Making Climate Data Actionable in Energy Investment Projects

A Working Method for Climate Data Collection, Desicion Support and LCA-Based Follow-up

Master's thesis in Quality and Operations management

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Abstract

Göteborg Energi has established ambitious targets to reduce the climate footprint of its procurement by 90% by 2030. While Life Cycle Assessment (LCA) is an established methodology for quantifying environmental impact, its practical integration into investment decisions is often constrained by organizational and data quality barriers rather than technical limitations. This thesis investigates how Göteborg Energi's working approach for climate data can be developed to support both early investment decisions, LCA-based follow-up and declarations in larger investment projects.

Using a mixed-methods approach structured around the DMAIC framework, a retrospective pilot LCA was conducted on the biomass-fired combined heat and power plant Rya BKV, delimited to the main supplier Valmet's scope of delivery. This were combined with semi-structured interviews, questionnaires, process observations, and supplier dialogue.

The analysis reveals three categories of barriers. Process-related barriers include late and unclear requirements specification in procurement. Data quality barriers including a strong reliance on generic emission factors due to limited availability of product-specific Environmental Product Declarations (EPDs). Organizational barriers arise from unclear allocation of responsibilities between project management, procurement, and the environmental function.

In response, an improved working method is proposed that separates climate data into two distinct flows: a limited decision-support flow for use in tender evaluation and a comprehensive follow-up flow post-award, utilizing a standardized supplier data template. The method is reinforced by a shared terminology structure for climate data types, explicit allocation of responsibilities, and a four-level fallback process for missing emission factors. The result is a scalable and structured approach that bridges the gap between early climate screening and rigorous LCA-based follow-up, without assuming complete product-specific data availability at all project stages.

Keywords: life cycle assessment, LCA, climate data, investment projects, procurement, environmental product declaration, EPD, DMAIC, district heating, biomass

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Alfred Lilliedahl & Daniel Åkerlund, Gothenburg, June 2026

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

BKV	Biokraftvärmeverk (Bio combined heat and power plant)
BOM	Bill of materials
BVB	Byggvarubedömningen
CSA	Civil, Structural, and Architectural
DMAIC	Define Measure Analyse Improve Control
EPD	Enviromental product declaration
GE	Göteborg Energi
LCA	Life cycle assesment
p-FMEA	Potential-Failure Mode and Effects Analysis
RFI	Request for information
RQ	Research question

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Introduction

This thesis is carried out in collaboration with Göteborg Energi and takes its starting point in the organization's ongoing transition toward reduced climate impact in energy production and investments. The study focuses on how life cycle assessment (LCA) can be used as a systematic tool to support this transition, as well as how organizational conditions affect the quality and utility of the analyses conducted. The following sections present the background motivating the study's direction, its delimitations, and problem formulation.

1.1 Background

Göteborg Energi is in a comprehensive transition phase with the objective that all district heating shall be derived from renewable or recovered sources by the end of 2025. A central part of this effort is the commissioning of a new biomass combined heat and power plant at Rya (Rya BKV), which is being taken into operation in early 2026. In parallel with the goal of fossil-free production, the organization has established ambitious requirements to reduce the climate footprint of its procurement by 90% by 2030.

Procurement includes the phases of raw material extraction, manufacturing and construction. Göteborg Energi has recently introduced new directives for climate calculations in investment projects. These have been developed with the support of external consultants but are not yet fully implemented and the working approach exhibits variation between projects. Previous analyses have focused primarily on the phases of raw material extraction, manufacturing and construction, while the significant emissions from the use phase and future end-of-life treatment have been excluded. The construction sector has since 2022 been required to produce climate declarations for buildings from a life cycle perspective (Boverket, 2024). Göteborg Energi assesses that similar requirements may in time come to encompass the energy sector as well, and therefore aims to introduce a working approach in which the entire life cycle is included.

Göteborg Energi currently uses an internal Excel-based climate spreadsheet to assess potential climate savings in investment projects. The spreadsheet is primarily designed to compare two alternatives, typically a reference case and a climate-improved case. For each alternative, quantities, emission factors, and cost data are compiled in order to calculate both the difference in climate impact and the additional cost of the climate-improving measure.

Within Göteborg Energi, a climate spreadsheet is mandatory for projects exceeding SEK 20 million. For projects exceeding SEK 2.5 million, a climate spreadsheet may be required in certain cases, but is not generally mandatory. The spreadsheet is therefore primarily relevant for larger investment projects, where climate impact, supplier involvement, and documentation requirements are more extensive.

The climate saving is expressed as the difference in kg CO2e between the two alternatives. The additional cost is then related to the achieved climate reduction and compared with Göteborg Energi's internal shadow price of 2 SEK per kg CO2e, corresponding to 2,000 SEK per tonne CO2e. This existing practice forms an important starting point for the thesis, as the study examines how early climate screening can be connected to supplier data collection and later LCA-based follow-up.

Despite the facility's strategic significance and substantial investment, a complete LCA has not been conducted during the design and procurement phase. There is therefore a need to carry out a retrospective analysis of the completed facility in order to identify the primary emission drivers and propose improvement measures.

Literature in the field shows that LCA's practical impact in investment and decision-making processes is often more constrained by organizational factors than by technical and methodological shortcomings in the LCA method itself. Lack of high-quality data, internal competence, insufficient organizational acceptance and difficulties in interpreting and using results are recurring barriers to LCA being used systematically as decision support (Hjellvik & Kirkels, 2025; Subal et al., 2024; Testa et al., 2022).

While the technical calculation model and methodology of LCA are well developed and well established in the literature (Baumann & Tillman, 2004), previous research shows that LCA's use within organizations' investment and decision-making processes is not determined solely by the method's technical quality. Studies on the implementation and use of LCA show that organizational factors such as internal competence, resource allocation, requirement specification in procurement and access to data are of great importance for how analyses are conducted and to what extent results are used as decision support (Hjellvik & Kirkels, 2025; Testa et al., 2022). Research thus indicates that barriers to LCA's practical application are often organizational rather than methodological.

At the same time, knowledge is limited regarding how these organizational factors affect the quality of climate data in larger investment projects in the energy sector. There is therefore a need to both identify the barriers present in the current system and design a new model for how information flows and collaboration can secure the quality of climate data throughout the entire project chain. Rya BKV therefore serves in this project as a pilot project and an empirical case for studying how governance, information flows and organizational conditions affect the robustness and decision-making value of environmental analyses.

1.2 About the Case Study: Rya BKV

Rya BKV is a major investment project within Göteborg Energi's production system. The project consists of a new biomass-fired steam boiler connected to the existing combined heat and power plant at Rya. The facility is dimensioned for approximately 150 MW of heat and 37 MW of electricity and is intended to strengthen Göteborg Energi's district heating and electricity production.

The project has an approved cost framework of SEK 2.65 billion at November 2022 price levels, making it a strategically significant investment project. Its scale, technical complexity, and supplier structure make it relevant as a case for examining how climate data can be collected, quality-assured, and used in larger investment projects.

The case is also relevant because Rya BKV was carried out during a period when Göteborg Energi's working approach for climate calculations was still under development. The project therefore provides an opportunity to study how LCA and climate data can be used in an actual investment project, as well as what limitations arise when climate data requirements are not fully specified in early project phases.

In this study, Rya BKV is used not only as a technical calculation object, but also as a pilot case for examining how data collection, supplier dialogue, and organizational processes function in practice.

1.3 Purpose

The purpose of this thesis is to conduct a pilot LCA of Rya BKV and using this as empirical material to analyze what process-related, data quality-related, and organizational barriers constrain the use of climate data investment decisions and LCA-based follow-up. The study also aims to design an improved working approach for the collection, quality assurance, and use of climate data within Göteborg Energi.

The pilot LCA is used both to compile climate impact, data sources and data limitations associated with Valmet's delivery and to examine how data collection, supplier dialogue, data quality and organizational responsibilities function in practice. The LCA thus serves both as a technical deliverable to Göteborg Energi and as a methodological tool for analyzing the current working approach.

By combining a technical pilot LCA with an analysis of organizational and process-related conditions, the study is expected to yield the following results:

- *Pilot LCA and climate documentation for Rya BKV*: A compilation of climate impact and data sources for Valmet's delivery. The material is used to understand how data quality, traceability, and data gaps affect LCA work.
- *Analysis of barriers and enabling conditions*: A compilation of the process-related, data quality-related, and organizational barriers that constrain the use of climate data as a basis for decisions.

- *Design of an improved working approach*: A concrete proposal for how the collection, quality assurance, and use of climate data can be structured to support both early decision bases and subsequent LCA-based follow-up.

In summary, the ambition is to contribute both a technical climate documentation for Rya BKV and a structured working approach for how climate data can be specified, collected, quality-assured and used more systematically in Göteborg Energi's investment projects.

1.4 Delimitations

Rya BKV is a comprehensive system with several actors and suppliers beyond the main supplier Valmet. In this project, the analysis will therefore be delimited to the parts delivered by Valmet, as only data from this supplier is currently available. The project also constitutes a special case, as requirements for the delivery of climate and construction data were not specified at an early stage at the project's outset.

The project's system boundaries will be defined within the scope of the boiler house. This encompasses both an outer system boundary that describes which components are initially included in the assessment at system level, and a delimitation of the level of detail at which the components will be addressed. As construction and production data may constitute sensitive information for Valmet and are normally not shared with the client without an agreement from the project's inception. The analysis will be limited to the data that Valmet is able to provide.

1.5 Research questions

LCA is an established method for quantifying environmental impact from a life cycle perspective. At the same time, previous research shows that the method's practical impact on investment decisions is often constrained by organizational factors such as governance, requirement specification, resource allocation and information flows. While the technical methodology of LCA is well developed, the extent to which organizational structures affect the quality of climate data and LCA's usefulness as decision support in larger investment projects has been studied to a lesser degree.

Against the background of Göteborg Energi's ongoing transition, the introduction of new but not yet fully implemented guidelines for climate calculations and the variation that exists between projects, there is a need to systematically analyze how organizational conditions affect the implementation and utility of LCA work. The overarching research question for the study is therefore:

> *How can Göteborg Energi's working approach for climate data be developed to support both investment decisions and LCA-based follow-up in larger investment projects?*

To answer this overarching question, the study is operationalized through the following sub-questions:

1. What barriers in process, data quality, and organization constrain the use of climate data as a basis for investment decisions and climate declarations?
2. How should the working approach for the collection, quality assurance, and use of climate data be designed to support both early decision bases and LCA-based follow-up?

2

Theory

This chapter presents the theoretical frameworks, concepts and models that form the foundation of the study's analysis. The theory is structured to support the study's two research questions. Sections 2.1–2.3 address LCA, system boundaries, data quality and environmental product declarations, which provide the methodological basis for analysing barriers related to data quality and comparability. Section 2.4 addresses procurement, requirement specification and supplier dialogue as process-level mechanisms governing access to climate data. Section 2.5 addresses climate data and LCA as decision support and the structural prerequisites that determine whether climate data can influence investment decisions. Together, Sections 2.1–2.5 establish the theoretical foundation for analysing barriers addressed in RQ1, while Section 2.5 also frames the design requirements for an improved working approach as addressed in RQ2. Section 2.6 presents DMAIC as the analytical and methodological framework.

2.1 Life Cycle Assessment

Life Cycle Assessment (LCA) is an established method for calculating and evaluating the environmental impact of a product, service or buildings over its lifetime (Baumann & Tillman, 2004). The methodology enables a comprehensive picture of environmental consequences and serves as a basis for identifying environmental improvements, comparing alternative solutions and communicating environmental performance to stakeholders. The international standardization of LCA occurs primarily through International Organization for Standardization, 2006b and International Organization for Standardization, 2006c, which specify principles, requirements and guidelines for implementation and reporting.

In this thesis, LCA is used as the overarching term for life cycle-based climate assessment. Within Göteborg Energi, the term climate declaration is also used in internal practice. In this context, a climate declaration may refer to a more limited climate assessment than a full LCA, depending on the project scope, purpose and system boundaries. The proposed working approach is therefore designed to support both LCA-based follow-up and climate declaration-like reporting, while maintaining transparency regarding the system boundaries applied in each case.

The choice of system boundaries is crucial for the relevance of results and is one of the most methodologically sensitive aspects of an LCA. System boundaries determine which processes and flows are included in the analysis and have a direct impact on the robustness and comparability of results. ISO 14044 requires that system boundaries are documented transparently and that decisions to exclude processes are justified to the extent possible (International Organization for Standardization, 2006c). Related to comparability, the functional unit must also be determined and well documented. It defines what is being analyzed and in what quantity, thereby establishing the reference basis for all data in the system. A well-defined functional unit enables meaningful comparisons between systems that fulfill the same function. For energy facilities, kilograms of carbon dioxide equivalents per produced megawatt-hour (kg CO2e/MWh) is often used, enabling normalization of climate impact in relation to production capacity (Wang et al., 2025).

In accordance with European building standard EN 15978, a building's or facility's life cycle is divided into modules designated *A* through *C*. The production stage (A1–A3) encompasses raw material extraction, transport to the factory and manufacturing. The construction process (A4–A5) includes transport to the construction site and installation work on site. The use stage (B1–B7) covers operation, maintenance and replacements during the facility's lifetime. The end-of-life stage (C1–C4) encompasses demolition, transport and waste management. In certain studies, Module D is also included, where potential net benefits beyond the system boundaries are reported.

Within the framework of larger energy investments, such as the pilot study conducted at Rya BKV, this means that the analysis encompasses everything from the initial raw material extraction and manufacturing of components to the use phase and final end-of-life treatment. Dividing the life cycle into different phases enables comparisons between phases and between different projects.

Each module gives rise to specific challenges regarding data collection and uncertainty. Phase B operational data is characterized by uncertainty regarding actual operating conditions, while Phase C in early project stages is often based on default assumptions given that the final disposal method has not yet been determined. This asymmetry in data quality has a direct bearing on results (Wang et al., 2025).

2.2 Data quality, uncertainty and comparability in LCA

The results of an LCA are always subject to uncertainty, which can be attributed to incorrect or incomplete input data, simplified representations of complex systems and assumptions about future conditions. A robust LCA requires that these sources of uncertainty are identified, quantified and communicated in a manner that enables well-founded conclusions (Wang et al., 2025).

Data quality in LCA is not a binary but a gradual concept. Data can be more or less representative, more or less verifiable and more or less adapted to the specific system being studied (Finnveden et al., 2009). In practice, this means that an LCA study rarely relies on uniform data of comparable quality, but rather on a combination of project-specific primary data, generic background data from databases and default estimates where neither primary nor secondary data are available. How these data categories are combined and how the combination is documented has direct significance for how results can be interpreted and used.

A central challenge is that uncertainty is not always evenly distributed across the life cycle phases. Production stage data is often better documented via supplier information, while the use phase and end-of-life stage in early project stages are typically based on assumptions about future operating conditions and disposal alternatives that have not yet been determined (Finnveden et al., 2009). This asymmetry means that the overall uncertainty in an LCA can be difficult to communicate to decision-makers, which in turn affects how results are valued as a basis for decisions.

Comparability between LCA studies requires that system boundaries, functional units and allocation methods are consistent. ISO 14044 International Organization for Standardization (2006c) explicitly emphasizes that studies with different system boundaries are not directly comparable and that claims about relative environmental performance require that methodological differences are reported openly. This places demands on documentation practices that extend beyond the individual study and toward an institutionalized practice for LCA reporting within an organization.

From a process perspective, data quality is not only a methodological challenge but also a governance challenge. The quality of data available for an LCA is partly determined by decisions made upstream in the project process, particularly in the requirement specification and supplier dialogue phases. This means that data quality barriers cannot be fully addressed through methodological improvements alone, but require changes to the organizational processes that govern data collection and verification.

2.3 Environmental product declaration and climate data in infrastructure projects

An Environmental Product Declaration (EPD) is a standardized document that presents quantified environmental information about a product based on a completed LCA. EPDs are governed by ISO 14025 (International Organization for Standardization, 2006a) and in European contexts are often linked to product-specific Product Category Rules (PCR) that specify methodological requirements for each product group (European Committee for Standardization, 2019). An EPD typically contains climate impact (GWP100 in kg CO2e) per functional unit for each life cycle module, enabling summation of climate impact along a facility's entire supply chain.

In construction and infrastructure projects, EPDs constitute the primary instrument for obtaining product-specific climate data. While standardized products such as steel profiles and concrete often have good EPD coverage, Hjellvik and Kirkels (2025) shows that the availability of environmental data from the supply chain still constitutes a critical barrier. This applies particularly to more complex components where suppliers often lack the resources to produce specific declarations, leaving decision-makers with limited or only aggregated data.

The absence of EPDs for complex subsystems forces the LCA practitioner to fall back on generic databases, such as Ecoinvent (Wernet et al., 2016) , whose background data does not necessarily reflect the specific supplier's production process. The degree to which EPDs are available and accessible is therefore not only a market maturity issue, but also a function of how early and how explicitly climate data requirements are formulated in the procurement process.

2.4 Procurement, requirement specification and supplier dialogue

Procurement constitutes a central mechanism for governing climate impact in complex investment projects. By formulating explicit environmental requirements in tender documents during procurement, a client organization can influence suppliers' incentives to document and develop their environmental performance (Brammer & Walker, 2011). The essentials for this to work in practice, however, is that requirement specification occurs sufficiently early in the project process for the supplier to have the opportunity to collect and quality-assure relevant climate data before contracts are signed.

Timing is in this regard a critical variable. The ability to influence what climate data can be collected decreases progressively the later in the project that requirement specification is initiated (Witjes & Lozano, 2016). In the early stages of a project, before detailed design and contract signing, the scope for action is greatest and the cost of changes is lowest. A reactive data collection that is initiated after contracts have been signed limits, by definition, what data can be obtained and at what level of detail, regardless of the supplier's willingness to collaborate.

At the same time, the client's requirement specification is not the only limiting factor. Hjellvik and Kirkels (2025) shows that the availability of product-specific environmental data from the supply chain constitutes a critical barrier in itself, particularly for complex components and systems where suppliers lack the resources, routines, or internal competence to produce EPDs or equivalent documentation. This means that even a well-formulated requirement specification can result in insufficient climate data if the supplier's own maturity in environmental data management is limited. The problem is thus not clearly located on either the client or supplier side, but arises at the intersection between the client's requirement structure and the supplier's capacity to meet these requirements.

Supplier dialogue, the ongoing communication about environmental data and climate requirements beyond the formal tender documents, can to some extent compensate for these shortcomings. Witjes and Lozano (2016) argues that effective environmental governance in the supply chain requires a shift from transactional procurement toward a more collaborative approach, where climate issues are integrated into a continuous dialogue rather than solely into contract documents. Such a dialogue, however, requires that the client organization possesses sufficient internal competence to conduct a substantive technical discussion with the supplier about methodological choices and data sources, which is itself an organizational prerequisite that is not always fulfilled.

Taken together, access to high-quality climate data in LCA work is a result of the interplay between three factors: the client's ability to formulate clear requirements at the right time, the supplier's capacity and maturity to meet these requirements and the quality of the ongoing dialogue between them. None of these factors is independently sufficient and a weakness in any one of them tends to reduce the quality of the climate data that is ultimately available for analysis. This reasoning forms the theoretical foundation for analysing barriers to climate data access as addressed in RQ1 and informs the design requirements for an improved working approach in RQ2.

2.5 Climate data and LCA as decision support in investment processes

Investment decisions in the energy sector are typically based on a combination of economic, technical and strategic criteria. For climate impact to function as effective decision support, proactive methods are required that can predict environmental performance at industrial scale. Erakca et al. (2024) emphasizes that LCA studies in early development phases are crucial for optimizing emerging technologies, but that results are often associated with high uncertainty if they are not scaled up systematically. This underscores the importance of integrating climate data early in the project process to support decision-making in both industry and policy before technological lock-ins occur.

While the technical methodology of LCA is well developed and well established (Baumann & Tillman, 2004), a growing body of research shows that the method's practical impact on investment decisions is largely determined by organizational rather than methodological factors. Hjellvik and Kirkels (2025) identifies in a systematic review of LCA implementation in industry that one of the most recurring barriers is organizational in nature. Insufficient internal competence, inadequate resource allocation, absence of clear requirement specification in the procurement process and difficulties in interpreting and communicating climate data to decision-makers without a technical background. These barriers are mutually dependent. An organization that lacks internal competence also tends to formulate unclear requirements toward suppliers, which in turn limits access to high-quality climate data.

Testa et al. (2022) further nuances the picture and shows that successful integration climate data in investment processes requires that the organization overcomes a number of mutually dependent barriers. They identify that a formal organizational mandate from senior management is crucial for transforming LCA from an isolated expert tool into a strategic priority. Furthermore, dedicated resources in terms of both time and expertise are required to manage complex data collection, as well as established interpretation norms that translate technical environmental data into decision-relevant information. By standardizing how these results are weighed against economic criteria, the organization can avoid reducing climate calculation to a formal compliance instrument and instead enable them to function as genuine decision support. This aligns with Subal et al. (2024), who in their study of LCA use in both the private and public sector find that environmental assessments often function as a parallel track rather than an integrated part of the ordinary investment process. The authors highlight that climate results rarely challenge the primary economic or technical criteria, but are often used to retrospectively legitimize decisions that have already been made. This results in the method having limited actual impact on design choices, particularly in complex projects where strategic decisions are made early in the process, long before a complete climate assessment is available.

A practical instrument for monetarily valuing climate impact in investment decisions is the internal carbon price, sometimes referred to as a shadow price. By setting an explicit price per tonne of carbon dioxide equivalents, a direct comparison between climate impact and cost implications becomes possible within the framework of existing investment calculations. The effectiveness of the shadow price is dependent on its consistent application and on results being linked to actual decision-making processes (Grubb et al., 2021). A situation where the shadow price exists as a policy document but is not applied uniformly by project managers constitutes an example of the gap between formal policy and operational practice that Testa et al. (2022) describes.

Taken together, the literature indicates that the organizational needs for climate data as decision support can be structured along three dimensions: the process dimension (when and how climate assesment are integrated into the project process), the competence and resource dimension (who is responsible and what resources are allocated) and the norm dimension (how results are interpreted and weighed against other decision bases). These three dimensions are used in this study to analyse organizational barriers to the use of climate data as decision support and to formulate design requirements for an improved working approach that supports both early decision bases and LCA-based follow-up.

2.6 DMAIC as an analytical framework

DMAIC *(Define, Measure, Analyze, Improve, Control)* is a structured problem-solving methodology originating from the Six Sigma methodology and is used to identify, analyze and address process deficiencies in a systematic and data-driven way (Magnusson et al., 2003). The methodology provides a logical sequence for moving from problem identification through current-state description and root cause analysis to concrete improvement proposals and is well suited for complex organizational processes where the root causes of problems are not obvious at the outset.

When applied as an analytical framework, the methodology structures the investigation into distinct phases. The *Define* phase serves to establish the purpose, scope and objectives of the process to be improved. The *Measure* phase involves mapping the current state to identify and where possible, quantify existing deficiencies. This is followed by the *Analyze* phase, which is carried out using a number of complementary analytical tools to identify root causes and performance gaps. The *Improve* phase focuses on generating concrete recommendations and solutions grounded in the analytical results to address the identified problems. Finally, the *Control* phase aims to ensure the sustainability of the improvements, although this stage is sometimes delimited in time-bound research projects depending on the study's scope.

2.6.1 Analytical tools within DMAIC

The DMAIC methodology is in practice combined with a number of established quality and analytical tools whose function varies depending on the phase in which they are applied. Common to these tools is that they structure complex problem pictures and enable systematic identification of causal relationships, which is a prerequisite for generating well-founded improvement proposals (Magnusson et al., 2003).

Is/Is Not analysis is used within the Define and Analyze phases to delimit a problem by explicitly specifying what the problem is and is not along dimensions such as object, location, time and scope (Kepner & Tregoe, 1997). The tool helps prevent the analysis from expanding into adjacent but irrelevant problem areas, which is particularly important in case studies where empirical observations can easily lead the analysis in unforeseen directions.

Process maps and Swimlane diagrams are both used to visualize processes, with swimlane diagrams doing so with a clearer delineation of actors, where each actor's activities are represented in a separate lane. Both tools are suited for visualizing processes, identifying information gaps and accountability gaps that span organizational boundaries (Carleton, 2016)

The Ishikawa diagram, also known as the fishbone diagram, is a cause-and-effect tool that structures possible causes of an observed problem along a number of categories. The tool facilitates systematic hypothesis generation and is particularly useful in the Analyze phase for distinguishing symptoms from root causes (Carleton, 2016).

Potential Failure Mode and Effects Analysis (p-FMEA) is a structured methodology for identifying and prioritizing potential failure modes in a process. Each failure mode is assessed along three dimensions: probability of occurrence (O), severity (S) and detectability (D). The product of these yields a Risk Priority Number (RPN) that enables prioritization of measures (Carleton, 2016). In this study, p-FMEA is applied to quantify and prioritize data quality deficiencies in the LCA material, providing the Improve phase with an objective basis for prioritization.

The Barrier/Enabler matrix structures identified barriers and enablers for a desired change and categorizes each factor by type and whether it is internal or external to the organization. This matrix is an interpitation of SWOT matrix (Learned et al., 1965). The matrix provides a basis for designing improvement initiatives that address real barriers rather than symptoms.

The Affinity diagram is an inductive grouping technique for organizing a large number of empirical observations into thematic clusters. The tool is suited for qualitative data and is used in this study to structure interview data around the organizational factors that affect LCA use. A combination of affinity grouping and interrelationship diagraphing known as The Affinity-Interrelationship Method (AIM) is used to move from a large number of unstructured ideas or problem descriptions to a clear visual map showing how these factors influence one another (Alänge, 2009).

3

Method

This chapter describes how the study was designed. The methodology is formulated to ensure transparency and reproducibility, meaning that the research design, data collection procedures and analytical tools are documented at a level of detail sufficient for the study to be replicated in a comparable organizational context with access to equivalent data.

3.1 Research strategy

The study adopts an abductive research strategy, which means that theory and empirical material are developed through an iterative interplay throughout the study (Bryman et al., 2022). This strategy is appropriate since the master's thesis combines established theoretical frameworks with an empirical investigation of how LCA is applied in practice within a specific organizational context.

The work begins with a review of relevant theories and standards within life cycle assessment, such as ISO 14040 and ISO 14044 (International Organization for Standardization, 2006b, 2006c) and EN 15978 (European Committee for Standardization, 2011), together with literature on climate declarations, decision support and organizational governance. These theoretical points of departure are used to structure the empirical investigation and define central analytical concepts (Baumann & Tillman, 2004).

At the same time, the study's research questions are exploratory in nature and aim to investigate how organizational mechanisms affect the quality and usability of the LCA process in investment decisions. Empirical observations from the case study have therefore been allowed to influence the direction and depth of the analysis during the course of the work.

The study is not deductive in the sense that a specific hypothesis is tested, nor is it strictly inductive, since the analysis is guided by established theory. Instead, theoretical perspectives are combined with empirical insights to gradually develop an understanding of the problem and formulate improvement proposals. The abductive strategy is therefore particularly justified since the purpose is to analyze how LCA can function as decision support in practice and to identify measures that strengthen the method's usability within the organization.

3.2 Research design

The research framework is structured around a single exploratory case study combined with a mixed methods approach, following the methodological guidelines outlined by Bryman et al. (2022). By deploying a case study, the research captures deep contextual insights into supplier interfaces, while the mixed methods design ensures that quantitative calculations are integrated with qualitative data.

3.2.1 Case study design

The research design is based on a single exploratory case study of Göteborg Energi's work with climate data in investment projects. This design was selected because the study investigates LCA as an organizational process in which technical data, procurement, supplier dialogue, and internal responsibilities interact.

Rya BKV was selected as the pilot project because it represents a large and technically complex investment project where climate data had to be compiled retrospectively. The case made it possible to study both the technical LCA work and the process-related barriers that arise when climate data requirements have not been fully specified in early project phases.

Within the case, the detailed pilot LCA was delimited to Valmet's scope of delivery, as this was the part of the project for which supplier dialogue and material data were available within the timeframe of the study. Other major suppliers are considered as part of the project context, but are not included in the detailed LCA calculation.

The pilot LCA serves two purposes in the study. First, it provides climate documentation for part of the Rya BKV project. Second, it functions as an empirical tool for examining how data collection, supplier dialogue, data quality, and allocation of responsibilities work in practice.

The purpose of the case study is analytical generalization. The aim is not to generalize statistically from Rya BKV, but to develop insights and principles that may be relevant for similar large-scale energy investment projects.

3.2.2 Mixed methods approach

The study applies a mixed methods approach in the form of a convergent parallel design (Bryman et al., 2022). This means that quantitative and qualitative data are collected during the same overall study period, analyzed partly separately and then integrated to provide a more comprehensive understanding of the research problem.

The quantitative component consists of the life cycle assessment of Rya BKV, in which climate impact is calculated based on technical documentation, material quantities, supplier data, EPDs and generic databases. This component enables the identification of climate-related hotspots, distribution across life cycle stages and assessment of the sensitivity of the results to varying data quality.

The qualitative component consists of semi-structured interviews, workshops, recurring meetings, observations during the implementation of the pilot project, a questionnaire study, document analysis and dialogue with external suppliers. The purpose of the data collection is to develop an understanding of how climate data is requested, collected, interpreted, and used in the organization's investment processes.

The choice of mixed methods is justified by the fact that the LCA results alone are not sufficient to answer the study's research questions. Quantitative results can show where climate impact arises, but they do not explain why data deficiencies occur, why processes are perceived as inefficient, or why the results in some cases have limited influence on decisions. These questions require qualitative methods.

The two types of data are initially analyzed separately. The climate results are analyzed in the LCA model, while the qualitative empirical material is analyzed through thematization, process mapping, and root cause analysis. The results are then integrated to analyze the relationship between technical outcomes and organizational conditions. The combination of methods enables methodological triangulation between technical calculations and organizational practice. This strengthens the study's internal validity, reduces the risk of one-sided conclusions and contributes to greater analytical depth.

3.3 Analytical approach

This section describes the analytical approach used in the study. DMAIC is applied as a framework to connect the technical LCA work with the analysis of Göteborg Energi's internal processes, responsibilities, and data flows. The following subsections present the rationale for using DMAIC and how the five phases were applied.

3.3.1 DMAIC as an improvement methodology

The work is structured in accordance with the five phases of the Six Sigma methodology: Define, Measure, Analyze, Improve, and Control (Magnusson et al., 2003). DMAIC is used as an analytical framework to systematically identify problems, analyze root causes and develop improvement proposals.

The choice of DMAIC is justified by the fact that the purpose of the study is not only to describe the current state, but also to improve an existing work process. The methodology is therefore well suited, as it combines structured problem analysis with practical change work.

In this study, DMAIC is as a process development model adapted to organizational and data-driven issues. The framework enables integration between technical LCA analysis and business development, where data quality, information flows, allocation of responsibilities and decision-making processes can be analyzed within the same structure.

DMAIC also contributes a clear common thread throughout the master's thesis, in which problems are defined, the current state is measured through the pilot study, root causes are analyzed, improvement proposals are developed and recommendations for long-term governance are formulated.

3.3.2 Workflow according to DMAIC

In the *Define* phase, the problem area, stakeholder needs, and study delimitations are established. This is done through a literature study, dialogue with supervisors, and a current-state mapping of Göteborg Energi's use of the internal climate spreadsheet and LCA. The phase identifies key actors, responsibilities, objectives, and main information flows.

In the *Measure* phase, empirical data are collected through the Rya BKV pilot project. The LCA is used to examine data collection, system boundaries, supplier dialogue, and handling of climate data. This generates quantitative climate impact results and qualitative observations of how the current process works in practice.

In the *Analyze* phase, the collected material is examined in relation to the research questions. The quantitative part identifies climate-related hotspots and sensitive life cycle stages. The qualitative part examines recurring issues related to requirements, information flows, responsibilities, and data quality. Tools such as Ishikawa diagrams, Is/Is Not analysis, swimlane diagrams, and p-FMEA are used to identify root causes and prioritize improvement areas.

In the *Improve* phase, improvement proposals for the LCA process are developed based on the identified root causes. Elements of the proposed working method are iterated, tested, and refined. The proposal is validated through dialogue with relevant roles and stakeholders expected to use, manage, or be affected by the working method. The final proposal is evaluated based on feasibility, expected effect, and practical applicability.

In the *Control* phase, recommendations are formulated for how the improved working method can be followed up and integrated into existing processes. This includes documentation, allocation of responsibilities, and follow-up points in the investment process. The purpose is to support long-term use and reduce dependence on individual employees.

3.4 Data Collection

The data collection process for this study relies on a dual-stream approach designed to capture both technical variables and organizational dynamics. The following sections detail the specific data requirements, sources, and protocols established to gather the necessary information.

3.4.1 Quantitative Data Collection

The quantitative data collection establishes the structural input data required to conduct the LCA of Rya BKV. The data material mainly consists of technical documentation, material quantities, Bill of Materials (BOM), supplier data the primary technology provider, the organization's existing climate spreadsheet, and climate data from EPDs and generic databases. Byggvarubedömningen, a Swedish building product assessment database covering chemical content and life cycle-related environmental aspects, serves as a supplementary data source.

Data from the supplier scope are established through a structured technical framework with engineering and environmental specialists. The collection workflow focuses on gathering primary inventory metrics, design specifications, and physical mass configurations. To accommodate corporate confidentiality surrounding components, the methodology incorporates a data-masking and aggregation procedure, ensuring that sensitive engineering information can be summarized into broader material profiles without reducing the validity of the overarching calculation model.

In addition to supplier data, data from Byggvarubedömningen, internal project documentation, and the previous climate spreadsheet are systematically integrated to complement the LCA model. These sources are utilized to identify materials, quantities, climate values, and potential overlaps between different parts of the project's system boundary.

The compilation workflow processes the gathered material data within a life cycle inventory model where climate impact is evaluated for each life cycle stage. When product-specific EPDs are unavailable, similar EPDs, generic databases, or default values apply. The type and assessed quality of each data source are systematically documented to enable subsequent analysis of the robustness of the results.

3.4.2 Qualitative Data Collection

The qualitative data collection utilizes semi-structured interviews, working meetings, workshops, observations embedded within the implementation of the pilot project, e-mail dialogues, and document analysis. The purpose was to understand how climate data is requested, collected, interpreted, and used within the project process, as well as how external suppliers are affected by and contribute to this process.

The selection of respondents was strategic and availability-based. Individuals were selected based on their active role in the process being studied, such as project management, climate spreadsheet, environmental data, building product assessment, procurement, asset ownership, end-of-life issues, and supplier perspectives. The selection thus included both internal key persons within Göteborg Energi and external representatives with relevant LCA or supplier expertise.

Interviews and meetings encompass, among others, project managers, a unit manager for project management, the developer responsible for the climate spreadsheet tool, an environmental engineer responsible for climate data and Byggvarubedömningen, representatives from the climate group, an asset manager with experience of demolition projects, LCA expertise, and representatives from the primary supplier. The supplier dialogue integrates both commercial contact persons and individuals with technical and LCA-related knowledge of the delivery.

The data collection relies on formalized records gathered through written meeting notes, summaries of e-mail dialogues, and continuous observations from the pilot work. These materials are selected to identify recurring patterns, deviations, and central problem areas related to allocation of responsibilities, information flows, requirements specification, and data availability.

3.4.3 Questionnaire study

A questionnaire study was conducted with four project managers within the organization to complement the interview data and capture experiences from several projects. The questionnaire focused on climate spreadsheet, data availability, data quality, requirements specification, procurement, work effort, use of results, and organizational barriers and enablers.

The questionnaire contained both fixed response options and open free-text responses. The fixed response options were used to compare the projects' working methods regarding, for example, project size, project phase, occurrence of a climate spreadsheet, share of generic versus specific data, and use of climate results in decisions. The free-text responses were used to capture the respondents' own descriptions of barriers, uncertainties, and improvement needs.

Since the number of respondents was limited, the questionnaire is not used as a statistically generalizable basis, but as an exploratory and complementary data source. The results are used to triangulate and nuance the patterns identified through interviews, observations, and the pilot study.

3.4.4 Handling of varying data availability

Access to supplier-specific climate data varied depending on the character of the project, the supplier's internal policy, the data maturity of subcontractors, and what information was covered by existing agreements. This was particularly relevant since climate data had not been specified as a requirement in sufficient detail during the early phases of the project.

The methodology was therefore designed to systematically document which data were available, which data were missing, and how these limitations affected the robustness of the analysis. When product-specific climate data could not be obtained, similar EPDs, generic databases or scenario-based assumptions were used instead, in accordance with established LCA methodology (Baumann & Tillman, 2004).

The handling of data gaps was not regarded solely as a practical limitation, but as part of the study's empirical results. Particular attention was directed towards how missing data was handled in practice, which manual steps arose, and how this affected both efficiency and reliability in the LCA work.

3.5 Analysis Methods

The analysis was conducted sequentially in order to first identify barriers in the existing process and then translate these findings into requirements for the proposed working method. Research Question 1 focuses on process-related, data quality-related, and organizational limitations. The analytical tools used to address this question are summarized in Table 3.1.

Table 3.1: Analytical tools used to address Research Question 1

Analysis method	**Purpose in the study**
Is/Is Not analysis	Delimits the problem by distinguishing observed deviations from parts of the process that function as intended.
Swimlane diagram	Maps information flows, communication interfaces, and the allocation of responsibilities between actors and functions.
Data quality matrix	Evaluates traceability, data type, and uncertainty contribution of individual LCA data items.
Potential FMEA	Scores and prioritizes data deficiencies based on severity, occurrence, and detectability to identify critical risks to LCA robustness.
Affinity diagram	Groups qualitative input from interviews and questionnaires into recurring organizational themes.
Barrier and enabler analysis	Examines internal and external factors that either hinder or support the organizational adoption of LCA.
Ishikawa diagram	Synthesizes the preceding analyses and structures the root causes behind the limited use of climate data.

Research Question 2 concerns the design of an improved working method. No separate analytical tools were applied specifically for this question. Instead, the results from the analyses above formed the empirical basis for the Improve and Control phases of the DMAIC framework. In these phases, the identified barriers and root causes were translated into improvement proposals and recommendations for long-term governance.

3.6 Reliability and validity

The reliability of the study is strengthened through a transparent methodology, the use of established LCA standards, and clear documentation of data sources and assumptions. The use of structured analytical tools further contributes to reliability by reducing the risk of ad hoc interpretation and ensuring that conclusions are traceable to the underlying empirical material.

The qualitative reliability is strengthened through semi-structured interviews, triangulation between interviews, questionnaires, observations, and document studies, as well as systematic analysis of empirical material.The triangulation across multiple data sources and methods reduces the risk that findings reflect a single respondent's perspective or a particular data collection situation.

The internal validity is strengthened by analyzing quantitative climate results together with the organizational context, and by combining several analytical tools to examine the same problem from different perspectives.

The external validity is limited since the study is based on a single case. Rya BKV is furthermore an atypical project in terms of scale and organizational context, which further restricts direct transferability of findings. The ambition is therefore analytical rather than statistical generalization. That the theoretical mechanisms and structural barriers identified in this study may be relevant in comparable organizational settings, even if the specific empirical findings cannot be assumed to hold universally.

3.7 Ethical considerations

Throughout the study, high ethical standards have been maintained regarding both empirical data collection and academic integrity. All respondents are treated with confidentiality and internal corporate documentation is handled with care. To protect the anonymity of the participants, empirical findings are presented at an aggregated level where appropriate. Furthermore, the study explicitly focuses on organizational process development rather than the evaluation or performance assessment of individual employees.

Another critical dimension of ethics in thesis writing concerns the deployment of artificial intelligence (AI) technologies. In this study, AI tools, specifically ChatGPT and Gemini, have been used exclusively for linguistic assistance and figure formatting. Their application was limited to refining sentence structures, identifying synonyms, and translating text, thereby ensuring that the core intellectual ownership, analysis, and generation of ideas remain entirely the authors' own.

4

Project execution

This chapter describes how the pilot study was carried out in practice. The focus is on the Rya BKV case study, the delimitation of the pilot LCA, data collection, the calculation of the A, B, and C phases, and how the empirical material was structured prior to analysis. The chapter mainly corresponds to the Measure phase of the DMAIC work, in which the pilot LCA is used as an empirical tool to investigate Göteborg Energi's work with climate data, requirements specification, supplier dialogue, and climate calculations in practice.

4.1 Execution of the Rya BKV pilot study

The Rya BKV pilot study was used to examine how climate data could be collected and applied in an actual project context involving several internal functions and external suppliers. During the study, the project was in the transition between final construction and handover, which made it possible to study retrospective climate data collection and the practical limitations that arise when climate data requirements have not been fully specified in early project phases.

The suppliers most relevant to the pilot study were Valmet, Veidekke, and Raumaster. Valmet was responsible for the steam boiler, boiler house, and associated process equipment. Veidekke was responsible for groundworks and civil engineering works, including asphalt and the concrete foundation. Raumaster was responsible for external fuel supply, the fuel supply structure, and fuel silos.

4.2 Delimitation of the pilot LCA

This section defines the scope of the pilot LCA, including the supplier scope and the life cycle stages included in the assessment. The delimitation clarifies which parts of Rya BKV were included in the detailed calculation and which parts were treated as project context.

4.2.1 Valmet's scope of delivery

The detailed pilot LCA was delimited to Valmet's scope of delivery. This delimitation was made because Valmet's delivery constituted a central part of the project and because supplier dialogue and material data were available within the timeframe of the study.

In this study, Valmet’s scope includes the boiler house, the structure surrounding the boiler, the boiler itself, and associated process equipment within the boiler system. The data collection included material related to the boiler, flue gas treatment, flue gas ducts, piping systems, and other subsystems within Valmet’s delivery.

Valmet’s delivery contained several component types and data levels, which made it suitable for examining both climate calculation and data quality issues. Certain parts of the delivery could not be shared at a detailed level for commercial or technical reasons. In such cases, aggregated data or simplified input data were used where possible.

Veidekke’s and Raumaster’s deliveries were not included in the detailed pilot LCA. These parts were instead used as project context to understand the broader data needs that would arise in a more comprehensive climate declaration or LCA for the entire project.

4.2.2 System boundary

The pilot LCA included life cycle phases A, B, and C. The A phase referred to material type, material quantity, and estimated transport emissions from the material supplier to the facility. The B phase referred to the use phase and included production of fuel, transport of fuel, and combustion of fuel over a calculated period of 30 years. The C phase referred to dismantling, transport, and end-of-life product management at the end of the life cycle.

Cut-off criterias were set to manage data asymmetry and maintain a proportional focus on environmental hotspots. Module A5 (installation, assembly, construction machinery, and on-site energy use) was excluded from the scope of this pilot study due to a lack of primary construction data and the limited traceability of site activities.

Similarly, the use-stage modules B2–B7 which cover routine maintenance, repair, material replacement, refurbishment, and operational water use—were omitted from the final calculation model. This systemic delimitation was driven by twofold considerations: first, high-fidelity data reflecting a 30-year operational maintenance schedule for specialized industrial subsystems was unavailable from the supply chain. Second, these modules reflect ongoing internal operational decisions and maintenance strategies handled internally by Göteborg Energi over the facility’s lifespan, rather than the physical scope of delivery provided by the supplier. Because the explicit purpose of this pilot LCA is to analyze and optimize the data collection and requirement interfaces between the client and external suppliers during procurement and project handover, extending the boundary to long-term internal maintenance operations would deviate from the study’s primary focus.

4.3 Data Collection for the LCA Pilot

Material, quantity, and emission data for the pilot LCA were collected from several sources. The main foreground data were provided by Valmet, which successively delivered material and mass data in Excel format. The input data included, among other things, the steam boiler, environmental systems, pipes, ducts, and other process-related equipment within Valmet's scope of delivery.

Valmet had not developed product-specific EPDs for all relevant components. According to the dialogue with Valmet, this was due to high costs, many subcontractors, and limited transparency in the supply chain. The pilot LCA was therefore largely based on material quantities combined with external emission factors.

Emission factors were identified using several sources and tools. One Click LCA was used to search for and match product-specific or representative EPDs and environmental datasets to the collected material and component data. When product-specific data were unavailable, representative EPDs, generic emission factors, or default values were used. Transport emissions were calculated using transport assumptions, such as country of origin, transport mode, and distance, together with DEFRA 2025 emission factors.

The data were also supplemented with input from Byggvarubedömningen, Göteborg Energi's internal climate calculations, project documentation, co2data.fi, and generic emission factors. Since different data sources could refer to overlapping parts of the project, the material was reviewed to reduce the risk of double counting. The main data categories, sources, and uses in the pilot LCA are summarized in Table 4.1.

4.4 Material classification and selection of emission factors

Material data from Valmet contained both general material names and more specific material designations. To link material quantities to climate data, materials were classified into broader categories such as carbon steel, stainless steel, duplex steel, aluminium, and mixed material categories. Designations such as 16Mo3, P265GH, and S235 were classified as carbon steel, while AISI316L and 1.4404 were classified as stainless steel. Unclear entries were handled through simplified classification based on description, component type, or conservative assumptions.

However, this manual categorization process was not applied uniformly across all data items. Product-specific EPDs were utilized as the primary source whenever they were directly accessible for an exact product or material. For a large number of the remaining components, OneClickLCA was deployed to facilitate the inventory process, using the platform's automatic material matching feature to cross-reference raw material designations with verified environmental datasets. To ensure robustness and accuracy, this automated mapping was systematically combined with a manual double-check of each matched item before executing the final climate calculations.

Table 4.1: Data categories and sources used in the pilot LCA

Data category	Source/provider	Use in the pilot LCA
Pressure vessel related Material and mass data	Valmet Excel input	Used as the main foreground data for boiler systems, process equipment, pipes, ducts, and subsystems in the A phase and for material end-of-life in the C phase.
Construction-related Material and mass	Byggvarubedömningen	Used as supplementary input for construction and CSA-related materials and to check potential overlaps between data sources.
EPDs and environmental datasets	One Click LCA, internal database and Byggvarubedömningen	Used to search for and match product-specific or representative EPDs and environmental datasets to the collected material and component data.
Transport emission factors	DEFRA 2025	Used to calculate transport emissions based on the transport assumptions.
Fuel use	Göteborg Energi fuel forecast	Forecasted use of GROT, RT wood chips, and oil over 30 years. Used for calculating the B phase.
End-of-life emission factors	co2data.fi	Used for calculating end-of-life product management in the C phase.
Fallback emission factors	Generic databases and default values	Used when product-specific or representative EPDs were unavailable. These values were documented as lower-quality fallback data.

Emission factors were selected according to a prioritized hierarchy reflecting data quality: product-specific EPDs as first priority, EPDs for similar products as second, generic databases such as Ecoinvent as third, and default values or simplified assumptions as a last resort. Each selected emission factor was documented together with its data type to enable subsequent assessment of data quality and robustness.

This layered approach was necessary because product-specific EPDs were rarely available for every individual industrial component within the scope of delivery. In the dialogue with Valmet, it emerged that Ecoinvent can provide a reasonable general picture for typical steel materials, but that special steels or specific production methods are not always captured correctly without modification in LCA software, a limitation that was noted in the input data. By combining direct EPD tracking, automated software matching, and manual categorization, the methodology enabled reproducible matching against emission factors across varying levels of data quality.

4.5 Calculation of life cycle phases

The calculation of the life cycle phases was executed not only to establish a technical baseline, but to empirically observe how data gaps, varying supplier inputs, and long-term assumptions manifest in the calculation process. By mapping the mechanical calculations to specific lifecycle modules, this section highlights the practical data limitations and process friction that directly inform the study's research questions regarding climate data governance.

A Phase: Production and construction

In the pilot study, modules A1–A3 included material- and manufacturing-related emissions, calculated by multiplying raw material quantities by the prioritized emission factors. Because product-specific data was rarely specified before procurement, this phase became a primary touchpoint for observing how a lack of early requirement definitions forces a reliance on generic background data and proxy values.

Module A4 (transport to the facility) was calculated by estimating logistics emissions based on the recorded country of origin, transported weight, and localized transport factors. Transport factors were developed by mapping the supply chain logistics for trucks, sea transport, or ferries. From an operational perspective, executing these calculations highlighted the extreme manual effort required to bridge the data gap when structured supplier inputs are missing.

B Phase: Use stage

The operational calculation model for the B phase was delimited to core energy and fuel flows as fuel production, transport, and combustion. The mathematical model relied on a 30-year operational forecast for biofuel flows, specifically wood chips (RT) and logging residues (GROT), alongside start-up oil. Fuel transports were modeled based on assumed regional logistics distances and standardized emission factors per tonne-kilometre. This process demonstrated the structural limitation of relying entirely on internal generic forecasts for early-stage baseline calculations before supplier-specific operational efficiencies can be verified.

C Phase: End-of-Life

The C phase was modeled as a scenario-based estimate for dismantling, transport, and end-of-life product management. Due to the systematic absence of verified, project-specific data for future demolition, assumptions were developed through internal interviews with asset management to reflect standard organizational practices, such as recycling metals and landfilling insulation. Demolition scope and crane work were estimated based on gross floor area, with end-of-life emission coefficients sourced from co2data.fi (Finnish Environment Institute (Syke), 2026). Documenting this future phase highlighted that without a standardized data structure, baseline scenario modeling relies on heavily unstructured manual assumptions.

4.6 Organizational Data Collection

In contrast to the LCA inventory data used for the climate calculations, the organizational data collection focused on how climate data is requested, transferred, interpreted, and used in Göteborg Energi's project process. Qualitative data were collected through internal interviews, a questionnaire study, supplier dialogue, and observations during the pilot work. The material was used to analyze responsibilities, information flows, requirements specification, procurement logic, supplier collaboration, and practical barriers in the current working method.

4.6.1 Interviews and working meetings

The organizational data collection was conducted through interviews, working meetings, and ongoing dialogue with people who had central roles in the climate calculation and LCA process. The selection included project managers, the unit manager for project management, the developer responsible for the climate calculation tool, the environmental engineer responsible for Byggvarubedömningen and climate data, representatives from the climate group, an asset manager, and individuals connected to the supplier perspective.

The internal functions contributed with different types of knowledge. The procurement perspective was used to understand how requirements are incorporated into tender documents and contracts. The climate group and those responsible for the climate calculation tool contributed knowledge about existing calculation tools, data sources, climate databases, and practical data needs. The project owner side for Rya BKV contributed project-specific knowledge regarding requirements specification, procurement, technical documentation, supplier dialogue, and access to 3D models. The project management organization contributed an understanding of how the working method needs to fit into Göteborg Energi's decision points, project roles, and ordinary project process.

The discussions addressed, among other things, current working methods for climate spreadsheet, allocation of responsibilities, requirements specification, data collection, EPD management, procurement, and how climate results are used in decisions. In addition to interviews and working meetings, regular weekly follow-ups were conducted with supervisors within Göteborg Energi. The work was carried out partly on site at Göteborg Energi, which enabled continuous informal check-ins, Teams meetings, e-mail dialogues, and shorter conversations with relevant people in the organization.

In total, approximately 14 planned meetings and working meetings were conducted within the scope of the organizational data collection. In addition, a study visit to Rya BKV was carried out on the 14th of April, led by the deputy project manager for Rya BKV. Meetings were documented through written notes and then used as input for thematization and process analysis.

4.6.2 Questionnaire

A questionnaire was sent to project managers within Göteborg Energi to complement the interviews with experiences from several projects. Four project managers responded to the questionnaire.

The questionnaire included questions about project size, project phase, whether a climate calculation had been produced, in which phase it had been produced, who conducted the calculation, data sources, share of specific versus generic data, use of a shadow price, work effort, confidence in the climate calculation work, collaboration with the environmental group, requirements specification in procurement, and barriers to using the climate calculation as decision support.

The responses were used as complementary empirical material and analyzed together with interviews and observations. Since the number of responses was limited, the questionnaire was not used for statistical generalization, but to identify recurring patterns and compare experiences between projects.

4.6.3 Supplier dialogue with Valmet

The supplier dialogue with Valmet was a central part of the implementation. The dialogue was mainly conducted with Martin Björk (Technical sales manager) and Pirkko Alander (Environmental analysis manager), as well as additional technical contact persons within Valmet. The purpose was to identify which data were available, which data could be shared, and which limitations existed in relation to confidentiality, subcontractors, and data availability.

The dialogue addressed, among other things, BOM, material quantities, system boundaries, manufacturing data, use phase, end-of-life assumptions, and possible LCA tools. Valmet was able to provide some material data, but not complete product-specific EPDs for all components. Supplier data were therefore combined with external climate data and generic emission factors.

One practical aspect was that certain data had to be aggregated before it could be shared, in order to avoid exposing sensitive design information or detailed geometries.

4.6.4 Observations during the pilot work

By conducting the pilot LCA ourselves, practical work steps and data limitations could be observed directly. This included, among other things, collection of material data, classification of material designations, searching for EPDs, matching against generic emission factors, and coordination between internal and external actors.

The observations were documented continuously to identify where data gaps, delays, and confusion occurred in the process. Informal conversations and shorter on-site check-ins were treated as supporting observational data rather than as separate interviews.

4.7 Handling of data limitations

Data limitations were handled continuously during the pilot study. When product-specific EPDs were lacking, similar EPDs for comparable products or materials were used as the first priority. If this was not possible, generic emission factors from databases or default values were used. For end-of-life product management in the C phase, co2data.fi was used where relevant emission factors were available.

Certain supplier data could not be shared at a detailed level. This applied especially to data that could reveal sensitive technical design, such as exact dimensions, geometries, or detailed component structures. To handle this, aggregated material quantities or processed BOM input were used where possible.

Generic values and proxy data were used when specific data were unavailable or when the data level did not justify more detailed modelling. For example, materials could be classified as carbon steel, stainless steel, or high-/low-alloy steel and then linked to representative emission factors. The use of such data was documented so that it could be analyzed in relation to data quality and robustness.

Since data were collected from several sources, the risk of double counting was also managed. This applied especially to potential overlap between Valmet's data, data from Environmental Systems, and data from Byggvarubedömningen. During the work, it was therefore checked which system parts each data source referred to.

4.8 Structuring of material prior to analysis

After data collection, the material was structured based on the study's two research questions. The input for the first research question consisted of process data, LCA input, data sources, emission factors, interviews, observations, and questionnaire data. The material was used to identify barriers related to process, data quality, and organization.

Process-related material, such as interviews, supplier dialogue, and observations from the pilot work, was used to analyze how climate data was requested, collected, and transferred between actors. The LCA model, emission factors, and documented assumptions were used to analyze data quality, traceability, and robustness. Interviews, the questionnaire, and meeting notes were used to analyze organizational barriers and enablers.

The input for the second research question consisted of the combined barrier analysis and the practical experiences from the pilot LCA. This material was used to formulate requirements for a developed working method for collecting, quality-assuring, and using climate data. The working method is presented in the results chapter and includes process logic, supplier template, data hierarchy, allocation of responsibilities, and follow-up.

5

Analysis

The analysis chapter constitutes the *Analyze* phase within the overall DMAIC framework and aims to systematically identify and structure the barriers that limit the effective use of climate data in Göteborg Energi's investment process and climate declaration work. The analysis is based on the empirical material collected through interviews, observations during the pilot study, and document review.

The analysis work is structured in four layers. First, the problem is delimited using an Is/Is Not analysis, which specfies where in the process the problems manifest themselves and what they do not include. Thereafter, a process and information flow analysis is conducted using swimlane diagrams, which make actors, allocation of responsibilities, and information flows visible. The data quality is then analyzed using a data quality matrix and a Potential Failure Mode and Effects Analysis (p-FMEA), in order to identify and prioritize the most critical data deficiencies. Finally, the organization's conditions are analyzed using an affinity diagram and a barrier and enabler matrix, after which a root cause analysis using an Ishikawa diagram connects all analytical layers. The chapter concludes with an integrated analysis that answers RQ1 and formulates the requirements that the results place on a developed working method.

5.1 Analysis of problem character

To specify the problem and isolate critical influencing factors, an Is/Is Not analysis based on the Kepner–Tregoe methodology is applied (Kepner & Tregoe, 1997). Unlike the study's initial scope definition, this tool functions here as a diagnostic step to contrast identified observations against situations where the problem does not occur. Based on interview data, process reviews, document studies and the pilot study, this analysis provides the initial specification for the subsequent in-depth analytical steps. The analysis is structured along four dimensions: *what*, *where*, *when*, and *extent*. This step is necessary in order for the subsequent analysis to focus on the variables that actually generate variation in data quality and availability.

What: Problem character and defect

At its core, the problem concerns requirements specification and supplier dialogue, the project stages in which Göteborg Energi (GE) formulates and communicates expectations regarding climate data, as well as the ongoing follow-up of these requirements. The defining characteristic is that the problem arises in the communication and data transfer interface between the client and the supplier. It is therefore an interface problem rather than a methodological problem. The problem thus does *not* concern internal data management once data has been received, the suppliers' own internal processes, or the LCA methodology itself.

The defect itself consists of relevant climate data not being available at the right point in the project. In many cases, suppliers lack the resources or incentives to develop product-specific EPDs, while the requirements specification is not designed so that the absence of data has real consequences for the supplier. The defect is, however, *not* that climate data is absent in an absolute sense, that communication channels are lacking, or that suppliers are uninterested. The infrastructure and willingness exist, but the problem lies in the working method, timing, and lack of resources. An important contextual change is that the demand for climate data has shifted from being a preference to being a formal requirement that is now requested significantly earlier in the project process, which has made visible a gap that was previously hidden.

Where: Geographical and processual location

The problem is strictly located at the interface between Göteborg Energi and its suppliers. It does not arise with authorities and governmental actors or in Göteborg Energi's internal systems after the data transfer has been completed. From a system perspective, it is precisely at the handover point between external and internal parties that the deficiencies manifest themselves.

Positionally, the problem is concentrated in the procurement and project development phase, that is, the stages in which dialogue with the supplier is most intensive and where fundamental requirements are formulated. After project delivery, the supplier leaves the project and the climate data issue becomes an internal quality assurance matter for GE. The problem therefore does not concern the phase that follows after delivery.

When: Timing and pattern

The problem was identified in connection with Göteborg Energi formulating its climate targets and introducing the climate calculation as a governance tool. Before the climate calculation was implemented, the absence of EPD data was not visible as a problem, since there was no context in which the deficiency had direct consequences. The problem thus existed structurally before then, but only became manifest when the organization actively began requesting EPDs in procurement.

The pattern over time shows that the problem occurs every time a climate calculation or LCA is conducted and data is to be collected. It is not situational, but systematically recurring. The problem does not primarily occur in the final stage of the project, since climate data requirements must now be formulated in the technical specification before the procurement is published – a requirement that, at present, is often not fulfilled early enough to give the supplier reasonable conditions for delivering relevant data.

Extent: Scope and tendency

The problem affects all projects within the Heating and Cooling department. No observed exceptions exist depending on project type, size, or supplier, which indicates a general and process-independent pattern. The magnitude of the defect is extensive; the share of specific EPD data varies, but the empirical material indicates that up to 90 % of the climate calculations in a given project may be based on generic emission factors rather than product-specific EPDs. Although some specific data is always present, it is never complete.

Finally, the problem shows no tendencies linked to project cycles, seasonality, or other external factors. It is stably recurring and independent of the conditions of individual projects, which supports the conclusion that the cause is structural rather than random or project-specific.

5.2 Process and information flow analysis

The process and information flow analysis is based on Göteborg Energi's project management process and aims to make visible how climate data involves several functions throughout the different project phases. Figure 5.1 shows the allocation of responsibilities and information flows between the project manager, procurement, the LCA responsible person and the supplier. The purpose is therefore not to identify individual knowledge gaps, but to create an overall picture of when different functions are involved and how decisions in early stages affect the possibility of collecting and using climate data later in the project.

In early project phases, before procurement has been published and before tenders have been received, supplier-specific information on material type, material quantity, technical solution and cost is normally lacking. The climate calculation that can be carried out at this stage therefore needs to be based on Göteborg Energi's internal resources, such as preliminary design, previous projects, the internal climate database, default values and generic emission factors. The calculation should therefore be understood as a rough reference or scenario analysis rather than as a detailed material-based climate calculation. Its function is mainly to identify potential climate-driving items and provide support for which climate requirements or climate measures should be considered in the procurement documents.

The current-state swimlane diagram was used to locate where the main process-related barriers occur in relation to the project and procurement process. The purpose of the figure is not to show an absence of climate data initiatives, but to identify where the emerging climate data practice is not yet sufficiently systematized. The marked problem areas summarize how unclear requirements, unclear data purpose, early reliance on generic data, and insufficiently standardized data structures constrain the use of climate data as both decision support and LCA input.

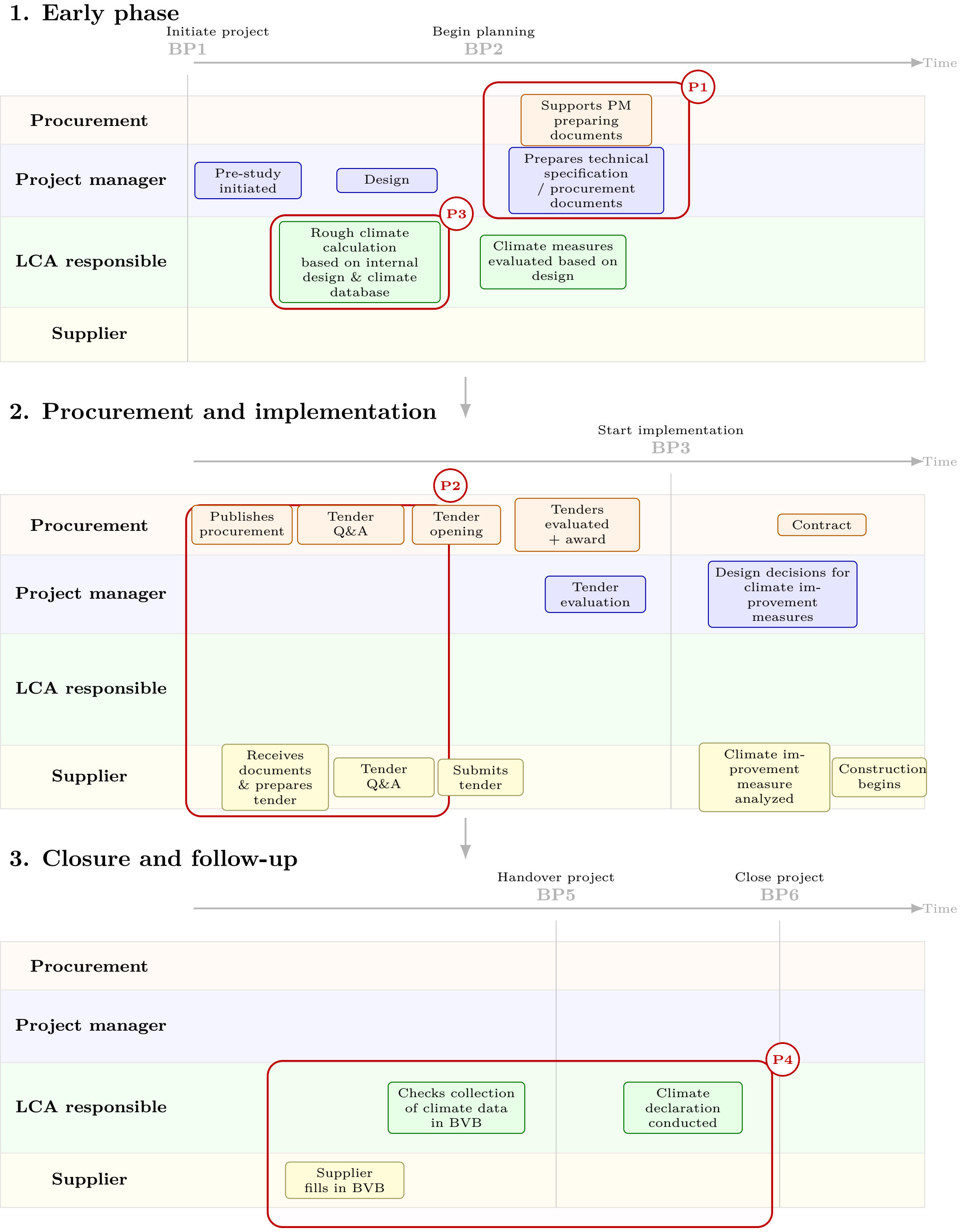


Figure 5.1: Current-state swimlane diagram with identified problem areas in the climate data process. The markers show where the emerging working method is not yet sufficiently systematized. P1 marks that climate data requirements are not sufficiently defined before procurement. P2 marks that the purpose of climate data is unclear, particularly whether the data should support tender decisions or later LCA-based follow-up. P3 marks that early climate calculations rely on internal and generic data before supplier-specific data is available. P4 marks that later LCA work lacks a standardized data structure and fallback process.

The problem markers in Figure 5.1 summarize how the current-state process constrains the use of climate data. P1 and P2 concern the early project and procurement stages, where climate data requirements and the purpose of data collection need to be clarified before procurement is published. P3 highlights the structural limitation that early climate calculations must rely on internal and generic data before supplier-specific information is available. P4 highlights the need for standardized basic data, data-type classification and fallback logic when later LCA or climate declaration is performed.

A central observation from the process analysis is that climate-related requirements need to be formulated before the procurement is published. The procurement function is responsible for publishing and administering the procurement, but does not itself define which technical climate data is to be collected. This instead needs to be specified by the project manager in the technical specification or in the procurement documents, in collaboration with environmental or LCA expertise. If climate data, climate improvement alternatives or requirements for later climate documentation are to be included in the supplier's undertaking, this must therefore be clearly described already before the procurement is released to the market.

In the tender phase, the data requirements should be adapted to what is reasonable for the supplier to produce before a contract has been signed. It is probably not appropriate to require complete LCA data or a complete climate data template already in the tender. However, the tender can contain decision-relevant information, such as the supplier's ability to deliver climate data later in the project, previous experience with EPD, LCA or climate data, and climate improvement alternatives for the largest climate items. For example, for concrete, steel, or major transport flows, the supplier can report a standard alternative, a climate-improved alternative, estimated additional cost, potential climate savings, and the data source or assumption behind the calculation. In this way, climate impact can be included as part of the tender evaluation without burdening the procurement with unreasonably detailed data requirements.

After award, the function of climate data changes. At that stage, data collection is no longer about supporting supplier selection, but about ensuring that sufficient data is available when a climate declaration or LCA is to be prepared. The standardized supplier template should therefore primarily be linked to technical documentation or final documentation. The key point is that the requirement is included in the contract from the outset, so that the supplier knows which information is to be delivered, in what format, and at what point in time. The data template thereby becomes a tool for securing a complete and traceable basis for later climate reporting, rather than a continuous decision basis at every project milestone.

The case study with Valmet illustrates the need for such a structured data flow. The supplier was able to provide material and mass data, but not complete product-specific EPDs for all components. Some information also had to be aggregated for confidentiality reasons. This shows that climate data is not only a technical issue, but is also affected by contracts, confidentiality, the supplier's internal data maturity, and which requirements have been formulated from the beginning.

Overall, the process and information flow analysis shows that a core barrier is that climate data is not managed in two separate but connected flows. The first unresolved gap is the lack of a distinct decision-supporting flow in procurement, where the supplier can report climate improvement alternatives or the ability to deliver climate data. The second deficiency is the absence of a follow-up flow after award, where a standardized data template is used to ensure input for a climate declaration or LCA. The failure to implement this division increases the risk that the tender stage is burdened with unreasonable data requirements, while failing to ensure that Göteborg Energi can collect the necessary climate data when the project is followed up.

5.3 Data quality analysis

Before the root causes can be identified, it is necessary to analyze the quality of the climate data actually used in the case study. A insufficient data basis affects not only the reliability of the calculation results, but also the possibility of using climate data as a governing decision basis. The analysis is conducted in two steps. First a data quality matrix that inventories and classifies the data sources used in the case study and then a potential-FMEA (p-FMEA) that prioritizes the identified deficiencies based on their consequences for the LCA result.

5.3.1 Data quality matrix

The data quality matrix inventories all data items included in the case study's climate calculation, classifies their quality level (specific or generic) and assesses traceability and uncertainty contribution. Table 5.1 summarizes the results.

The matrix shows a consistent pattern. Most data items with direct impact on the climate result, such as emission factors for materials, demolition data, and reuse factors, are based on generic values with low traceability. Specific data primarily occur for quantitative input values (weight, fuel consumption, distances), but are consistently lacking for the emission coefficients that convert these quantities into climate impact in carbon dioxide equivalents.

A methodologically central observation is that product data and material data are handled distinctly in the calculation basis. Product-specific EPDs, which would reflect a specific supplier's actual manufacturing process, are consistently replaced by generic material values, which represent industry averages and lack a connection to the actual climate performance of the purchased product. The consequence is that individual calculation items receive an apparent precision that does not reflect the actual uncertainty, a risk that is reinforced when the generic values are also obtained from sources without verification (e.g. the reuse factor from Boverket).

5.3.2 Potential-FMEA

Based on the data quality matrix, a p-FMEA was conducted on the data items with high uncertainty (see Table 5.2). The p-FMEA systematically prioritize the

Table 5.1: Data quality matrix – climate data in the pilot study

Phase	Data item	Source	Quality	Traceability	Uncertainty
A1–A5	Material data – weight	Supplier Valmet	Specific	Medium	Low
	Material data – type	Supplier Valmet	Specific	Medium	Low
	Material data – emission factor	OneClickLCA / GE collection	Generic	Low	**High**
	Manufacturing country	Supplier Valmet	Specific	Medium	Low
	Transport factor	DEFRA 2025	Generic	Low	Medium – known variation
B1	Fuel consumption	Internal forecast	Specific	High	Low
	Transport factor	Internal GE value	Generic	Low	Medium – known variation
	Transport distance	Internal forecast	Specific	High	Medium – known variation
C1–C4	Material data – emission factor	Swedish EPA & SLU	Generic	Low	**High**
	Demolition data	IVL	Generic	Low	**High**
	Transport factor	Boverket's database	Generic	Low	Medium – known variation
	Reuse factor	Boverket	Generic	Low	**High – no verification**
	Material data – weight	Valmet	Specific	Medium	Low

identified data quality deficiencies. By weighting the consequences of the deficiencies for the LCA result against their severity, occurrence and detectability, the most critical uncertainties could be isolated.

The analysis identifies two failure nodes with critical priority (RPN = 140): the absence of product-linked emission factors in phases A1–A5, and the unverified reuse factor in phases C1–C4. What these share is that they combine high occurrence (O = 7) with moderate to high severity and limited detectability. In other words, they are common, difficult to notice without active review and have major effects on the LCA result if they pass undetected.

For demolition data (C1–C4), the risk priority number (RPN) amounts to 50. This value is mainly derived from extremely high occurrence (O = 10), which reflects the systematic absence of verified data for this stage. However, the total risk value is mitigated by a low severity score (S = 1) compared with the most critical items.

The emission factor in the operating phase (B1) generates an RPN of 20. Here, the risk is driven by a balanced distribution between severity (S = 5) and occurrence (O = 4). Although the absolute RPN value is significantly lower than for the other items, it is categorized as a medium priority, in line with the demolition data, to ensure a comprehensive improvement process.

Table 5.2: pFMEA – prioritized data deficiencies in the climate calculation process

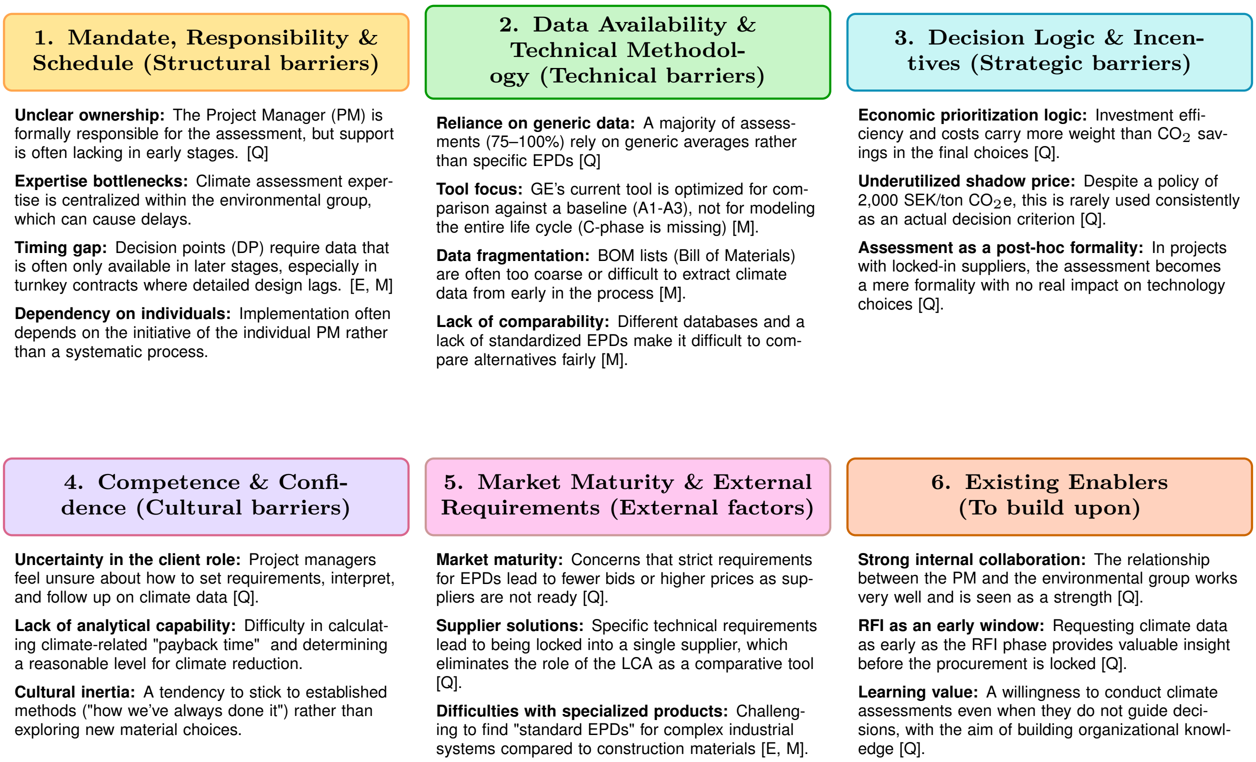
Phase	Input	Failure/deficiency	Consequence for LCA	S	O	D	RPN	Priority
A1–A5	Material data – emission factor	Material data is not linked to the actual materials	Incorrect emissions, not grounded in reality	4	7	5	140	**Critical**
B1	Material data – emission factor	The emission factors are generic and not specific	Incorrect emissions in the operating phase	5	4	1	20	Medium
C1–C4	Demolition data	Based on an unverified method. High uncertainty	Emissions from demolition become incorrect/uncertain	1	10	5	50	Medium
C1–C4	Reuse factor	Not material-specific or verified	Incorrect emissions, not grounded in reality	4	7	5	140	**Critical**

5.3.3 Findings: Data quality

The pFMEA analysis confirms and sharpens the picture outlined by the data quality matrix. The reuse factor and the material data/emission factor are the most critical factors, where data variation directly leads to lower robustness in the LCA result and reduces its usability. Because these specific failure nodes combine high occurrence with limited detectability, they hide critical data gaps behind an apparent numerical precision. This systemic issue directly leaves decision-makers without the transparency required to accurately interpret the environmental uncertainty of the results. The improvement work should primarily focus on making the process robust against these two failure nodes.

5.4 Organizational analysis

The organizational analysis aims to identify structural conditions such as roles, competence, decision logic, and external conditions that either hinder or enable the systematic use of climate data within GE's investment process. The analysis is conducted in two steps. First, an affinity diagram is applied to group and thematize empirical signals from meeting notes, questionnaire responses and pilot study observations into natural themes without predefined categories. In the second step, the entries are structured in a barrier and enabler matrix along two axes, internal/external and barrier/enabler, in order to make visible the strategic pattern that forms the basis for the recommendations in the results chapter.



1. Mandate, Responsibility & Schedule (Structural barriers)

Unclear ownership: The Project Manager (PM) is formally responsible for the assessment, but support is often lacking in early stages. [Q]

Expertise bottlenecks: Climate assessment expertise is centralized within the environmental group, which can cause delays.

Timing gap: Decision points (DP) require data that is often only available in later stages, especially in turnkey contracts where detailed design lags. [E, M]

Dependency on individuals: Implementation often depends on the initiative of the individual PM rather than a systematic process.

2. Data Availability & Technical Methodology (Technical barriers)

Reliance on generic data: A majority of assessments (75–100%) rely on generic averages rather than specific EPDs [Q]

Tool focus: GE's current tool is optimized for comparison against a baseline (A1-A3), not for modeling the entire life cycle (C-phase is missing) [M].

Data fragmentation: BOM lists (Bill of Materials) are often too coarse or difficult to extract climate data from early in the process [M].

Lack of comparability: Different databases and a lack of standardized EPDs make it difficult to compare alternatives fairly [M].

3. Decision Logic & Incentives (Strategic barriers)

Economic prioritization logic: Investment efficiency and costs carry more weight than CO_2 savings in the final choices [Q].

Underutilized shadow price: Despite a policy of 2,000 SEK/ton CO_2e, this is rarely used consistently as an actual decision criterion [Q].

Assessment as a post-hoc formality: In projects with locked-in suppliers, the assessment becomes a mere formality with no real impact on technology choices [Q].

4. Competence & Confidence (Cultural barriers)

Uncertainty in the client role: Project managers feel unsure about how to set requirements, interpret, and follow up on climate data [Q].

Lack of analytical capability: Difficulty in calculating climate-related "payback time" and determining a reasonable level for climate reduction.

Cultural inertia: A tendency to stick to established methods ("how we've always done it") rather than exploring new material choices.

5. Market Maturity & External Requirements (External factors)

Market maturity: Concerns that strict requirements for EPDs lead to fewer bids or higher prices as suppliers are not ready [Q].

Supplier solutions: Specific technical requirements lead to being locked into a single supplier, which eliminates the role of the LCA as a comparative tool [Q].

Difficulties with specialized products: Challenging to find "standard EPDs" for complex industrial systems compared to construction materials [E, M].

6. Existing Enablers (To build upon)

Strong internal collaboration: The relationship between the PM and the environmental group works very well and is seen as a strength [Q].

RFI as an early window: Requesting climate data as early as the RFI phase provides valuable insight before the procurement is locked [Q].

Learning value: A willingness to conduct climate assessments even when they do not guide decisions, with the aim of building organizational knowledge [Q].

Figure 5.2: Affinity diagram: Final categorization of empirical signals.

5.4.1 Affinity diagram

The affinity analysis resulted in six themes that together cover the organizational dimensions highlighted by the empirical material (see Figure 5.2). Data marked with [Q] indicate that the information comes from questionnaire responses, and [M] indicates meeting notes and interviews. Items without any marking are empirical data from gemba and the pilot study.

The first three themes constitute structural and cultural barriers, the fourth contains competence and confidence issues, the fifth highlights external factors and the sixth gathers identified enablers.

Theme 1: Mandate, Responsibility, and Schedule (Structural Barriers)

The most prominent structural barrier is unclear ownership: the project manager (PM) is formally responsible for the calculation, but often lacks the data required to do this in early stages. The responsibility is nominal but not operational, it is accompanied by weak routines, tools and mandate to set and follow up climate requirements towards suppliers.

In parallel, climate calculation expertise is centralized within the environmental group, which creates vulnerability: changes in staffing can directly affect the organization's ability to carry out climate calculations. It also creates a competence gap between those who make project decisions (PM) and those who possess climate expertise (the environmental group).

A third structural dimension is *timing*: the decision points in GE's project model require data that is often absent in the stages where it is needed most, this applies above all to early investment stages and turnkey contracts, where climate data is not available until late in the project. In addition, it is noted that implementation is dependent on individuals: the change depends to a large extent on the initiative of the individual PM rather than on systematic process support.

Theme 2: Data Availability and Technical Methodology (Technical Barriers)

A majority of the data in the climate calculations estimated at 75–100 % is generic data rather than product-specific EPDs. GE's current toolset is optimized to model only the A and B phases in a life cycle and to compare them against a given baseline, but lacks functionality for extracting and integrating climate data in project phases such as the C phase for demolition.

Data fragmentation constitutes another technical barrier: BOM lists (Bill of Materials) are often too coarse or difficult to extract data from at an early stage. Finally, limited comparability, different databases and the absence of standardized EPDs, limits the possibility of comparing alternatives in a fair and reproducible manner.

Theme 3: Decision Logic and Incentives (Strategic Barriers)

The empirical material indicates an economic prioritization logic in which investment efficiency and kronor per kilowatt carry more weight than CO_2 savings in the final investment choices. Despite an organizational policy of 2 000 SEK per tonne CO_2, this is rarely used consistently as an actual decision criterion.

Furthermore, an underutilized shadow price is identified: the calculation is often used as a post-hoc construction, and in projects with locked-in suppliers, climate and price become a formality without real influence on technology choices.

Theme 4: Competence and Confidence (Cultural Barriers)

Project managers feel uncertain about how to set requirements for, interpret, and follow up climate data. This uncertainty in the client role manifests itself in a tendency to stick to established methods rather than explore new material alternatives, a cultural inertia summarized as preferring to do things as we have always done.

A complementary observation is the difficulty of making a climate-related assessment of payback time: what is a reasonable level of climate reduction, and how should this be valued against economic return? This uncertainty contributes to climate data being perceived as difficult to interpret and difficult to translate into practical decisions.

Theme 5: Market Maturity and External Requirements (External Factors)

The market's EPD maturity is a central external barrier. Concern that strict EPD requirements lead to fewer tenders or higher prices means that the level of requirements is lowered to keep competition open. The supplier relationship further complicates this: specific climate requirements tend to create lock-in regarding which supplier is chosen, which makes it more difficult for the LCA to function as a comparison tool.

Turnkey contracting as a procurement form means that Göteborg Energi receives information late in the process, which makes it structurally difficult to integrate climate data into early decision bases. Finally, specialized products are highlighted as a specific problem: it is difficult to find standardized EPDs for complex industrial systems, compared with more standardized construction materials.

Theme 6: Existing Enablers (To Build Upon)

The affinity analysis identifies three concrete enablers that constitute real organizational resources:

Strong internal collaboration: the relationship between the PM and the environmental group functions well and is seen by the interviewees as a strength.

RFI as an early window: requests for information (RFI) in the early phase of projects provide valuable insight into suppliers' climate work even before the procurement is locked.

Willingness to learn: there is a clear willingness to conduct climate calculations even when they do not guide a decision, with the aim of building organizational knowledge and preparing for future requirements.

5.4.2 Barrier and enabler matrix

With affinity diagram as input, the main factors were structured in a barrier and enabler matrix along the axes *internal/external* and *barrier/enabler* (Figure 5.3).

The analytically most significant pattern in the matrix is not the barriers or enablers in themselves, but the *relationship* between them. The three internal enablers, good communication between the PM and the environmental group, an established BP structure and an existing requirement for climate calculation in projects exceeding 20 MSEK are all real and functional. They represent organizational resources that are already in place. Nevertheless, the effect of these enablers is limited because the internal barriers systematically block their impact, collaboration between the PM and the environmental group exists but lacks full formal process support. The BP structure offers natural integration points, but climate data is not linked to these gates, the climate calculation requirement exists but is not associated with clear ownership or a data flow. In other words, the enablers are underutilized not due to a lack of resources, but due to a lack of structure.

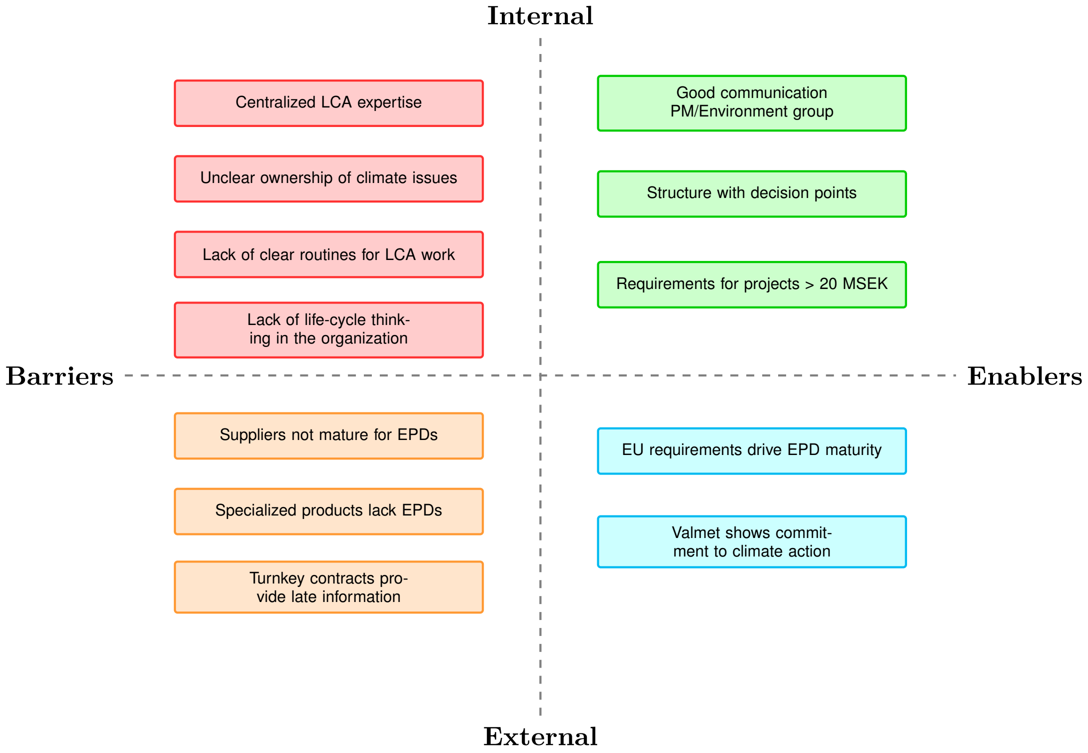


Figure 5.3: Matrix of internal and external barriers and enablers

The distribution of barriers is also analytically telling. The majority of the barriers are *internal*, centralized competence, unclear ownership, absence of routines, and limited life-cycle perspective which means that they are within GE's own control to address. The external barriers, primarily the supplier chain's limited EPD maturity and the information asymmetry inherent in turnkey contracts, are real structural limitations that cannot be eliminated in the short term. This is an important distinction. It justifies a strategy that simultaneously addresses the internal barriers, where the room for action is greatest, and designs a working method that is robust enough to function even within the external constraints.

Overall, the matrix shows that GE's organizational challenge is primarily about activating and formalizing what already exists, rather than building something new from scratch.

5.4.3 Findings: Organizational analysis

The affinity diagram and the barrier and enabler matrix together provide a coherent picture of GE's organizational conditions. The affinity analysis identifies what the barriers are and how they are thematically connected. The matrix specifies where they are located and how they relate to the enablers that are actually available. Together, they point towards a central analytical conclusion. The dominant problem is not a lack of willingness, competence or resources, it is a lack of formalization.

The strategically most important finding is that the internal enablers are blocked by the internal barriers. The organization has a functioning collaborative relationship between the PM and the environmental group, an established BP structure, and an existing formal requirement for climate calculation but none of these resources reaches its full potential. They lack the process support, ownership and system support required to turn them into systematic outcomes. The required change is therefore primarily about strengthening and formalizing what already exists, not about creating something new from scratch. This is a decisive insight for the design of the working method presented in the results chapter.

5.5 Root cause analysis

The root cause analysis aims to identify and structure the underlying causes of climate data not functioning as an integrated decision basis in GE's investment process. The analysis is conducted using an Ishikawa diagram, also called a fishbone diagram, an established quality tool for systematizing complex causal relationships (Carleton, 2016). The problem statement analyzed is: *Climate data is underutilized in investment decisions and LCA follow-up.*

The causes are structured along six categories: *Method and process*, *Material and information*, *Measurement and data quality*, *People and competence*, *Tools and systems* and *External environment and market.* The classification enables a systematic review covering the study's three analytical dimensions: process, data quality, and organization. The analysis is based on the combined empirical material from interviews, observations, document review and the pilot study.

5.5.1 Analysis by category

The most significant category is **Method and process**. The fundamental problem is not that climate data is absent in an absolute sense, but that the process for defining, requesting, and receiving data is insufficiently structured. In practice, climate data is treated as a preference rather than a requirement. There is no early definition of the data needs of the project, requirements are specified late and without operational follow-up, and there is no standardized handling when data is not provided. A further process-critical deficiency is that the purpose of climate data is unclearly defined, whether it is collected for early investment decisions or for final LCA follow-up entails fundamentally different requirements for quality, level of detail, and timing. The absence of this distinction means that the process is optimized for neither purpose.

Material and information reinforces the process problem through a structural temporal limitation. The early climate calculation must be carried out before a supplier has been selected and product-specific data is available. The calculation therefore relies on default values and internal experience, and there is no established process for how these rough early estimates should gradually be replaced by more specific supplier data during the course of the project. In other words, the information gap is built into the project logic. The critical issue is not to eliminate it, but to manage it deliberately.

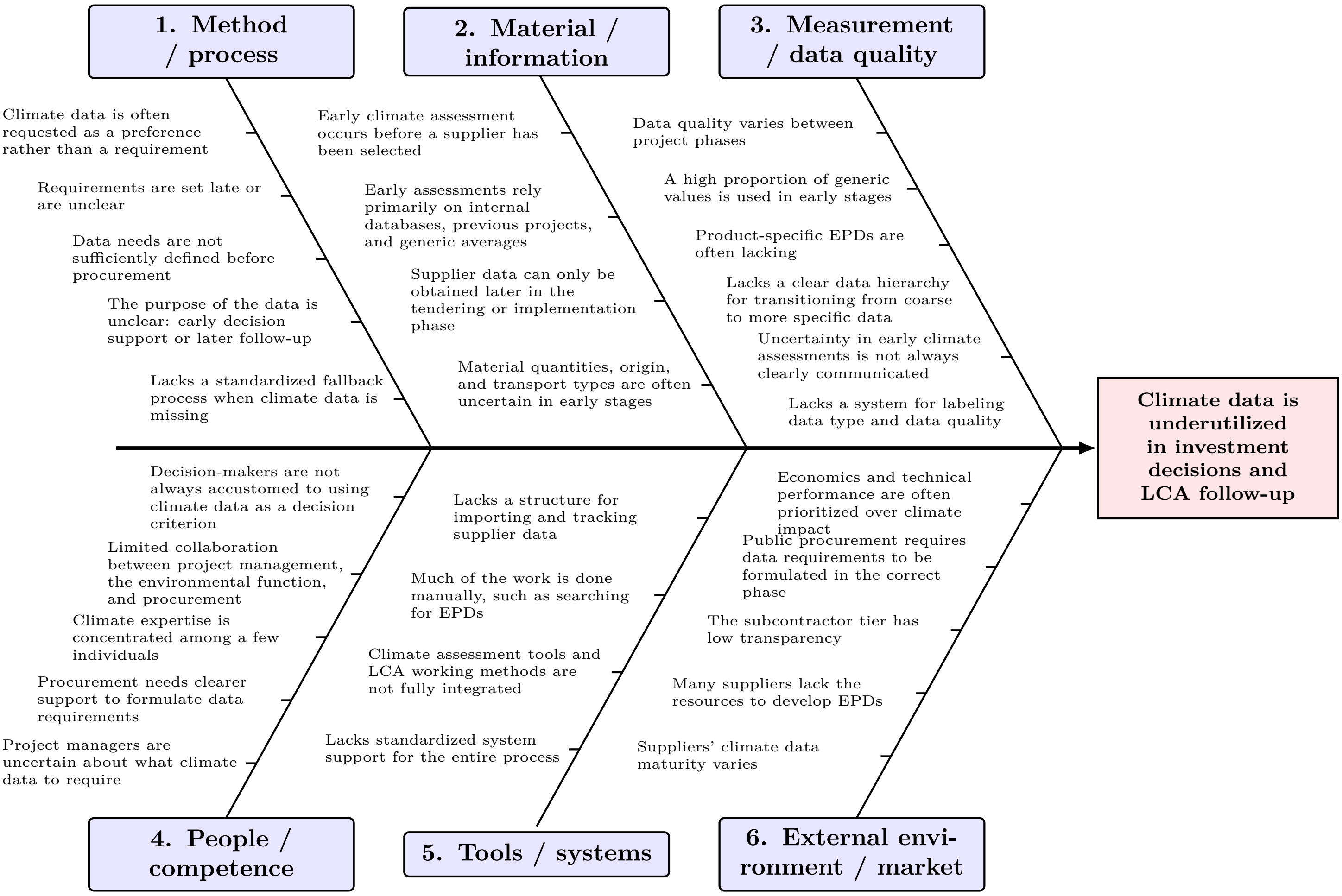


Figure 5.4: Ishikawa diagram of root causes for underutilized climate data in investment decisions and LCA-based follow-up.

Within the category **Measurement and data quality**, the most critical finding is not the high share of generic data in itself, this is unavoidable given the material category, but rather that this uncertainty is rarely communicated explicitly. There is no data hierarchy, no system for labeling data quality, and no practice for reporting the degree of uncertainty in presented climate documentation. As a result, decision-makers lack the conditions to assess what a climate result actually can and cannot say, which either leads to overinterpretation or to climate data being dismissed due to uncertainty. Both reactions counteract effective use.

People and competence shows that deficiencies in process and data are reinforced by a competence gap. LCA knowledge is concentrated within the environmental group, while project management and procurement, the functions that actually drive supplier dialogue and own the decision bases, lack sufficient support to specify requirements and interpret climate data. The limited collaboration between these three functions means that no one owns the shared responsibility for the climate data flow as a whole. In addition, there is no established practice for how climate data should be weighted as a decision criterion, which means that climate documentation in practice competes with familiar parameters such as price and technical performance without a clear framework for the trade-off.

Tools and systems reinforce all of the above problems. There is no system support that covers the entire chain from early estimation to final climate declaration. Tools are not integrated with one another, data is transferred manually between process steps, and there is no clear structure for tracing source data. The manual working method makes climate work resource-intensive and difficult to integrate into the project's ordinary flow, which pushes climate work into later phases and reduces the incentives to conduct it continuously.

External environment and market constitutes the external framework within which all internal causes operate. Low EPD maturity among suppliers, limited transparency in the subcontractor chain, and the information asymmetry inherent in turnkey contracting are factors that Göteborg Energi cannot address unilaterally. The decisive issue is that the internal processes and requirement structures that Göteborg Energi can influence are designed to maximize the outcome within these external constraints, something that the current-state analysis shows they are not.

5.5.2 Findings: Root cause analysis

The analysis shows that the causes of climate data not reaching decision-makers in the right format and at the right time are not isolated deficiencies, but rather part of an interconnected pattern. Process-related vagueness including the absence of defined data needs, an unclear distinction between early decision support and final LCA, and climate requirements without follow-up all represents the underlying cause that limits the impact of improvements in the other categories. The competence gap and lack of system support further reinforce this situation and contribute to climate work becoming a specialist activity alongside the project process instead of a fully integrated part of it.

The dominant barrier is not a lack of willingness or technical knowledge. Instead, it is the absence of structural conditions such as clear processes, defined ownership, and integrated system support. The enabling factors already exist within the organization. Competence, collaborative relationships, and the decision-point structure are established resources that need to be strengthened and formalized rather than created from the beginning.

5.6 Cross-analytical synthesis

The analysis shows that Göteborg Energi already has an emerging working method for climate calculations and requirements specification for climate data, including through guidelines and support developed with external consultants. The problem is therefore not that climate data entirely lacks organizational anchoring, but that the working method is not yet sufficiently formalized, comprehensive or integrated into the project and procurement process. Above all, there is no clear structure for how climate data is to be specified as a requirement, collected, quality-assured, and used throughout the entire chain from early project development to procurement, project implementation, and later LCA- or climate declaration-based follow-up.

The process analysis shows that climate data handling currently fails to adapt systematically to the shifting requirements of each project phase. Before procurement and supplier selection, supplier-specific information about material type, material quantity, and actual technical solution is normally lacking. The early climate calculation can therefore primarily function only as a rough reference or scenario analysis based on internal resources, previous projects, and generic emission factors. The fundamental process barrier preventing climate data from influencing supplier selection is that decision-relevant information is rarely specified as a requirement in the procurement documents, such as the supplier's ability to deliver climate data or climate improvement alternatives for significant material items.

At the same time, the data quality analysis shows that the later LCA and climate declaration work requires a different type of data than what is reasonable to request in the tender stage. For follow-up, structured basic data is needed on components, materials, quantities, origin, transport type, data type, and source. Since product-specific EPDs are often lacking, the systematic absence of a clear hierarchy for how emission factors are selected and how uncertainties are documented. Without such a structure, data quality becomes difficult to assess and the results become less useful as a basis for follow-up.

The organizational analysis shows that several necessary conditions already exist within Göteborg Energi, such as climate expertise, project management structure, decision points, and a growing internal body of work on climate calculations. The limitation lies mainly in the fact that these resources are not coordinated within a shared working method. The project manager has a central role in formulating technical requirements, procurement is responsible for transferring these requirements into the procurement process, and the environmental or LCA function is structurally isolated when attempting to support requirements specification, review, and interpretation of climate data. When this allocation of responsibilities is not clearly defined, data collection becomes dependent on individuals and difficult to follow up.

Overall, the analysis shows that the current systemic underutilization of climate data stems from a failure to separate two two distinct operational purposes. The first purpose demands decision support in procurement, where climate-related information needs to be limited, comparable, and possible for the supplier to produce during the tender stage. The second purpose demands LCA-based follow-up or climate declaration after project implementation, where a more complete and traceable data template is needed as technical documentation or final documentation. The core structural barrier lies in the lack of intentional connection between these two independent flows, a gap that remains unbridged due to a lack of early requirements specification, clear allocation of responsibilities, and a shared terminology and data structure.

The results chapter builds on these conclusions by formulating a proposed working method for climate data in investment projects. The synthesis of these barriers dictates the exact design criteria for any upcoming improvement framework; it must resolve precisely when climate data should be specified as a requirement, what information is reasonable to request at different stages, who is responsible for what, and how data can be used systematically for both procurement and later LCA-based follow-up.

6

Results

The results chapter corresponds to the *Improve* phase and parts of the *Control* phase in DMAIC. The chapter on the barriers and root causes identified in the analysis and formulates a proposed working method for how Göteborg Energi can specify requirements for, collect, quality-assure, and use climate data in larger investment projects. The working method should not be regarded as a fully implemented solution, but as a structured improvement proposal based on the pilot LCA, the process analysis, and the organizational data collection.

6.1 From identified barriers to requirements for the working method

The analysis shows that Göteborg Energi already has an emerging working method for climate calculations and climate data. The main problem is therefore not an absence of climate data initiatives, but that the process is not yet sufficiently systematized or integrated into the ordinary project and procurement process. Climate data requirements may be formulated as general requests or ambitions, without a sufficiently clear definition of purpose, data type, format, responsibility, and timing. As a result, climate data risks becoming fragmented: relevant as an ambition, but not always translated into a structured requirement that can be followed up contractually and used consistently in later calculations.

The identified barriers can be summarized in three areas. First, process-related barriers arise when climate data requirements are not clearly defined before procurement and when the purpose of the data is unclear. This creates uncertainty regarding whether climate data is intended to support supplier selection in the tender stage or later LCA-based follow-up. Second, data quality-related barriers arise when product-specific climate data and EPDs are unavailable, when generic emission factors are used without a clear fallback structure, and when data type, source, and uncertainty are not documented consistently. These barriers are reinforced by inconsistent terminology, where EPDs, generic values, default values, and climate data are not always clearly distinguished. Third, organizational barriers arise when climate data work is not sufficiently integrated into otherwise established roles and responsibilities. Project management, procurement, suppliers, and the environmental or LCA function therefore need a shared understanding of what data is needed, when it is needed, and how it will be used.

Based on these barriers, the proposed working method needs to meet four requirements. It must clarify the purpose of climate data collection before procurement is published, distinguish between tender-stage decision input and later LCA or climate declaration data, standardize the supplier's data delivery, and define how missing or uncertain climate data should be handled. It must also make responsibilities explicit, so that climate data is not dependent on individual initiative or requested without a clear process connection.

The proposed working method responds to the problem areas identified in the current-state process in Figure 5.1. P1 is addressed by requiring climate-related requirements to be formulated in the technical specification before procurement. P2 is addressed by separating climate data for tender decision support from climate data for later LCA or climate declaration. P3 is addressed by treating early climate calculations as screening tools and by using fallback logic for missing values. P4 is addressed through the standardized climate data template, data-type classification, and fallback process.

This enables the results chapter to move from the identified barriers to a proposed working method for how climate data can be specified, collected, quality-assured, and used in investment projects in a way that is compatible with Göteborg Energi's project and procurement process.

6.2 Proposed working method for climate data

The proposed working method clarifies how climate data should be specified, collected, quality-assured, and used in Göteborg Energi's investment projects. It should be understood as a systematization of ongoing work with climate calculations, requirements specification, and climate documentation, rather than as a separate new system. The main contribution is to define the purpose of climate data collection and to specify what type of data is needed at different stages of the project.

The working method is based on two connected data flows. The first flow concerns decision support prior to supplier selection, where climate-related information needs to be limited, comparable, and possible for suppliers to provide as part of a tender. The second flow concerns later climate declaration or LCA, where Göteborg Energi needs more complete and traceable basic data from the selected supplier, such as materials, quantities, origin, data type, and source. This distinction is central because climate data should not be requested without a defined purpose. The required level of detail depends on how the data will be used.

Figure 6.1 and Figure 6.2 visualize the proposed working method. Figure 6.1 shows when different functions are involved and where climate-related requirements should be integrated into the project and procurement process. Figure 6.2 shows how the data basis changes over time: from internal and generic values in early stages, via limited tender information from several potential suppliers, to more complete data delivery from the selected supplier after award.

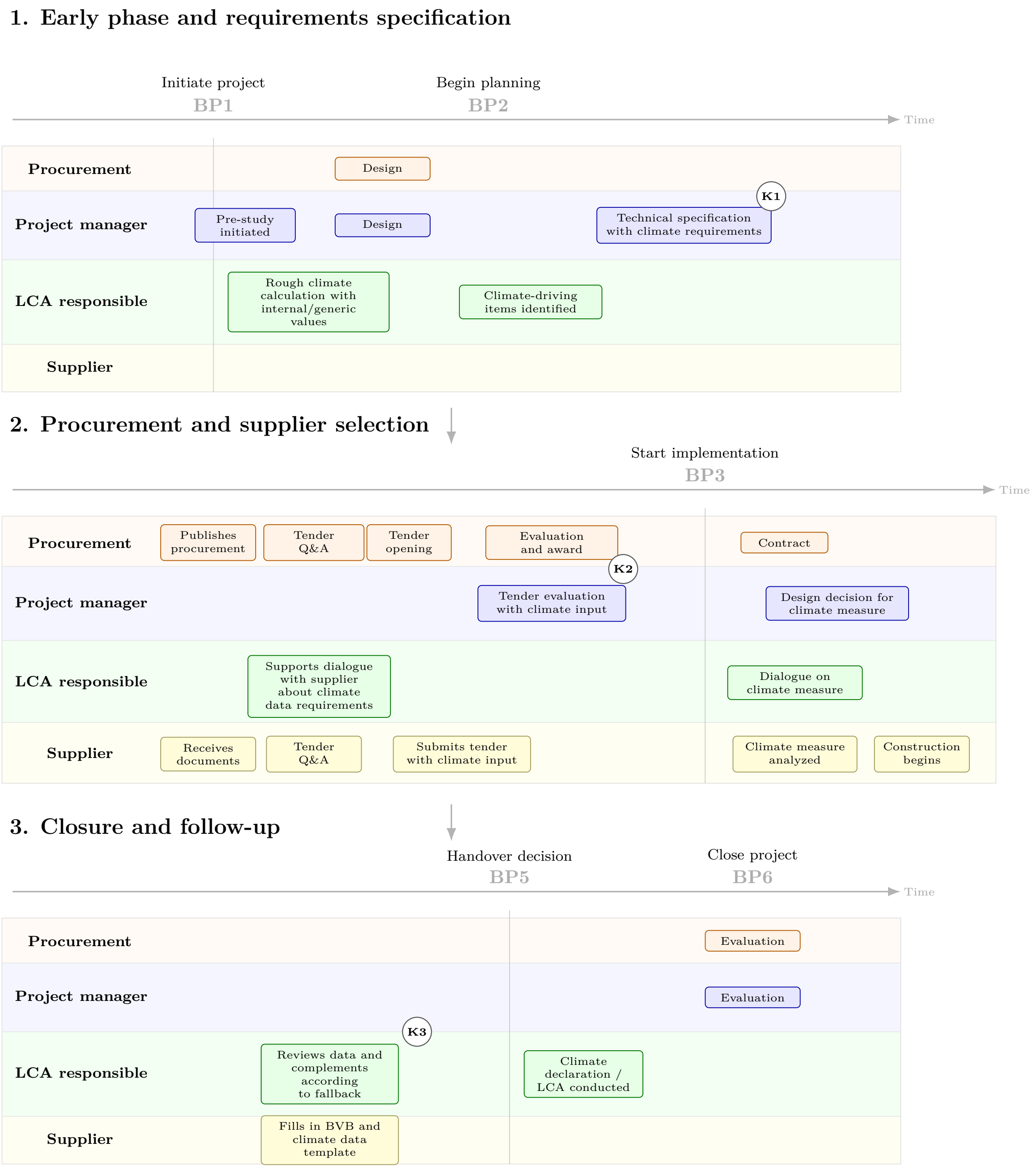


Figure 6.1: Process map of the proposed working method for climate data, showing the main activities, roles, and key points K1–K3.

The process map in Figure 6.1 highlights three key points in the working method. K1 marks the point where climate-related requirements should be formulated in the technical specification before procurement is published. K2 marks the tender stage, where suppliers can provide limited but decision-relevant climate input, such as climate improvement options or information about their ability to deliver climate data later in the project. K3 marks the later data delivery, where the selected supplier submits BVB and the climate data template as input for climate declaration or LCA.

The figure shows that the proposed change is not simply to request more climate data. Instead, the purpose of the data needs to be defined before procurement, the type of information requested must match the project stage, and the data must be delivered in a format that can be followed up.

Figure 6.2 further develops the proposed working method by illustrating how the type and flow of climate data change over the project timeline. The figure distinguishes between early internal data, tender-stage supplier input, and final data delivery from the selected supplier.

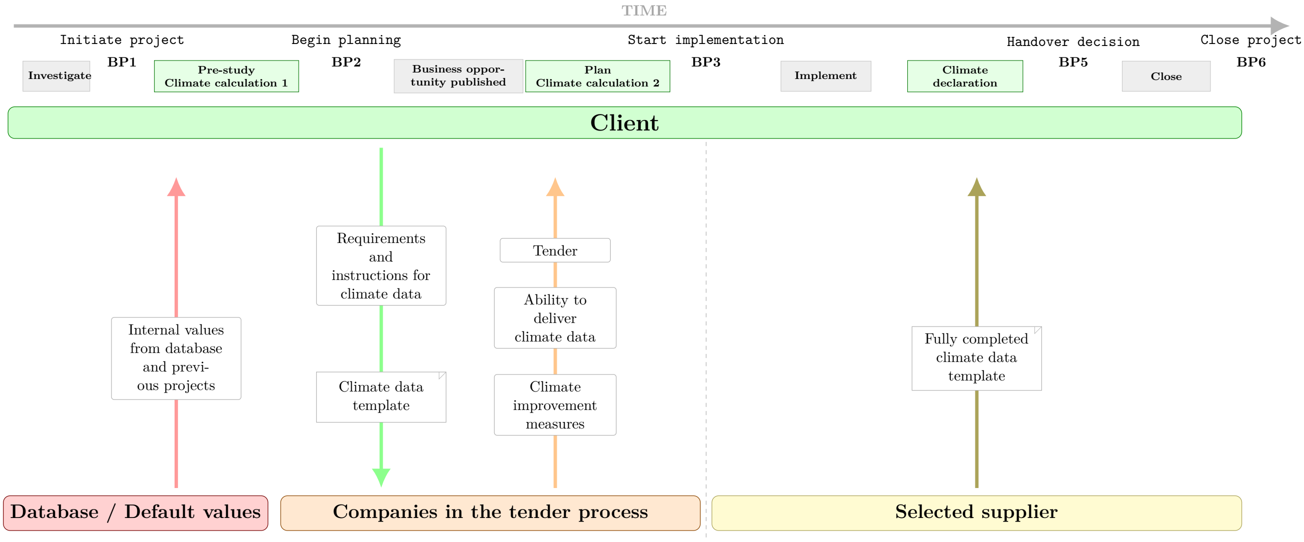


Figure 6.2: Information flow in the proposed working method, showing how climate data changes from internal estimates to tender-stage input and final supplier data.

The information flow map in Figure 6.2 complements the process map by clarifying that different types of climate data are needed at different project stages. Before procurement, climate assessments are mainly based on internal databases, previous projects, default values, and generic emission factors. During procurement, several potential suppliers may provide limited climate-related information for decision support, such as climate improvement options or their ability to deliver climate data later in the project. After award, the information flow shifts to the selected supplier, who provides the structured climate data template required for climate declaration or LCA.

6.2.1 Process for collecting and using climate data

Based on the figures, the working method can be understood as a phase-based process in which climate data has different functions depending on the project stage. Before a supplier has been selected, supplier-specific information on material type, material quantity, actual technical solution, and cost is normally unavailable. The early climate calculation should therefore be based on Göteborg Energi's internal resources, such as previous projects, the internal climate database, default values, and generic emission factors. Its purpose is not to produce a final product-specific result, but to function as a rough reference or scenario analysis that identifies climate-driving components, materials, or activities.

The identified climate-driving items can then be translated into targeted tender questions or climate improvement options. In this way, the internal calculation does not need to eliminate all uncertainty before procurement. Instead, it provides enough direction to guide the procurement process, while the supplier's tender input can provide more specific information on feasible alternatives, costs, and potential climate reductions.

Before procurement is published, the project manager, with support from environmental or LCA expertise, should formulate climate-related requirements in the technical specification. This corresponds to K1 in Figure 6.1. The requirements should distinguish between two types of information: information to be submitted in the tender and used in tender evaluation, and documentation to be delivered later as input for climate declaration or LCA. This distinction is necessary because the same climate data cannot be expected to serve both purposes without clarification.

Supplier dialogue after award can still be important for identifying feasible climate improvement measures during implementation. However, such dialogue becomes more effective when the objective and documentation requirements have already been defined before procurement. If climate data is only discussed after contract signing, the dialogue risks depending on voluntary cooperation rather than being part of the supplier's formal undertaking.

In the tender stage, the supplier should not normally be required to submit a complete climate data template or full LCA input. Such requirements should only be used if they are justified by the project scope and included in the procurement documents. Instead, the tender requirement should be limited to decision-relevant information, corresponding to K2 in Figure 6.1. This may include the supplier's ability to deliver climate data later in the project, previous experience of EPD or LCA work, and a limited number of climate improvement alternatives for the largest climate items. For major items such as steel, concrete, or transports, the supplier may, for example, report a standard alternative, a climate-improved alternative, estimated additional cost, and estimated climate saving. This can provide procurement and project management with a more concrete basis for supplier selection, without requiring a complete LCA in the tender.

After award, the purpose of climate data changes from supplier selection to climate reporting. At this stage, Göteborg Energi needs sufficiently complete and traceable input for climate declaration or LCA. This corresponds to K3 in Figure 6.1. The standardized supplier template should therefore be used as required technical documentation or final documentation. The central point is that this requirement must be included in the contract from the outset, so that the supplier knows which data is to be submitted, in which format, and at what point in time.

6.2.2 Shared terminology structure for climate data

An important part of the working method is to establish a shared language for climate data. At present, terms such as EPD, climate data, generic value, and default value are sometimes used without clear distinction. This creates a risk that different data types are treated as equivalent, even though they differ in quality, traceability, and usability.

In the proposed working method, each climate value should be labeled with data type. A product-specific EPD should be distinguished from an equivalent EPD, a supplier-specific climate value, a generic emission value, and a default value. This makes it clearer which type of data is being used, how reliable it is, and how it should be interpreted in climate declaration or LCA.

This classification is particularly important because the case study shows that product-specific climate data is often lacking for complex industrial components. In such cases, the objective should not be to stop data collection, but to document which data level is used and why. In this way, Göteborg Energi can conduct climate calculations even when complete product-specific data is unavailable, while making the uncertainty visible.

6.2.3 Supplier template for climate data

The standardized supplier template is primarily intended to support later climate declaration or LCA. Its purpose is to ensure that Göteborg Energi receives complete basic data in a consistent and traceable format. The template should therefore be specified as a requirement for technical documentation or final documentation, rather than as an extensive tender requirement.

The template should be understood as a minimum structure for climate data collection. The exact level of detail may vary between projects depending on project size, technical complexity, contract form and documentation needs. However, the fields below represent the basic information needed for Göteborg Energi to assess the data, apply the fallback process and use the information in a climate declaration or LCA.

Since product-specific climate data is often lacking for complex industrial components, the supplier should not be expected to provide climate values for all items. The minimum requirement is instead a complete and traceable material and component list, together with the best available climate data. If a climate value is missing, the supplier should state the reason.

The supplier should provide the following basic data:

- component or material
- specification or product name
- unit
- quantity
- climate data where available, expressed as kg CO_2e per unit
- data type
- source or reference
- reason if climate data is missing

The distinction between component and material is important because it affects which type of climate data can reasonably be used. For a component, a product-specific EPD or supplier-specific climate value may be available. For a material, the most relevant value may instead be a generic emission factor, for example for galvanized steel or stainless steel.

The data type field should classify whether the value is based on a product-specific EPD, an equivalent EPD, supplier-specific climate data, a generic emission factor or a default value. This enables Göteborg Energi to assess how much of the calculation is based on specific versus generic or estimated data, and to apply the fallback process in Table 6.1 consistently.

The source or reference field is needed so that Göteborg Energi can review the submitted values before they are used. Verified values, sources and assumptions can also be fed back into Göteborg Energi's internal climate database and improve future early-stage climate calculations.

If climate data is missing, the item should not be excluded from the climate declaration or LCA. Instead, the stated reason allows Göteborg Energi to assess whether the missing value is acceptable and to complement it through the fallback process. Databases such as Ecoinvent could be used as fallback sources, provided that Göteborg Energi defines them as accepted sources for the project.

Additional fields may be added in projects with higher complexity or more detailed LCA requirements. For example, country of origin, transport origin, transport type, manufacturing location, installation assumptions or end-of-life assumptions may be relevant when transport emissions, construction processes or scenario-based life cycle stages are included. These fields should be specified when needed, but are not part of the basic minimum structure for all projects.

The function of the template is therefore to separate basic data from emission factors. The supplier is responsible for describing what is delivered, in what quantity, in which unit, and which climate data is available. Göteborg Energi's climate or LCA function is responsible for reviewing the submitted values, assessing data type and source, and complementing missing emission factors according to the fallback process.

6.2.4 Fallback process for emission factors

The fallback process defines how missing or uncertain emission factors should be handled after the supplier template has been submitted. It is needed because suppliers may lack product-specific climate data or the competence and sources required to provide generic emission factors. In such cases, the supplier should state why climate data is missing, while Göteborg Energi's climate or LCA function reviews the submitted information and complements missing values according to the hierarchy in Table 6.1.

The purpose of the fallback process is to ensure that all relevant material and component items can be included in the climate declaration or LCA, even when product-specific data are unavailable. It also makes data quality transparent by documenting whether each value is based on product-specific data, representative data, a generic emission factor, or a default value.

The fallback process can also support early internal climate calculations. When supplier-specific data are not yet available, the same hierarchy can be used to document whether an estimate is based on an equivalent EPD, a generic emission factor, or a default value. This creates consistency between early screening calculations and later LCA or climate declaration, although the level of data quality differs between project stages.

Table 6.1: Fallback process for emission factors. Applied per component or material item. Each data item should be labeled with data type, source, and any justification.

Level	Type	Description
1	Product-specific EPD or supplier-specific climate data	Used when climate data exists for the actual product, component, or material. This provides the highest traceability and relevance.
2	Equivalent EPD or representative climate data	Used when product-specific data is unavailable, but an EPD or other climate data exists for a comparable product or material category. Representativeness should be documented.
3	Generic emission factor from a predefined fallback source	Used when supplier-specific climate data is unavailable or when the submitted value is not sufficiently traceable. The source should be defined by Göteborg Energi or agreed for the project, for example through a selected database or other standardized source.
4	Default value or conservative assumption	Used only when no relevant value can be identified through levels 1–3. The assumption should be clearly documented, justified, and marked as lower data quality.

In this process, the supplier is responsible for providing the best available climate data and stating the reason when climate data is missing. Göteborg Energi's climate or LCA function is responsible for reviewing submitted values and complementing missing emission factors according to level 3 or 4 in Table 6.1. Each data item should also be labeled with data type, source, and any justification. In this way, it becomes clear whether the climate impact is based on product-specific data, representative data, a generic emission factor, or a default value. The fallback process thereby functions both as a data quality structure and as a practical allocation of responsibilities between supplier and client.

6.2.5 Allocation of responsibilities

The working method does not introduce new main roles, but clarifies how climate data work should be integrated into established responsibilities. The project manager, procurement, supplier, and Göteborg Energi's environmental or LCA function each have distinct responsibilities in the process.

The project manager is responsible for ensuring that climate data requirements are included in the technical specification. This includes both limited decision input for the tender stage and requirements for later climate documentation.

Procurement is responsible for carrying these requirements forward into the procurement and contract documents. Procurement does not define the technical climate data need, but ensures that the requirements specified by the project are included in the formal procurement process.

The supplier is responsible for providing the information that has been specified as a requirement. In the tender stage, this may concern climate improvement options or the ability to deliver climate data. In the final documentation, it concerns complete basic data according to the supplier template and the best available climate data. If climate data is missing, the supplier must state the reason.

Göteborg Energi's environmental or LCA function is responsible for supporting requirement formulation, reviewing submitted data, assessing data type and source, complementing missing emission factors according to the fallback process, and using the input in climate declaration or LCA.

This allocation of responsibilities reduces the risk that climate data collection becomes dependent on individual initiative. It clarifies who specifies the requirement, who carries it into procurement, who provides the data, and who reviews and uses the data in the climate calculation.

6.3 Implementation

This section describes how the proposed working method can be introduced into Göteborg Energi's ordinary project and procurement process. The aim is not to present a detailed implementation plan, but to define the main conditions required for the working method to be tested, followed up, and further developed. Implementation should therefore be understood as an integration into existing routines, rather than as a separate new process.

6.3.1 Integration into technical specification and procurement

A central condition for implementation is that climate-related requirements are formulated in the technical specification before the procurement is published. Procurement can carry the requirements forward in the procurement process, but the content must be defined in the technical documentation prepared by the project manager. The technical specification therefore becomes the main place for defining what climate-related information the supplier should provide, when it should be provided, and how it will be used.

In practice, the technical specification should include two types of climate data requirements. First, it should define limited climate-related information for the tender stage, such as climate improvement options or the supplier's ability to deliver climate data later in the project. Second, it should define the later data delivery required for climate declaration or LCA, primarily through the standardized supplier template.

Before the procurement is published, the climate data requirements should be checked as part of the existing review of the procurement documentation. This checkpoint should verify that the technical specification includes the purpose of the climate data request, the required data format, the expected delivery point, and the distinction between tender-stage information and later documentation. The project manager is responsible for formulating the requirements, while procurement verifies that they are included in the procurement and contract documents.

The main implementation shift is therefore not to add a separate climate data process, but to move climate data requirements into the formal procurement documentation. This reduces the risk that climate data is requested only retrospectively and ensures that the supplier's data delivery is included in the undertaking from the outset.

6.3.2 Integration with existing climate calculation tool

Göteborg Energi's current climate calculation tool is an internal Excel-based system, developed according to the organization's own specifications and available via the intranet. The proposed working method is therefore designed to be compatible with existing workflows rather than requiring a transition to dedicated LCA software. By standardizing supplier input and structuring it in a format that can be used in existing Excel-based models, the working method can reduce manual processing without requiring extensive system investments.

At the *data level*, the supplier template structures information such as component or material, specification, quantity, unit, climate data, data type, and source. This makes the input easier to link to the climate calculation or LCA model and reduces the risk of errors when supplier data is transferred from project documentation to the calculation tool.

At the *procedural level*, the working method supports a feedback loop between early and late project stages. Early climate assessments can be based on internal databases, previous projects, and generic data, while later climate declaration or LCA can use the more complete basic data submitted by the selected supplier. Reviewed emission factors, fallback decisions, and experience values can then be documented and reused in future early-stage calculations.

This feedback loop also enables reviewed supplier data, assumptions, and fallback decisions to be fed back into Göteborg Energi's existing internal climate database, improving future early-stage climate calculations.

A limitation is that the current internal EPD and climate database has limited coverage and mainly reflects values collected manually over time. As more projects use the working method, the database can be systematically expanded. The climate group and environmental engineers should therefore review submitted climate values, sources, and assumptions before they are used in climate declaration or LCA. This also makes it possible to transfer verified values back into Göteborg Energi's internal database, which strengthens future early-stage calculations based on internal data.

6.3.3 Follow-up and quality assurance

For the working method to have lasting effect, follow-up and quality assurance need to be built into the process rather than being dependent on individual initiative. The implementation should therefore include simple follow-up metrics, risk management, and experience feedback between projects.

Completion rate as a follow-up metric. The primary follow-up metric is the *completion rate* of the supplier template, defined as the share of rows where all mandatory basic data fields are fully completed. The target should be a 100 % completion rate for mandatory basic data fields, while climate values should be provided where available. If climate data is missing, the reason should be stated. The project manager checks that the data delivery is received at the agreed time, while the climate group or environmental engineers review data quality, data type, and source.

Quality review of submitted data. The review of submitted data should be carried out by the climate group or environmental engineers. This is close to how BVB and climate-related documentation are already handled, but the proposed supplier template makes the work less dependent on manual searching and interpretation. Instead of first having to identify basic material and component data, the review can focus on checking submitted values, sources, data type, and missing information. Where values are missing, the climate group or environmental engineers complement the data according to the fallback process.

Risk management. A potential-FMEA was conducted to identify risks in the implementation of the working method, in accordance with the Control phase of DMAIC. Since the risks concern an administrative and organizational process rather than a manufacturing process, the Risk Priority Number (RPN) was calculated as the product of Severity (S) and Occurrence (O). Detectability (D) was excluded because failures such as missing documentation or incomplete supplier data are normally visible when the supplier template is submitted. The main risks requiring proactive action ($RPN \geq 12$) are missing climate requirements in the technical specification, incomplete basic data, climate values without traceable sources, and the absence of an established fallback practice. Table 6.2 presents the potential-FMEA input.

Table 6.2: Potential-FMEA for implementation of the working method

Potential risk	S	O	RPN	Action
Climate requirements are not written into the technical specification before procurement	5	3	15	Introduce a checkpoint before procurement is published; the project manager is responsible, procurement verifies that requirements are included in the documentation.
Supplier submits incomplete material and component list	4	3	12	Mandatory fields in the supplier template; the project manager follows up deficiencies according to the agreed timetable.
Supplier provides climate values without a clear source or data type	4	3	12	Requirement for data type and source in the template; the climate group or environmental engineers review reasonableness and traceability.
Supplier does not state a reason when climate data is missing	3	3	9	The field “reason if climate data is missing” is made mandatory when a climate value is missing.
Göteborg Energi lacks established fallback practice	4	3	12	Define accepted fallback sources and document default values and assumptions.
Tender requirements become too extensive and discourage suppliers	3	3	9	Limit tender requirements to capability, experience, and climate improvement options for significant items.
Competence leaves the organization	5	2	10	Document the method in a handbook; train at least two people in the climate group and relevant project roles.

Experience feedback and versioning. As the final activity in each project where the working method is applied, the climate group, procurement, project management, and technical standard team should jointly document experiences and, if needed, revise the working method. This includes which data requirements worked in procurement, which fields in the supplier template were difficult to complete, which fallback values were used, and which assumptions should be reused or revised in future projects.

Preliminary validation. The working method should be tested in a future investment project and evaluated through feedback from project management, procurement, suppliers, and the climate group or environmental engineers. Such testing should be described as preliminary validation, not as full-scale implementation. The purpose is to assess whether the requirements are understandable, whether suppliers can provide the requested information, whether procurement can carry the requirements forward into the procurement documents, and whether the climate group can use the data in climate declaration or LCA.

6.4 Summary of results

The result of the study is a proposed working method for climate data in investment projects. The working method addresses the main barriers identified in the analysis: insufficiently systematized requirements specification, varying data quality, conceptual ambiguity regarding climate data, limited integration into established roles, and the absence of a standardized process for missing emission factors. The result should therefore be understood as a systematization of an emerging practice, rather than as a response to a complete absence of climate data initiatives.

The central element of the working method is the distinction between two data flows. The first concerns decision support in procurement, where climate-related information should be limited, comparable, and possible to use in tender evaluation. The second concerns climate declaration or LCA, where the selected supplier should provide complete basic data in a standardized template. Climate values should be provided where available, while missing values should be justified and complemented by Göteborg Energi's climate or LCA function according to the fallback process.

The working method integrates climate data earlier and more clearly into the project and procurement process without assuming that suppliers can always provide complete product-specific climate data. Through requirements in the technical specification, shared terminology, a standardized supplier template, a fallback process, and clarified responsibilities, Göteborg Energi can strengthen both climate-informed supplier selection and later LCA-based follow-up.

The proposed implementation should be regarded as a preliminary plan rather than a full-scale implementation. The next step is to test the working method in a future investment project and collect feedback from project management, procurement, the climate group, and suppliers. Such testing should assess whether the purpose, timing, format, and responsibility for climate data are sufficiently clear for the information to be used in both procurement decisions and later LCA-based follow-up.

7

Discussion and Conclusion

7.1 Interpretation of results

The results show that the use of climate data in investment projects is not only limited by data availability. It is also limited by how climate data is connected to the project process, procurement, responsibilities, and later LCA-based follow-up. The main issue is therefore not whether climate data is relevant, but whether it is requested with a clear purpose, in the right format, at the right time, and by the right function. Without this process connection, climate data risks becoming input for retrospective reporting rather than a basis for decisions in earlier project phases.

A central interpretation is that climate data needs to be distinguished according to function. Before procurement, climate data is primarily used to identify climate-driving items and formulate requirements. In the tender stage, it can support comparison of limited climate improvement options. After supplier selection, it becomes input for climate declaration or LCA. This means that the same type and level of data cannot be expected throughout the whole project process.

Before supplier selection, a climate calculation cannot normally rely on supplier-specific information, since the final technical solution, material quantities, supplier, and cost structure are not yet established. Early calculations therefore need to be based on internal experience values, previous projects, default values, and generic emission factors. This limits precision, but it still makes the calculation useful as a screening tool. Its purpose is not to determine the final climate impact, but to identify where procurement should ask more specific questions, for example regarding steel, concrete, transport, or other climate-driving items.

This distinction is particularly important in larger investment projects. Since climate calculation is mandatory for Göteborg Energi projects exceeding SEK 20 million, while projects exceeding SEK 2,5 million are only covered in certain cases, the working method needs to be scalable. Larger projects can justify more extensive climate data requirements because the climate impact, supplier involvement, and documentation needs are greater. Smaller projects may require a simplified application in order to avoid disproportionate administrative burden.

The timing of requirements is also critical. Climate data has the greatest potential to influence decisions before procurement is published. If climate-related requirements are not included in the technical specification and procurement documents, the possibility of using the data in supplier selection is reduced. After supplier selection, climate data may still be important, but its function changes from decision support to documentation and follow-up. The proposed working method addresses this by separating limited climate-related decision input in the tender from more complete data delivery for later LCA or climate declaration.

A further interpretation is that terminology affects both requirements specification and data quality. If terms such as EPD, climate data, generic value, and default value are used without clear distinction, different data types may be treated as equivalent even though they differ in traceability, representativeness, and uncertainty. For example, using an EPD for a different component as if it represented a material value can create a false sense of precision. In such cases, a clearly documented generic value may be more transparent than an incorrectly matched EPD. A shared terminology structure is therefore not only a communication issue, but a condition for consistent data quality.

Overall, the results indicate that a functioning working method for climate data needs to combine early requirements specification, clear responsibility, shared terminology, a standardized supplier template, and a fallback process for missing emission factors. Only when these parts are connected can climate data move from being reactive information input to becoming a systematic part of investment decisions and LCA-based follow-up.

7.2 Usability and limitations of the proposed working method

The main usefulness of the proposed working method is that it clarifies what should be requested, when it should be requested, and who is responsible for the information. The process map and the information flow map together show why climate data requirements need to be formulated early, while also explaining why complete climate data cannot be expected in all project stages.

The supplier template is useful because it standardizes the basic data required for later climate declaration or LCA. Instead of relying on project-specific or supplier-specific formats, the template creates a common structure for components or materials, quantities, units, climate values, data type, source, and missing data. This reduces the risk of reactive and person-dependent data collection. However, the template does not solve the lack of product-specific climate data. Its main function is to ensure that Göteborg Energi receives the basic information needed to review submitted values and complement missing emission factors.

The fallback process is therefore central to the robustness of the working method. It makes climate calculations possible even when suppliers lack product-specific EPDs or complete climate data. By distinguishing between product-specific data, representative data, generic emission factors, and default values, the calculation can be completed without hiding the uncertainty. However, the fallback process should not be interpreted as making generic data equivalent to product-specific data. It is a practical way of managing data gaps, provided that the lower data quality is clearly documented.

The allocation of responsibilities is also important. The supplier should describe what is delivered, in what quantity, and with the best available climate data. Göteborg Energi should define the requirements, review submitted data, assess data type and source, and complement missing emission factors according to the fallback process. This division is practical because suppliers may have varying levels of climate data competence. If each supplier is expected to develop generic emission values independently, the risk of inconsistent data quality increases. A standardized fallback practice allows Göteborg Energi to manage missing values more consistently between projects.

A limitation of the working method is that it does not in itself guarantee that climate data becomes guiding in investment decisions. For climate data to influence supplier selection, climate-related criteria need to have sufficient weight in the tender evaluation. If climate-related information is requested but does not affect the evaluation, it may still become informative rather than decision-guiding. The working method therefore creates conditions for better decision support, but it does not determine how climate benefit should be weighed against cost, technology, schedule, or risk.

Another limitation is that the working method should not be treated as an exact recipe that can be applied identically in all projects. Investment projects differ in size, technical complexity, contract form, supplier structure, and climate impact. The proposed working method should therefore be understood as a scalable structure rather than a static method. In some projects, it may be sufficient to use BVB or simpler climate documentation. In larger or more climate-significant investments, it may instead be justified to specify a more extensive supplier template and later LCA or climate declaration.

7.3 Implementation in the investment and procurement process

Implementation of the working method depends on its integration into Göteborg Energi's ordinary investment and procurement process. The most critical point is still the technical specification. If climate requirements, data requirements, and later documentation requirements are not included in the technical documentation before procurement is published, procurement has limited possibility to carry them forward into the procurement and contract documents. This means that the project manager, with support from environmental or LCA expertise, has a central role in translating climate data needs into requirements early enough for them to become part of the supplier's undertaking.

Procurement therefore has an indirect but important role in climate data work. Procurement does not define the technical climate data need, but ensures that the requirements specified by the project are included in the formal procurement process. This makes procurement a link between the project's climate ambitions and the supplier's contractual responsibility. If climate requirements are not formalized before publication, later data collection risks becoming dependent on voluntary supplier cooperation rather than on an agreed requirement.

The level of climate data requirements should also be adapted to the type of project. Since climate calculation is mandatory for Göteborg Energi projects exceeding SEK 20 million, the working method is most relevant for larger investment projects where climate impact, supplier involvement, and documentation needs are more extensive. For projects exceeding SEK 2,5 million, where climate calculation may be relevant but is not generally mandatory, a simplified version may be more appropriate. The implementation should therefore be scalable rather than uniform across all projects.

Contract form is another important condition. In a turnkey contract, the supplier has greater responsibility for the technical solution, material choices, and execution. This makes it particularly important that requirements for climate data and climate improvement options are included in the procurement documents from the beginning. In projects where Göteborg Energi has greater control over design and material choices, the organization may itself have better conditions to influence early climate calculations and data sources. The working method therefore needs to be adapted according to how design responsibility, material choices, and documentation responsibility are distributed between client and supplier.

The feedback from Göteborg Energi's internal functions can be interpreted as preliminary validation of the working method's relevance. Procurement confirmed the importance of including climate requirements in the technical specification before publication, while the climate group and climate calculation tool perspective helped assess how the supplier template can connect to existing tools, data sources, and calculation models. Input from the Rya BKV project organization and project management also helped assess whether the working method can fit into existing roles, documentation flows, and decision points.

This feedback should not be interpreted as full-scale validation. It shows that the working method is relevant in principle, but the details need to be tested in an actual project. A suitable next step is to test the supplier template and requirement formulations in a future investment project. Such a test should assess whether suppliers understand the requirements, whether the data is submitted in the correct format, whether the climate group or environmental engineers can use the input, and whether procurement can manage the requirements without creating an unreasonable administrative burden.

7.4 Methodological and data limitations

The study has several limitations that affect how the results should be interpreted. One limitation concerns the pilot LCA. The case study is primarily based on Valmet's delivery, while other parts of Rya BKV are treated more generally or separately. The results should therefore not be interpreted as a complete climate assessment of the entire investment project. Instead, the pilot LCA should be understood as a basis for identifying data needs, data gaps, and practical difficulties in LCA-based follow-up.

A second limitation concerns data quality. Some items could be linked to more specific data, while others had to be estimated using generic values, default values, or rough assumptions. This affects the precision of the climate calculations and means that the numerical results should be interpreted with caution. At the same time, this limitation is also an important empirical finding, since it illustrates why a clear fallback process and documented data type are needed.

The organizational data collection also has limitations. Interviews, meetings, the questionnaire, and supplier dialogue provided important insights into process-related and organizational barriers, but the material is not extensive enough to represent all projects, functions, or supplier types. The questionnaire results should therefore be interpreted as complementary indications rather than statistically generalizable results.

Another limitation is that the C phase in the LCA is mainly scenario-based. The results for waste management, recycling, and end-of-life processes are therefore based on assumptions rather than verified project-specific information. This is common in early or ongoing projects, but it increases uncertainty and needs to be reported transparently.

Finally, the proposed working method has not been fully implemented in a completed project. The solution should therefore be understood as an analytically grounded improvement proposal, derived from identified root causes and preliminary feedback from relevant functions. Its actual effect can only be assessed through testing in future investment projects.

7.5 Generalizability

The case study is specific to Rya BKV and Göteborg Energi's project and procurement context. The project's technical complexity, supplier structure, and connection to the existing combined heat and power plant mean that some findings are project-specific. Data needs, component types, contract conditions, and suppliers' ability to provide climate data may therefore differ in other projects.

At the same time, several findings are transferable to other larger investment projects. This applies particularly to the need for early requirements specification, standardized data collection, clear allocation of responsibilities, and a fallback process for missing emission factors. These challenges are not unique to Rya BKV, but are likely to arise in other projects where climate data is intended to support both procurement decisions and later climate reporting.

The working method may also be relevant for other energy companies or organizations that carry out technically complex investments with many suppliers and long project life cycles. The general lesson is that climate data needs to be managed as an information flow through the project, rather than as an isolated calculation at the final stage. However, the details of the supplier template, data sources, requirement formulations, and decision points need to be adapted to each organization's processes and systems.

The generalizability of the study therefore lies primarily in the principles rather than in the exact design of the proposed working method. These principles are to distinguish between decision data and follow-up data, specify climate data requirements before procurement, standardize the supplier's basic data, document data type and source, and define a process for missing emission factors. These principles should be transferable even when the technical content of the projects differs.

7.6 Conclusion

This section summarizes the key findings of the study in relation to the two research questions.

7.6.1 Research Question 1

The first research question addressed which process-related, data quality-related, and organizational barriers limit the use of climate data as input for investment decisions and LCA-based follow-up.

The study shows that the main process-related barriers are late or unclear requirements specification, insufficient connection between climate data needs and procurement, and a gap between early climate calculation and later LCA-based follow-up. When climate data requirements are not defined before procurement, the possibility of using climate data as decision input in supplier selection is reduced.

The main data quality-related barriers are limited access to product-specific climate data, lack of EPDs for several components, varying data types, and insufficient documentation of source, representativeness, and uncertainty. Conceptual ambiguity around EPDs, generic values, default values, and climate data reinforces this problem, since different data types may be treated as comparable despite differing quality.

The organizational barriers are mainly related to how climate data work is integrated into established roles and responsibilities. Project management, procurement, the climate or LCA function, and suppliers all have important roles, but the process needs to define more clearly when each function should act and how the information should be transferred. Overall, the study shows that climate data needs to be integrated earlier and more systematically into the project and procurement process to support both investment decisions and later follow-up.

7.6.2 Research Question 2

The second research question addressed how the working method for collecting, quality-assuring, and using climate data should be designed to support both early investment decisions and later LCA-based follow-up.

The study proposes a working method based on two data flows. The first data flow supports early investment and procurement decisions. At this stage, climate data should be used to identify climate-driving items, formulate requirements, and request limited decision-relevant input in tenders, such as climate improvement options and the supplier's ability to deliver climate data later in the project.

The second data flow supports later LCA or climate declaration. At this stage, the selected supplier should provide complete and traceable basic data in a standardized supplier template. Climate values should be provided where available, while missing values should be justified and complemented by Göteborg Energi's climate group or environmental engineers according to the fallback process.

The proposed working method consists of five main parts: early requirements specification in the technical specification, a standardized supplier template, shared terminology for climate data, a fallback process for missing emission factors, and a clear allocation of responsibilities between Göteborg Energi and the supplier. Together, these parts allow climate data to be used both for early decision support and later LCA-based follow-up, without assuming that complete product-specific climate data is available in all project stages.

7.7 Study contribution

The main contribution of the study is that it combines technical insights from a pilot LCA with an organizational analysis of how climate data is specified, collected, quality-assured, and used in a larger investment project. The study shows that data quality is not only determined by access to emission factors, but also by when the data is requested, how the purpose of the data is defined, how responsibilities are allocated, and which format suppliers are expected to use.

For Göteborg Energi, the study provides a concrete proposal for how climate data can be integrated into the investment and procurement process. The proposal includes a process logic, a standardized supplier template, a shared terminology structure, a fallback process, and an allocation of responsibilities. It can be used as a starting point for continued development of internal routines, but should be tested and revised before being introduced as a standard working method.

From a broader perspective, the study contributes by showing how LCA-related data challenges in infrastructure and energy investments are connected to procurement, organizational roles, and information flows. This is relevant because the practical use of LCA in investment projects depends not only on calculation methods, but also on whether the required data can be specified, delivered, reviewed, and reused in a structured way.

7.8 Recommendations for future work and research

Future work should primarily focus on testing the supplier template and requirement formulations in a future investment project. The test should evaluate whether suppliers understand the requirements, whether the requested data can be submitted in the correct format, whether the data is usable for climate declaration or LCA, and whether the requirements are reasonable to include in procurement. To expand on these industry-specific insights, future academic research should explore how different project delivery methods, particularly turnkey versus design-build agreements, structurally influence the timing, transparency, and ownership of life-cycle environmental data.

In addition, future studies should also investigate the interplay between public utility procurement directives and corporate environmental requirements, investigating how legal rules affect an organization's ability to enforce supplier climate reporting after contract is awarded.

Göteborg Energi should also review supplier data, climate values, assumptions, and fallback decisions to be systematically fed back into their existing internal climate database. This would strengthen future early climate calculations by providing better reference values before a supplier has been selected.

Finally, Göteborg Energi should further develop criteria for when different levels of climate documentation are justified. This may involve distinguishing between projects where BVB or simpler climate documentation is sufficient, projects where the supplier template should be required, and projects where a more comprehensive LCA or climate declaration should be specified from the outset. On a broader theoretical level, future research is needed to expand standardized screening and scale-up methodologies for prospective LCAs when dealing with complex, low-transparency subcontractor tiers in turnkey industrial projects.

Overall, the study shows that the value of climate data depends not only on its availability, but on the process through which it is requested, structured, reviewed, and used. Strengthening this process is therefore a necessary step if climate data is to support both investment decisions and later LCA-based follow-up.

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