well defined	Shift working is required Safety incident Schedule Delay/slower working (impacting interdependencies, missed turnaround window) Difficulty staging works (e.g. Staging areas) Cost impact of delays	Threat	4	3			12		Coordination Matrix to be drafted Develop Project Execution Plan Clear definition of roles and responsibilities for each vendor		
	3	E&I	19-04-2017		Poor alignment between Project Plant (e.g. Power group, E&I infrastructure) and interfaces (e.g. control systems, power and distribution)	Not all stakeholders (e.g. plant) currently involved in interface meeting Lower level staff not involved in interface meetings (e.g. Engineering) Projects are at different stages/phases Poor Process for claiming of existing E&I infrastructure	Schedule delays Additional costs e.g. to procure additional equipment, to reengineer Overbooking or failure to book equipment	Threat	4	4			16		Interface list to be discussed and agreed with plant Interface list to be distributed to project teams Plans to be obtained ready for coordination study (verified and updated)		Assumptions are made at this stage, which need to be verified in a study from a third party (outside the scope of this project).
	4	EHS and Construction	19-04-2017		Poor Vendor/Supplier Management	Contractor (engineering) not fulfilling duty ensuring vendors comply with work requirements Providing incomplete or poor quality scope to vendors/suppliers Aggressive bids are accepted	Quality issues (Output) Safety issues Compliance issues Reworks and delays	Threat	3	4	4		12		Contract/requisition for vendor shall clearly and completely describe requirements and responsibilities. Ensure effective organization scheme of ph4 EPCm contractor.		
	5	EHS and Construction	19-04-2017		Environment factors impact delivery	Harsh weather (salty due to close to the sea) Poor planning of works to consider weather factor	Inefficiency or slow working	Threat	2	1	2		4				
	6	EHS and Construction	19-04-2017		Plant operations disrupt project delivery	Poor communication or poor prioritisation of deliverables taking into account plant operations Conflict of interest Availability of personnel to grant permits Site evacuations	Delay or slow working, inefficiencies Staff morale affected Cost impact (waiting time)	Threat	3	2	2		6		Appoint an Operations representative for the project and make him part of the team Start tie-in planning discussions in an early phase.		
	7	EHS and Construction	19-04-2017		Incomplete Scope definition in phase 3	Acting on wrong assumptions Material quantity not as defined Wrong estimation of prices Pressures to meet deadline Poorly defined contract strategy	Schedule delay Cost overrun deterioration in relationship between partners	Threat	2	4	3		8				Pressure to meet deadline is the mother of all causes mentioned. Find the right balance between schedule and risks.
	8	EHS and Construction	19-04-2017		Safety Incident	Not following procedures Commitment or approach to safety not suitable Not having SQEP (Suitably Qualified and Experienced Personnel)	Schedule Delay Reputational impact Litigation Plant Shutdown Injury or Death of personnel Not performing well against GoalZero requirements	Threat	1	5	5		5		Safety records and commitment to safety shall be an important criterium for selecting contractors. EHS requirements shall be made part of the contract documents. Safety supervision at site.		
	9	Project Wide Risk	19-04-2017		Not Identifying and Obtaining SQEP for Project	Numerous projects in area are fighting for the same resource Budget may not stretch for most experienced personnel Unclear on some skills required Underperforming foreman or supervisor	Schedule delay Quality issues Rework (additions costs) Inefficiencies Safety Incidents	Threat	3	2	3		9		Safety records and commitment to safety shall be an important criterium for selecting contractors. Proposed key personnel shall require LYB's approval. EHS test of contractor's personnel prior to start of the works.		
	10	EHS and Construction	19-04-2017		Not meeting permit requirement and deadlines	Receiving poor input information Not receiving information in a timely manner Acting on wrong assumptions	Schedule delay (incurring additional cost or delaying start of construction) Loss of contractor and resource Contractual conflicts	Threat	2	2	4		8				Unclear what is meant here.
	11	EHS and Construction	19-04-2017		Late awarding of contracts	Design not ready Not having approved budget Incomplete or excessive bids Slow internal process to review bids and agree Terms & Conditions with contractor	Delay to schedule Unsafe work due to projects acceleration Last time to obtain/mobilise contractor	Threat	3	2	4		12		Ensure proper interface management between interconnecting scope and PU's. Manage bid evaluation process. Assign person responsible for that.		
	12	EHS and Construction	19-04-2017		Unclear Roles & Responsibilities (setup, commissioning and handover)	Not defined clearly before phase 4 (poor planning) Disagreement on Roles & Responsibilities Availability of the right personnel Poor delegation, or mandate	Safety impact Schedule delay Poor operability poor Accountability	Threat	3	2	3		9		Develop a clear Project Execution Plan including subsidiary plans for commissioning and handover.		
	13	Piping and Mechanical	20-04-2017		Difficulty in procuring Package Units	There is a limited number of Vendors who can supply package Unit and they may all have other orders to fulfilling lead times	Schedule and Cost Impact	Threat	3	4			12				

Figure 10: Overview of identified risk (Risk Register)

5. Interface Management

In the Feed phase, interfaces was identified and basic solutions were agreed between relevant stakeholders. Interface management was done because project consisted of two units supplied by two different contractors and an interconnecting scope by consultant for the success of the project and also because unidentified interfaces would lead to more cost and time. In addition to that, HAZOP and SIL sessions was organized with selected vendors to manage the interface between the units and the interconnecting scope.

The only lesson learned according to **interviewee one**, is that it could be disastrous to meet the sustainability requirements if the project is not finished on time and especially if it is delayed in the FEED phase because according to us and your thesis FEED phase is the foundation to integrate sustainability in the project.

6. Value Improving Practices

In the FEED phase, consultant implemented value improving practices to increase the value of money and following studies were overseen during the FEED phase

- **Value Engineering Session:** A brainstorm session was held to identify the opportunities to save money without compromising the performance or objectives of the project goal
- **Process reliability monitoring:** A spare philosophy was developed during the FEED phase. In addition to this, all the vendors were asked to provide a recommended spare part list.

Value Engineering workshop were conducted with the relevant stakeholders to address the sustainability goals. Also adding to this, external specialist was called from different companies to transfer their expertise knowledge to the suppliers as well as to other stakeholders. The external specialist was mainly called to address sustainability goals especially on the subjects related to the reduction of greenhouse gas emissions, energy efficiency and spillages that might cause environmental hazards.

7. Project Schedule Control

Consultant developed a project schedule in close cooperation with all the stakeholders to ensure commitment in reaching the project goals. Bidders were also asked to include a detailed planning of the bid to give the stakeholders a good understanding of the bidders approach and to enable the stakeholders to challenge the proposed schedule. The first focus in the FEED phase was defining the URS/Requisition on time. Also, to keep the track of the project, a clear level 3 biweekly meeting was done along with coordination meetings to ensure that the team stays aware of the projects milestones and their input is given.

Consultant organized interactive sessions with the integrated team and selected vendors for the project to develop consistent planning which will ensure that all stakeholders commit to the project objectives. This agreed planning schedule by all stakeholders was part of the package unit vendors scope of work. Every two weeks the project status was updated with the status line in the project schedule and an S curve was created to give management a clear view on the situation.

Interviewee one did not feel like there was tight schedule in the FEED phase because in the early feed phase that is conceptual phase, more than 2 years was taken in researching and finding of the right technology or technological solution to be used to solve the problem. Choosing the right technology was the main motive to integrate sustainability which was exactly done in FEED phase.

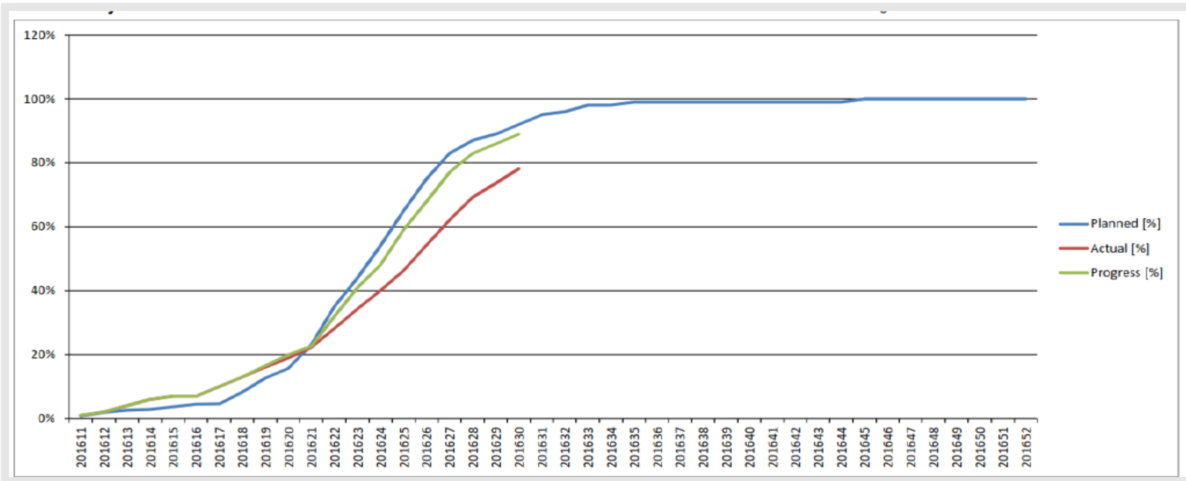
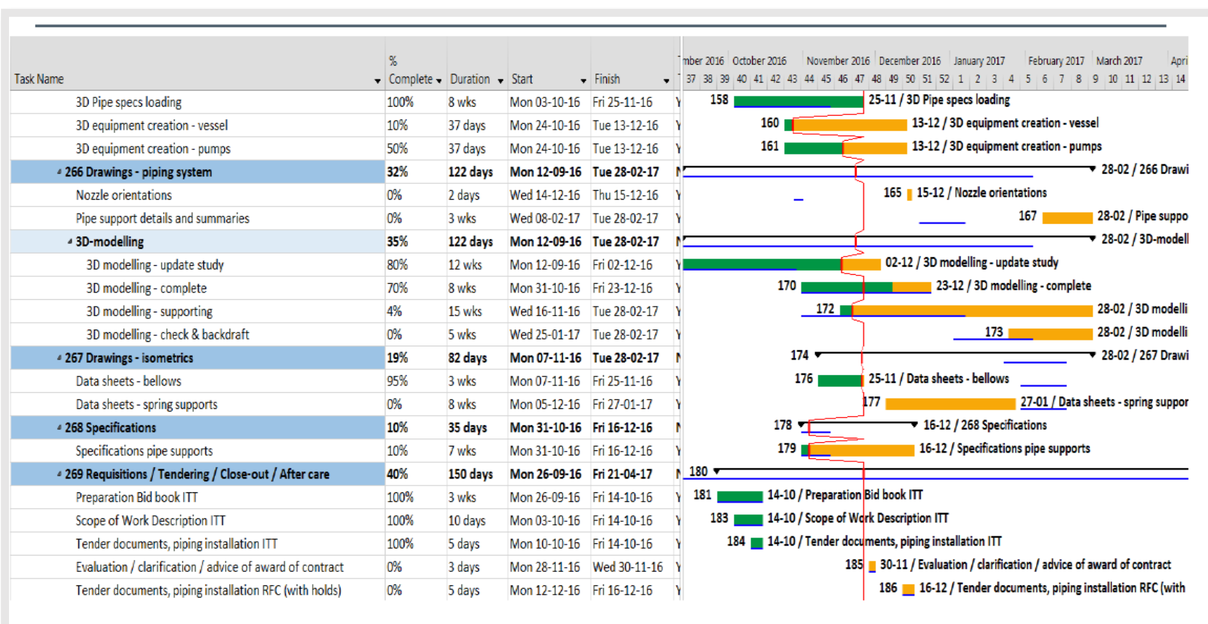


Figure 11: Overview project baseline



Task Name	% Complete	Duration	Start	Finish
3D Pipe specs loading	100%	8 wks	Mon 03-10-16	Fri 25-11-16
3D equipment creation - vessel	10%	37 days	Mon 24-10-16	Tue 13-12-16
3D equipment creation - pumps	50%	37 days	Mon 24-10-16	Tue 13-12-16
266 Drawings - piping system	32%	122 days	Mon 12-09-16	Tue 28-02-17
Nozzle orientations	0%	2 days	Wed 14-12-16	Thu 15-12-16
Pipe support details and summaries	0%	3 wks	Wed 08-02-17	Tue 28-02-17
3D-modelling	35%	122 days	Mon 12-09-16	Tue 28-02-17
3D modelling - update study	80%	12 wks	Mon 12-09-16	Fri 02-12-16
3D modelling - complete	70%	8 wks	Mon 31-10-16	Fri 23-12-16
3D modelling - supporting	4%	15 wks	Wed 16-11-16	Tue 28-02-17
3D modelling - check & backdraft	0%	5 wks	Wed 25-01-17	Tue 28-02-17
267 Drawings - isometrics	19%	82 days	Mon 07-11-16	Tue 28-02-17
Data sheets - bellows	95%	3 wks	Mon 07-11-16	Fri 25-11-16
Data sheets - spring supports	0%	8 wks	Mon 05-12-16	Fri 27-01-17
268 Specifications	10%	35 days	Mon 31-10-16	Fri 16-12-16
Specifications pipe supports	10%	7 wks	Mon 31-10-16	Fri 16-12-16
269 Requisitions / Tendering / Close-out / After care	40%	150 days	Mon 26-09-16	Fri 21-04-17
Preparation Bid book ITT	100%	3 wks	Mon 26-09-16	Fri 14-10-16
Scope of Work Description ITT	100%	10 days	Mon 03-10-16	Fri 14-10-16
Tender documents, piping installation ITT	100%	5 days	Mon 10-10-16	Fri 14-10-16
Evaluation / clarification / advice of award of contract	0%	3 days	Mon 28-11-16	Wed 30-11-16
Tender documents, piping installation RFC (with holds)	0%	5 days	Mon 12-12-16	Fri 16-12-16

Figure 12: Project control overview

Appendix 2: Project B (Detailed)

1. Managing the package unit vendors

Engaging stakeholders from both client and contractor to side during the scope of the design package was a key element as it helped in choosing the right technology and materials to reduce the greenhouse gas emissions as one of the clear definitions of ownership of design & deliveries before contracting essential elements. Managing the vendors did not affect the sustainability goals of this project, as the goals were defined in the functional description prepared as part of the tendering phase and at the end of the contract. This was part of the awarding phase. The contract was managed based on functional requirements, and the rest was up to the vendors. Vendors who did not meet their functional requirements were removed from the shortlist.

2. Team integration

Team integration in this project was achieved by collaborating with different departments with a clear common goal. The client managed the construction and procurements while the supplier was involved with the regular progress meeting, kick-off meeting, review, and constructability meetings. For other contractors, the same was done, but it was less intensive due to the smaller scope. There is collaboration in this project through separate aspect models for each discipline and coordination models from suppliers / subcontractors. The piping E3D (Everything 3D from Aveva) model serves as the basis and main model. The other disciplines will also be created as separate 3D models that are linked to the master model. If E3D is not being used as 3D modelling program, the 3D information is based on an open exchange format:

- *.step / *.stp
- *.sat
- *.SDNF (Preferred format for steel structures)

Project partners	Organisation/ Company	Contact person
Project Manager	EKC	Peter Meijers
Process Engineer	EKC	
Project manager	Tebodin	Sidney Bakker
Civil Engineer	Tebodin	Chi-wa Tang
Piping Engineer	Tebodin	Marvin van der Valk
Process Engineer	Tebodin	Chris Hofman
Instrumentation Engineer	Tebodin	Brain van den Berg
Electrical Engineer	Tebodin	Tjipke Feenstra
Suppliers		
Contractor(s)		

Figure 13: Team integration

3. Lessons learned and project risk.

During the FEED phase, different lesson learning sessions were conducted, aiming to assess risks done during the project. The permitting procedure was included in the FEL2 design phase, and the same team members were boarded in the follow-up phase; this was a part of the project cycle review. An EIA (Environmental impact assessment) was made as part of the permitting procedures to identify common Environmental risks like reduction of GHGs emissions or spillages. The practices/tools used in determining the mitigation actions of such environmental risk and how engaged were the stakeholders involved in identifying, assessing, and determining the mitigation actions of the risks were mostly included in the contracts as performance guarantees and subjected to gate reviews.

Risk assesment

Company:	Techno Project Industriale	Work to be performed:	Installing, connecting and commissioning of CO2 plant on the AVR Duiven location. Work will be carried out by and under supervision of Techno Project Industriale (TPI). Deployment of subcontractors is also under supervision of TPI Managent	Version:	1.0
Location:	AVR Duiven			Version Date:	1-11-2018
Attendees:	TPI Employee			Risk assesment team:	A de Ruijter HSEQ Manager E. Tonellotto Project Manager

Numb:	Task or activity	Numb:	Risc / Danger Exposure	Risk before measures E	B	W	R	Numb:	Controle measures / Actions	Measures by	Remaining Risk E	B	W	R
1	Tasks, responsibilities and competences	1.1	Lack of clarity among employees in their function about the tasks, responsibilities and competences.	3	6	3	54	1.1.1	Company manual with function profile	TPI	3	6	0,5	9
								1.1.2	Instruction program new employees	TPI				
								1.1.3	Supervision by Fieldsupervisor on the job	TPI				
								1.1.4	Work instructions client	Client				
2	Information and education	2.1	Insufficient knowledge of employee	3	6	3	54	2.1.1	Policy complying to the minimum training requirements	TPI	3	6	1	18
								2.1.2	Organizing repetitive training courses	TPI				
								2.1.3	Periodic workplace inspection by supervisors and management	TPI				
		2.2	Expiry of diplomas and certificates	3	6	3	54	2.2.1	Presence of personnel file	TPI	3	6	0,5	9
								2.2.2	Planning system	TPI				
								2.2.3	Periodic concultation of human resources	TPI				
3	Behavior of employees in use of personal protective equipment	3.1	Eye injury, head injuries, cuts and burns	7	6	10	420	3.1.1	Free providing en delivery of PPE	TPI	3	6	1	18
								3.1.2	Providing information about the use of PPE	TPI				
								3.1.3	Periodic workplace inspection by supervisors and management	TPI				
								3.1.4	Periodic inspections by client	Client				
								3.1.5	PPE policy client	Client				
								3.1.6	Safety signs onsite	Client				
								3.1.7	Periodic Safetytoolbox	TPI				
								3.1.8	Workpermit system in place	client				
								3.1.9	Conducting LMRA	TPI				
								3.1.10	Minimum of a VCA certificate	TPI				
4	Use of medication, alcohol and drugs	4.1	Perfoming work under the influence of medication, alcohol and drugs	7	3	3	63	4.1.1	All employee of TPI will be informed about the zero tolerance policy regarding alcohol and drugs. The use of medication must be communicated by the employee to TPI. An certified consultant must give positive advice for using the medication	TPI	7	0,5	0,5	1,75
								4.1.2	Operational supervisors are instructed to recognize alerts of influence.	TPI				
								4.1.2	Periodically perform alchol testing by means of a breath test	TPI				
								4.1.3	cooperation with medical authority to allow an employee to voluntarily test if they are under the influence of drugs	TPI				
5	Access and routing on location	5.1	Falling slip, trip due to presence of unwanted objects / materials	7	6	6	252	5.1.1	Keep walkways free from obstructions	TPI /Client	3	6	1	18
								5.1.2	Housekeeping policy client	TPI /Client				
								5.1.3	Identified walkways	Client				
								5.1.4	Workpermit system in place	Client				
		5.2	Falling slip, trip due to froze walkways	7	1	6	42	5.2.1	Frost preventionplan	TPI	7	1	1	7
								5.2.2	Monitoring of weather forecast	TPI /Client				
								5.2.3	Periodic Safetytoolbox	TPI				
6	Walking and being pressent in workarea	6.1	Falling into a hole	15	3	3	135	6.1.1	Presence of barriers	TPI /Client	7	3	0,5	10,5
								6.1.2	Sufficient lighting	Client				
								6.1.3	Conducting LMRA	TPI				
								6.1.4	Workinstructions TPI employee	TPI				
		6.2	Bumping of head	3	3	3	27	6.2.1	Continuous wearing of PPE	TPI /Client	1	3	1	[illegible]
								6.2.2	Marking of risk areas	TPI /Client				
								6.2.3	Conducting LMRA	TPI				

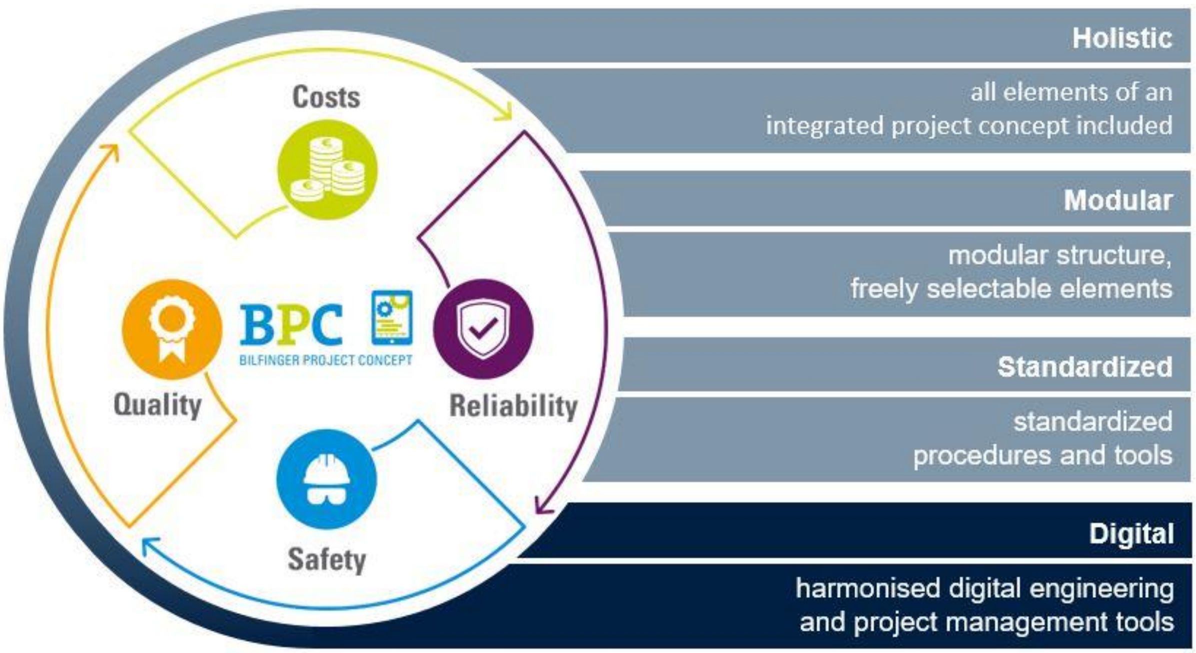
Figure 14: Risk Register

4. Interface Management

In a project in which the process is supported for use of a 3D Model interface protocol, the project partners must make some clear agreements on the working methods to be followed. The objective of this Protocol is therefore to create a clear picture of the approach for all involved and expectations regarding deliver (the quality of) results for each stage in the process. The project required new and well-designed interfaces and tie-ins on the existing and operational waste to the energy plant. Definition of overall performance while selecting proper interfaces with impact on material and energy flows was critical in design activity. The basis for the design in the interface management was a 3D model prepared by contractor based on conceptual information. During the project, all the different lots were exchanged by 3D models of the vendors. This way, the interfacing was possible, and clashes were managed. Regarding sustainability, the focus was on loss of containment and spills. Foundations and disposal facilities done by client / Civil contractor must be such that it meets the possible leakage and overflow scenarios of the other items.

5. Value Improving practices

To identify the opportunities to save money without compromising the performance or sustainability objectives, value improving was made part of the awarding phase, especially with the CCU vendor. Several options were identified as part of the contract. It was decided if a certain party did the scope during the project. For example, in the end, the MEA storage (chemical to capture CO_2) was outsourced to another company because they were more experienced in certified double-wall tanks, which limits the possibility for loss of containment. In cases where sustainable options were done, they were determined based on proven technology, ALARP, and timing.



6. Project Resourcing

No specific tools were used to fulfil resource demand and effective management of resourcing. Resources were mainly outsourced, and it was the responsibility of the contractors. This was essential as it encouraged the involvement of the contractors as early as possible and limited the AVR project team. On "design and engineering" activities, a clear gate review for engineering deliverables was defined. These activities were resource-based for each engineering discipline. A well-defined and implemented quality system with clear workflow management was the key basis for the proper resource planning of the project. Sustainability plans and guidelines were part of the functional description to the vendors.

7. Project scheduling

Tight scheduling affected the attention of sustainability as some delays were experienced from vendors responsible for material delivery. Scheduling also affected the additional scope to meet the loss of containment guidelines regarding NH3. This chemical was used as a cooling material and needed more detection to overcome a large NH3 emission as initially foreseen.

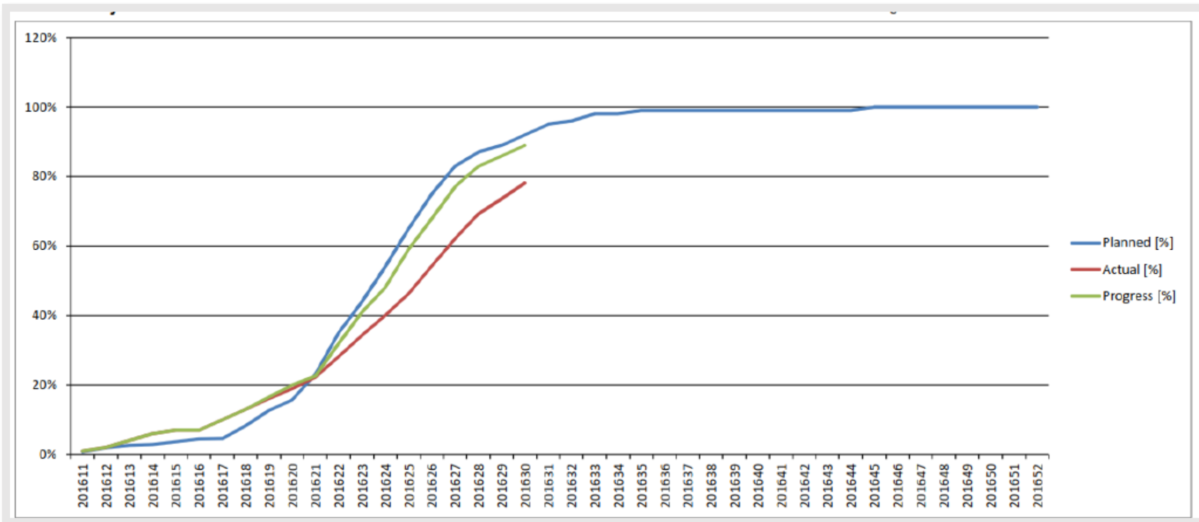


Figure 15: Project baseline overview

8. Research and Development

The project being a showcase demo for the next generation to capture plant expected soon to be implemented either for client or elsewhere, was the first of its kind project with subsidy on CO2 capture on a commercial scale. Research and development required the involvement of specialist contracting company who was to investigate proof of concept, which are still involved for supporting , monitoring and propose design and operational improvements. The research was mainly done by the selected vendors who had the knowledge and possible solution. Managing functional loss of containment/emission as part of the contract agreements.

Appendix 3: Project C (Detailed)

1. Managing the package unit vendors

To overcome the challenge of new technologies and methods used in this project, the client issued a basic engineering package (BEP) to the contractor which included all the technology specifications to be used after the discussion with the stakeholders from the client side. After the receival, the team of senior leader engineers from the contractor side started reviewing the package to understand the scope and to identify whether the information provided is sufficient. A follow up stakeholder meeting was held with all the stakeholders from client as well as contractor side to discuss about the finalized scope of the project and to convey the changes made by the contractor with respect to it. In some areas, vendor-specific process technology was employed (for example, within Package Units) which was not fully defined/ explained. This section was treated as a **black box**, where in the absence of information was addressed in such a case (technology wise, geometry wise, and automation wise). Contractor coordinated the **black box** within the overall project after obtaining the required vendor information.

A package unit manager oversaw managing the vendors and ensuring that the milestones was completed on time. To have the overview of the work done by the package unit manager, client set up a package unit managing team comprising of 4 people in it. The package unit manager along with the package unit managing team from the client side had weekly meetings with all the vendors to discuss about the progress, changes made to package unit and the follow ups and agreed methods given to them after consultation with the stakeholders.

2. Organization structure.

The organization structure was comprised of 3 teams, 2 teams from the contractor side and one team from the client side. 2 teams from the contractor side were the core team and the central engineering team (CET). Core team comprised of 4 people who were just responsible for taking the final decision and to approve changes if they were any. They were also responsible for keeping the project on track by having weekly meetings with the central engineering team to check the updates and progress of the projects. Central engineering team was comprised of 10 people, they were from different disciples like civil /structural, permitting, process, BIM coordination, procurement, construction management etc. The responsibility of CET team was parallel design requirement and to report the progress and the decision taken to the core team every week. All disciplines of CET along with the core team had weekly progress meetings for interdisciplinary alignment and steering. Communication to the client and stakeholders was done by a 3D model and through one common engineering data base (COSMOS). The project director and core team had weekly progress meetings with the client team and all the major stakeholders of the project. The CET team was also available on standby to elaborate on specific issues during the weekly client progress meeting to the client and other stakeholders.

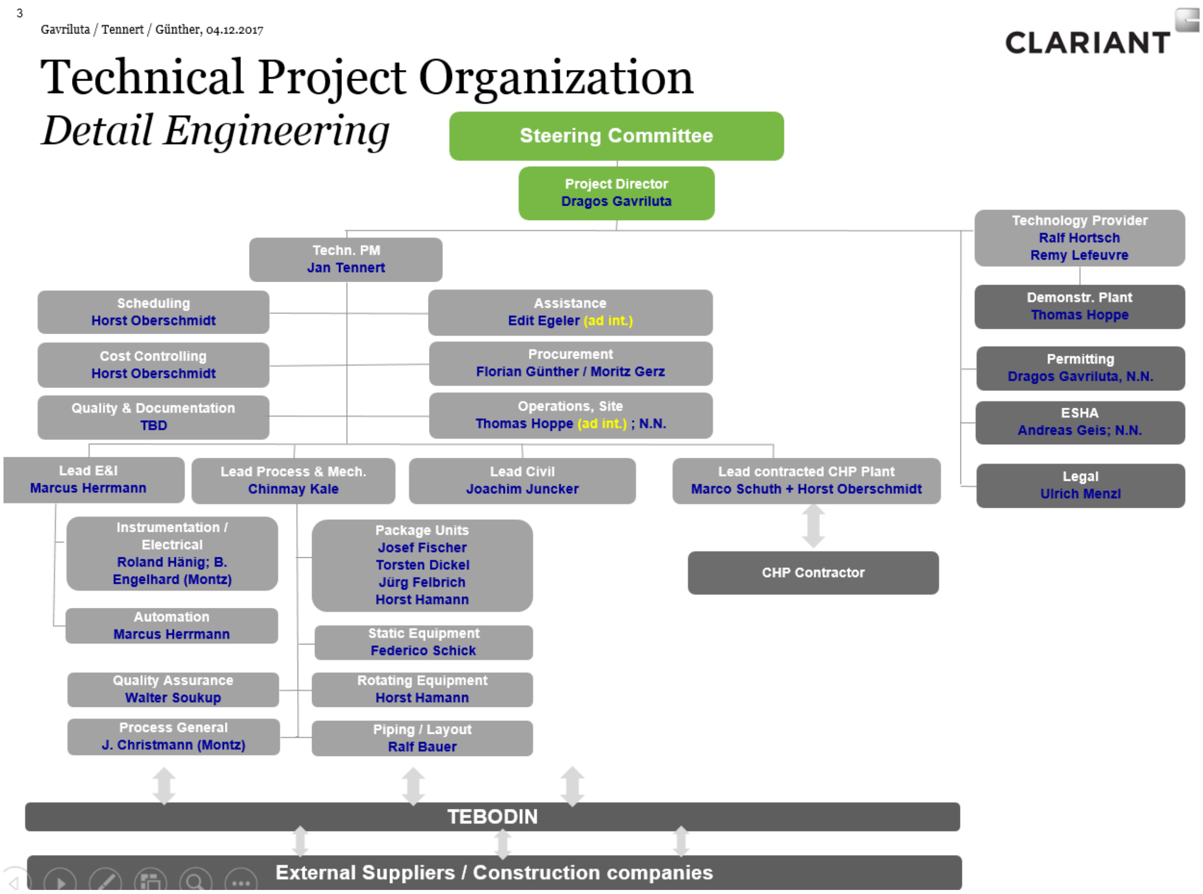


Figure 16: Client organization chart

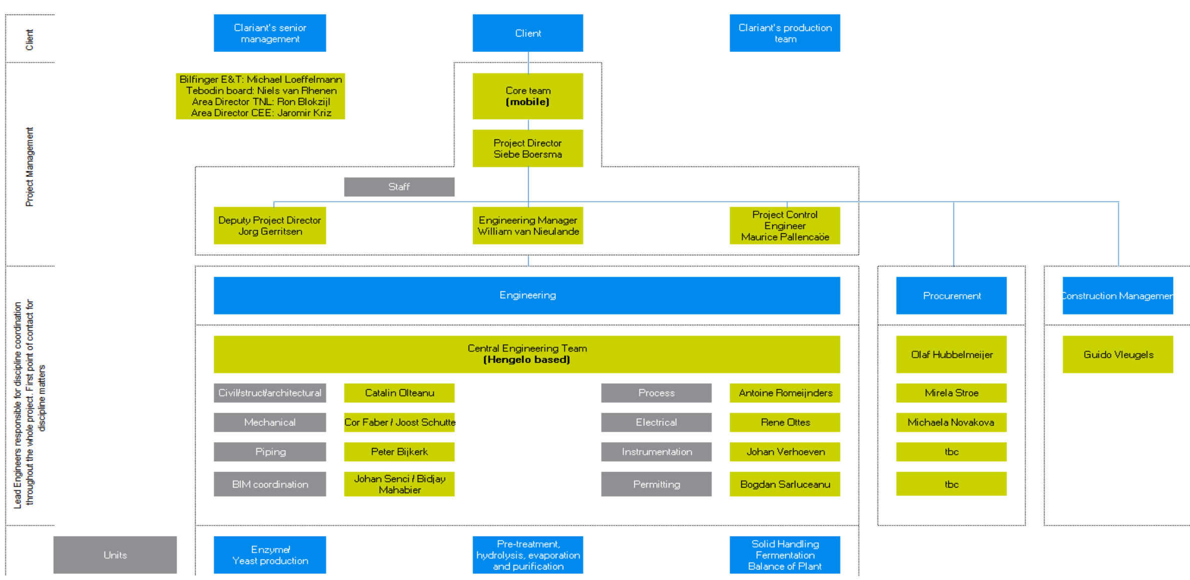


Figure 17: Contractor organization chart

3. Interface Management:

The interface manager was responsible to control the information flow on 3D model platform between the engineering design teams and the information from vendors during the FEED phase. He was responsible for coordinating the VDC team (vendor document control) from the procurement group which expedited the vendors for their timely (re) submission of (commented) documents and/ or their delivery of STEP data files for image insertion into the 3D model. The interface control is an important management tool for achieving sustainability in the early phases of the project in combination with the concurrent engineering that is required because of the time schedule requirements.

Adequate breakdown into the process units with clear boundary managed by the interface manager allowed the contractor and many vendors to have concurrent engineering work done in parallel with the early start of the civil part of the construction works.

4. Project Resourcing:

The project resource planning was done by lead engineers of the central engineering team and were assigned by the line management. A line manager was also appointed to perform various functions which revolved around the project resourcing. The project resources were optimised within the boundaries of client's requirements and the result of such optimization was beneficial for the client. The engineering was construction and commissioning-driven where input from the team and all the vendors was received early in the FEED phase of the project. The procurement team of contractor was responsible for procuring all identified demands (civil, services, equipment, packages, package units, etc) in the name and for the account of client. The procurement team of client created the PO to procure all identified demands (civil, services, equipment, packages, package units).

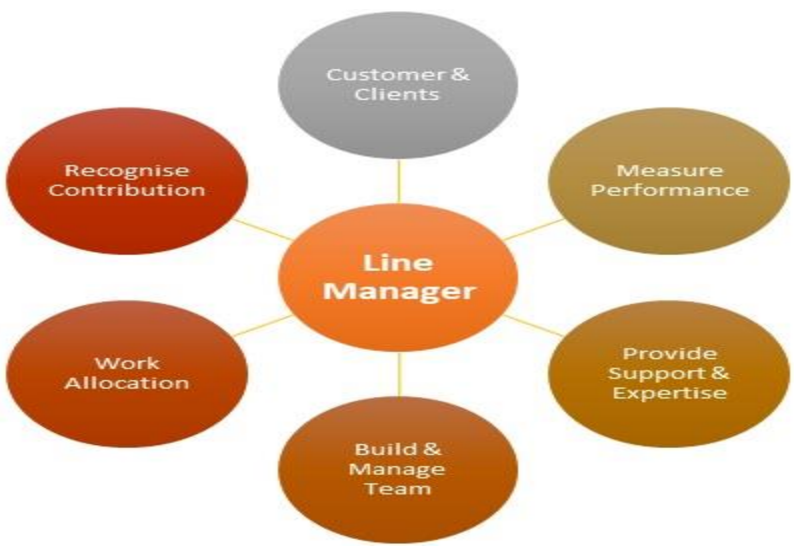


Figure 18: Functions of line manager

5. Research and Development:

Since the project was first of a kind and there was not much knowledge about the technologies to be used and for the selection of vendors who can best supply these materials and technologies. To overcome this a research and development area was set up in close collaboration with the client and all the stakeholders in the FEED phase of the project. The research was mainly focused on the long lead items and Package Units inquired on a budget level. The client organized brainstorming sessions thrice a week to bring the best ideas and knowledge regarding the technologies and materials to be used in the project. The best vendors from the market as well as the regular suppliers for the organization were called to provide their inputs from the research done and how they plan to implement these ideas and how will it be benefitted for the client with respect to the whole project. The team mainly involved in this research and development was the Central Engineering Team (CET) from the contractor organization and the steering team from the client organization. The drawback of the research was that it did not focus on ancillaries or utility requirements which led to around 500 major changes on the project.

6. Lessons learned during the FEED phase

The FEED phase was focusing on the functional performance of the main processes only and the long lead items and Package Units were only inquired on a budget level. This meant that all vendors just replied that they can deliver the equipment at a minimal price and there was no focus on ancillaries or utility requirements.

The project budget was based on the main process units only using budget quotations. Items like piperacks, small bore pipe, etc. was not considered, leading to a too low budget. These budget constraints lead to cost cutting measures during the detailed design that were not beneficial for the projects as a whole

Core team from the contractor organization tried to mitigate this by utilizing a Basic Design Review and Basic Design Update exercise which focused on the non-defined items between the several ISBL units and all OSBL requirements. They also considered that the process design within the ISBL units was correct and complete which turned out to be incorrect, leading to huge engineering spend during the Detailed Design phase to correct and align.

What the team learnt from this was that a proper Stage Gate process is vital, especially in projects using relatively new technology, such as energy transition and renewables projects. By defining the Stage Gates, they can properly define the goals for a FEED

- What will be engineered, and what will be left out?
- What will be the detail level of the engineering?
- What is the accuracy of the cost estimate / budget and are the contingencies properly defined?
- How to handle the non-defined items.

Appendix 4: Interview Protocol

This appendix will contain the interview questions which have been framed for all 3 projects based on the research objectives. The interviews will be semi structured meaning there will be room for additional questions and follow ups based on the interviewees answer on the list of questions prepared.

Preliminary Interview:

Following the initial email interaction with the interviewees, project documents containing specific information about the project are sought from one of the interviewees of that project. These can be documents related to tender, organizational chart, contract agreements, plans and specification, schedules, progress, and inspection reports, change orders, communication documents etc. During the preliminary interview, the topic of my research is first introduced to the interviewees and basic information like their role in the projects, years of experience in similar kind of projects and the stage which they were involved in the project were gathered. This preliminary interview lasted for about 20-25 mins.

Semi structured Interview:

Based on the project document analysis and insights from the literature review conducted, following interview questions were prepared and during the interview some questions were skipped or more questions were added. This interview approximately lasted for 90 mins.

Informal questions:

1. Can you please tell me about your role in Bilfinger, as well as in this Project?
2. How many years have you been working on this kind of large infrastructure Projects?
3. In which stages where you involved in this project?
4. How would you define sustainability in the context of your project?

FEED phase: - General questions

1. Who were present at the kick-off meeting and how were sustainability goals addressed in the kick-off meeting?
2. Was enough effort spent during this start-up phase? (yes/no: why, what were the consequences?
3. How were the quality criteria in choosing the technologies and materials in the project assessed?

Managing the package unit vendors:

1. From the document study, it seems managing the package unit vendors was a key hurdle for this project. Was this indeed the case? Why (not)?
2. How did managing these vendors affect the sustainability goals of the project?
3. How did engaging stakeholders from both client and contractor side during the scope of the design package help in choosing the right technology and materials to reduce the greenhouse gas emissions?

Team integration:

1. What does team integration mean to you? To what extent would you consider the team an integrated one?
2. How was team integration facilitated and how does the team integration facilitate sustainability?
3. What was the practices/tool used to ensure the engagement of stakeholders from client and contractor in the project in defining requirements of materials and technologies and how beneficial was it?

Lessons learnt and project risk:

1. What kind of lesson learning sessions were conducted during the FEED phase, who were involved and how were the sustainability issues addressed in such sessions? What were the practises/tools used in identifying the risk in the project?
2. What were the practises/tools used in identifying common Environmental risks like reduction of GHGs emissions or spillages? why certain choices were made and what were the consequences of these choices, how did it work out?
3. What were the practises/tools used in determining the mitigation actions of such environmental risk and how engaged were the stakeholders involved in identifying, assessing, and determining the mitigation actions of the risks?

Interface Management:

1. How was sustainability addressed in interface management?
2. What were the sessions organized with selected vendors and the stakeholders from both client and contractor side to manage the interface between the units and the sustainability scope?
3. How were the sustainability interfaces in the project managed?

Value Improving practises:

1. What were the practices/tools used to identify the opportunities to save money without compromising the performance or sustainability objectives? Who were involved? How did it work?
2. What kind of value engineering sessions on sustainability was conducted during the FEED phase with the stakeholders and how were the sustainability goals addressed?

Project Resourcing:

1. What tools/practises were used for fulfilment of resource demand and for effective management of resources. Why was it used and what was the effects of using it?
2. What were the plans/guidelines for project resourcing to engage sustainability in the project? How was it implemented?

Project scheduling:

1. How did the (tight?) schedule influence the attention for sustainability?

Research and Development:

1. What was the motive behind setting up a research area in this project?
2. What development and innovation have been explored to decrease GHG emanations or adjust to environmental change?

FEED cost:

1. How engaged were the stakeholders in discussion regarding the monitoring the progress cost of the project?

Conclusion questions:

1. Which of the project activities was the most critical to the project's success? And most critical to address sustainability? And why is that?
2. What was the most important lesson learnt from this project and how would you implement that lesson in a next project? In hindsight, what would you have done differently in this project?
3. What else comes to your mind regarding this project that hasn't been discussed so far?

Appendix 5: List of Interviewees

	Respondents	Position	Company
Project A: Circular Steam Project			
	Interviewee 1	Senior Project Manager	Engineering and consultants
	Interviewee 2	Project Manager	Engineering and consultants
	Interviewee 3	Package unit manager	Engineering and consultants
Project B: Carbon capture and utilization storage project			
	Interviewee 1	Lead energy specialist	Engineering and consultants
	Interviewee 2	Project Manager	Engineering and consultants
Project C: Cellulosic Ethanol Project			
	Interviewee 1	Senior Project Manager	Engineering and consultants
	Interviewee 2	Construction Manager	Engineering and consultants
	Interviewee 3	Project Manager	Engineering and consultants

Table 10: Overview of Interviewees

Expert Committee:

Respondents	Position	Company
Expert 1	Head of the procurement department	Engineering and consultants
Expert 2	Senior project Manager	Engineering and consultants
Expert 3	Senior project Manager and Procurement Manager	Engineering and consultants

Table 11: Expert Committee