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From Ambition to Occupancy

Identifying Early Phase Activities Contributing to Use Value in Occupancy Phase of Building Projects: Case Studies of Energy Academy Europe, Groningen, and ZEB Laboratory, Trondheim

Master's thesis

NTNU
Norwegian University of Science and Technology
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Master's thesis in Project Management
Supervisor: Ole Jonny Klakegg
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ABSTRACT

This thesis focuses on the value creation in construction projects, particularly in relation to value for userss during the occupancy phase. The research aims to identify key activities or factors in the early phases of building projects that contribute to use value creation. Two case studies, the ZEB Laboratory in Trondheim, Norway, and the Energy Academy Europe building in Groningen, the Netherlands, were conducted using a mixed-methods approach combining interviews with key stakeholders for both case studies, and post occupancy evaluation survey and walkthrough for ZEB Laboratory project.

The results of the study highlight ten key activities/factors that contribute to successful building realization, including defining clear goals and objectives, user involvement, effective communication methods, collaborative project delivery models, building trust, utilization of low technological methods, visualization, involving experts in building physics, flexibility in design, and team building. A post-occupancy evaluation of the ZEB Laboratory indicates a generally high level of user satisfaction with the building's performance and use value. Feedback from occupants suggests areas for improvement such as air quality, ventilation, and technical functionality, while also providing valuable insights for future enhancements and updates to the building's design.

This research contributes to the existing knowledge by bridging the gap between early phase activities and use value. It provides insights into early phase activities, conducts a comprehensive post-occupancy evaluation, and derives lessons and recommendations from the case studies. The findings emphasize the importance of use value and value co-creation for in building projects, offering valuable guidance for future endeavors in creating optimal work and research environments within NTNU campus.

Keywords: value creation, use value, early phase activities, post-occupancy evaluation

PREFACE

This master's thesis serves as the final component of my Master of Project Management in Civil Engineering at the Department of Civil and Environmental Engineering, Norwegian University of Science and Technology (NTNU). The thesis was written during the spring semester of 2023 and holds a credit value of 30. Notably, certain parts of the research were conducted in the previous autumn as part of the specialization project.

This master's thesis, titled "From Ambition to Occupancy: Identifying Early Phase Activities Contributing to Use Value in Occupancy Phase in Building Projects: Case Studies of Energy Academy Europe, Groningen, and ZEB Laboratory, Trondheim," aims to contribute valuable insights to the construction industry by highlighting the significance of early phase activities in building projects and their impact on use value during the use phase. By identifying and integrating these activities, the industry can meet user needs, and ensure long-term value delivery.

I would like to express my sincere gratitude to my supervisor, Ole Jonny Klakegg, for his invaluable support, guidance, and encouragement throughout the journey of this thesis. I extend my thanks to the members of the OptimalTid research team, specially Paulos Wondimu, Nadina Memic, and Allen Tadayon for their invaluable inputs. I am also grateful to Ola Lædre and the campus development project for funding this project, enabling its successful completion. I would like to acknowledge Vedran Zerjav for his help and guidance throughout the process of this thesis. Special thanks go to Tore Kvande and Erlend Andenæs for their valuable contributions in conducting the post-occupancy evaluation in the ZEB Laboratory. I extend my appreciation to the construction team at the University of Groningen, particularly Martin Kranenborg and Kees Bulthuis, for arranging the guided visit to the Energy Academy Europe building. Thanks are also due to Jan Willem van Kasteel and Teun van Wijk for their assistance in connecting with individuals involved in the Energy Academy Europe project.

I am grateful to all the experts who participated in the interviews conducted for this thesis. Additionally, I would like to thank the occupants of the ZEB Laboratory for their participation in the survey and walkthrough. Their contributions have been instrumental in the successful completion of this thesis.

Sara Hajizadeh,
6th June 2023, Trondheim

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ONE

INTRODUCTION

Traditionally, project management has been centered around delivering outputs with a focus on meeting deadlines, staying within budget, and maintaining a certain level of quality. This approach is often described as adhering to the "iron triangle," and while it may be effective in ensuring that a project is completed, it doesn't necessarily lead to the creation of value for the stakeholders involved in the project (Winter and Szczepanek, 2008). In recent years, there has been a shift towards a more holistic view of project management which recognizes the importance of creating both products and value. This shift has been reflected in academic literature, which has begun to pay more attention to the creation and realization of benefits in projects (Winter et al., 2006). While this focus on value creation may seem new, it has been a part of value management for many years. Despite this, it is still an area that is underemphasized in project management practice and education.

The latest project research has shifted its focus to the idea of projects and project-based operations as a means to define, create, and deliver value (Laursen and Svejvig, 2016). The concept of value refers to the perceived "worth" of the project and its deliverables, which encompasses the immediate outputs, lifecycle benefits and sacrifices, and the buyer's willingness to pay for the deliverable. Moreover, projects are not only about economic values but also moral and social values, which refer to abstract beliefs of what is good and right (Bowman and Ambrosini, 2000). Therefore, project success is not merely measured by the goals achieved at project completion but also by the benefits, costs, and value realized over the project lifecycle compared to the original value expectations of various stakeholders.

Value creation is a fundamental concept in management and organizational literature that is relevant to different levels, including the micro level (individuals, groups), meso level (organizations), and macro level (networks, industries, society). However, there is confusion surrounding this term, with scholars in different fields approaching it differently. The complexity arises from value creation referring to both content (what is value?) and process (how is value generated?), and the process of value creation being confused with who creates value and who captures value.

To clarify this confusion, Lepak et al. (2007) defined value creation as the amount of value realized by a target user (buyer), which is subjectively assessed and translates into their willingness to exchange a monetary amount for the value received. Thus, value creation involves perceived use value and monetary exchange value (Lepak, Smith, and Taylor, 2007). It follows from this definition that there is perceived use value, subjectively assessed by the user (or buyer), and then monetary exchange value, the price paid for the use value created (Bowman and Ambrosini, 2000). The term "value" in this thesis is used as benefits/costs (alternatively satisfaction of needs/use of resources), where value is not absolute, but relative, and may be viewed differently by different parties in differing situations.

Moreover, in the stakeholder approach, different stakeholders may have diverse opinions on what is valuable due to their unique knowledge, goals, and context. Furthermore, they may have conflicting interests and perspectives on what is valuable. For instance, investors may prioritize value-creating activities that add to short-term profits, while environmentalists may prioritize only those activities that preserve the environment. As a result, it is essential to take a broader and longer-term view when it comes to the targets of value creation (Lepak, Smith, and Taylor, 2007). For instance, designers collaborate with other actors to deliver designs that address diverse stakeholder needs. Such multidisciplinary design processes revolve around integrating various, often divergent values, including the ideals that collaborating actors have, and the different kinds of worth that they attempt to realize. As values are multidimensional and continuously in flux, the process of designing for divergent values requires conscious action.

Synthesizing insights from workshops with architects and literature from a wide range of scholarly domains, Marina Bos de Vos presented a first step towards an integrative framework that can help different stakeholders to effectively discuss and reconcile divergent values in multidisciplinary settings. She named it "Project Value Blueprint" which is an octagon showing eight different dimensions in a project. Project Value Modelling is a useful tool for creating and capturing values in design projects. By answering value-related questions step by step, important relationships, tensions, and opportunities can be identified, enabling informed decision-making on project selection, contract negotiation, and collaboration (Vos, n.d.).

The Project Value Modelling Blueprint provides a structured approach to determine an appropriate value model for a project. This is achieved by filling in the blueprint horizontally, vertically, and diagonally. The horizontal axis helps identify the values to be realized for others (1) and the values desired from the project (2). The vertical axis, with questions about the professional expertise brought in (3) and the risks willing to be taken (4), helps determine the core values of the project. These values can then be achieved and secured by selecting the right partners (5), activities (6), collaboration agreements (7), and revenue model (8) along the diagonal axes. This thesis will use the Project Value Modelling Blueprint to discuss the creation and capture of values in one of case studies (Vos, n.d.).

The significance of use value in buildings cannot be emphasized enough, as it directly impacts user satisfaction, which in turn contributes to the overall success of a building project. However, it's not just the end-users who place a high value on use value. Investors, developers, and even the government acknowledge the importance of creating value for users. For instance, developers may prioritize user satisfaction to enhance the marketability of a building, while the government may prioritize user safety and accessibility to adhere to building codes and regulations. Therefore, it's crucial to take into account the viewpoint of different stakeholders while creating value in buildings.

In this thesis, the focus will be on use value to ensure that the needs and expectations of users are met while simultaneously achieving the objectives of other stakeholders. Especially, ensuring high levels of end-user satisfaction is crucial for the success of sustainable buildings, as users can influence the acceptance or rejection of advanced energy concepts through their experiences and opinions. With new energy requirements, buildings are exposed to various designs and technologies, making it essential to investigate how users perceive quality, comfort, and interact with these technologies for optimal performance. In this regard, Post-occupancy evaluations have become a well-established line of research in the social sciences, especially in the energy-efficient building sector, to measure user satisfaction levels (van der Grijp et al., 2019).

The use value of a built environment is directly impacted by the Architecture, Engineering, Construction and Operations (AECO) sector responsible for creating and managing it. However, the use of buildings and infrastructure also affects the surrounding environment and can lead to environmental pollution, resource depletion, socio-economic development, and even occupants' health and well-being. While the design and construction phases of a building receive significant academic attention, it is the operational phase of building occupancy and use that is the primary contributor to performance metrics. Therefore, it is crucial to review and evaluate building performance in-use to ensure the optimal use value of the built environment (Roberts et al., 2019).

A common approach to evaluating a building's operations and performance is through a post-occupancy evaluation (POE). This method assesses whether decisions made by design, construction and facilities management professionals have met the requirements of both end-users and the development's commissioners. The insights gathered from POE have important implications for soft landings, as they enable future decisions about building designs to be informed by lessons learnt from operational performance and user satisfaction. POE takes into account a variety of performance metrics such as building use, energy consumption, maintenance costs and user satisfaction. To measure a building's operational performance, POE relies on feedback from project teams during commissioning and construction phases, end-users on finishes and functional performance, technical performance data from a building's systems, and a strategic overview that incorporates data from all evaluation stages (Roberts et al., 2019).

To assess a building's operations and performance, the POE process is employed to evaluate whether design, construction, and FM decisions meet end-users' needs and the development's commissioners' expectations. The POE process involves two primary lines of investigation, namely technical performance and functional performance. Technical performance examines the building's background environment, including thermal comfort, acoustics, indoor air quality, fire safety, and visual comfort. On the other hand, functional performance considers whether a building is suitable for user activities, including space management, finishes, proximity to other facilities, and human factors. In this thesis the focus is on how users felt and experienced regarding technical and functional performance. Post-occupancy evaluation (POE) is widely believed to have numerous benefits, including the transfer of knowledge gained from operations to inform future building designs, iterative improvement of an existing facility's performance, and the ability to compare building performance between facilities (Roberts et al., 2019).

A study based on evaluations of nearly-zero energy home demonstration projects in Germany, Austria, and Switzerland found that energy efficiency was not a significant factor in residents' decision to move in. Instead, factors like neighborhood, economic benefits, and property ownership were the most commonly cited reasons. However, the study showed that nearly-zero energy homes were generally well-received by their residents, with comfort being an important aspect of satisfaction. Despite this positive reception, the study also revealed technical issues with heating and ventilation systems in several demonstration projects and larger-scale projects. Users were dissatisfied when they lacked sufficient control over building services or were unable to vary temperatures between different rooms (Mlecnik et al., 2012). Similar research in Australia found that residents complained about substandard work, inferior products, and technology that was not user-friendly or reliable. Policy action was deemed necessary to address these issues, and there was a call for the building and installation industry to improve learning and skill development (Fowler et al., 2010).

A research on post occupancy evaluation in residential nearly zero emission buildings in the Netherlands shows that valuable lessons can be learned from the cases studied regarding engaging end-users and social learning potential. To improve the success of innovative building projects, pro-active communication and education deserve a higher priority. It could be beneficial to involve aspiring residents in the visioning, design, and building process and keep them involved throughout. Access to independent advice and control of building quality and technical installations, perhaps in the form of quality assurance systems, would also be appreciated by end-users. The study suggests that associations of house owners could perform an intermediary role to streamline the process. The study also found that strong leadership and commitment of an influential partner can serve as a catalyst for the successful development of nearly zero emission building projects. However, involving end-users in a less top-down manner could enhance their sense of ownership and commitment and hence their motivation to change energy-related behaviour (van der Grijp et al., 2019).

In this thesis, the primary focus is on ddressing the knowl- edge gap by identifying critical factors and activities in the early phases of building projects that lead to use value in the backend of projects. By examining these activities, the research aims to provide insights into how decisions made during the early stages can impact the overall user experience and value derived from the building. This comprehensive investigation will contribute to the body of knowledge in the field and support informed decision-making in future building projects.

1.1 Importance and relevance of case studies

The use of case studies is fundamental to understand the complexities of building performance and user experience. The case studies of the ZEB laboratory at NTNU and the Energy Academy Europe building in Groningen have been selected for this study based on their focus on sustainable design and energy efficiency.

Both the University of Groningen and NTNU have demonstrated a commitment to building sustainable buildings in recent years, making this study particularly relevant for their future projects. Both universities have recognized the importance of sustainable design and the role it can play in reducing energy consumption and carbon emissions. This shared commitment to sustainability makes the case studies of the ZEB laboratory at NTNU and the Energy Academy Europe building in Groningen even more relevant to the study, as they offer examples of sustainable building design that align with the universities' goals. Additionally, both Groningen and Trondheim, the cities where these universities are located, have large student populations, which creates a unique opportunity for the implementation of sustainable design in student housing and other campus buildings. By understanding the relationship between early phase activities and use value in the occupation phase, universities can make informed decisions about the design and development of their campus buildings, ensuring that they are sustainable and meet the needs of their occupants.

Moreover, the sustainability image of the ZEB laboratory and the Energy Academy Europe building is another commonality between the two case studies. Both buildings have achieved high levels of sustainability through their innovative design, use of renewable energy sources, and focus on reducing carbon emissions. This emphasis on sustainability is not only important for reducing the environmental impact of buildings, but also for creating healthy and comfortable indoor environments for building occupants.

The ZEB Laboratory is a building that has achieved a zero carbon emissions status. This means that the building's energy consumption has been optimized to reduce its carbon footprint to zero which is achieved by using energy-efficient systems and technologies. As a result, the ZEB Laboratory serves as a model for sustainable construction and design practices, and it is a valuable case study for exploring the potential of zero-emissions buildings. On the other hand, the Energy Academy Europe is a five-star building that has been awarded the prestigious BREEAM certification. This certification is an international standard for the assessment of building sustainability, and a five-star rating indicates that the building has achieved outstanding environmental and social performance. The Energy Academy Europe is a prime example of a sustainable building that demonstrates how the use of innovative design, technology, and materials can reduce energy consumption, minimize environmental impact, and create a healthy and productive working environment.

Despite sharing a similar focus, the two case studies present notable differences. The ZEB laboratory is a research facility and living laboratory that explores and tests new sustainable solutions in building design in full scale, whereas the Energy Academy Europe is a multi-purpose education center that aims to promote sustainable development through training and research. Moreover, the ZEB laboratory was designed to meet a specific set of requirements, such as energy efficiency, low carbon emissions, and adaptability, while the Energy Academy Europe aims to showcase different sustainable solutions in construction and building management. These differences in function, purpose, and design provide a rich context for exploring the relationship between early phase activities and use value in the occupation phase.

Furthermore, the front-end process of the two case studies also differs. The ZEB laboratory was designed and built using an Collaborative project delivery model, which emphasizes collaboration, innovation, and sustainability. In contrast, the Energy Academy Europe building was developed using a more traditional project management approach, which does not necessarily prioritize collaboration to the same extent as collaborative models. This difference in front-end approach offers a unique opportunity to compare and contrast the impact of different project management approaches on building performance and user experience.

In summary, the case studies of the ZEB laboratory and the Energy Academy Europe building are highly relevant to this study as they provide an opportunity to explore the impact of sustainable design on building performance and user experience. The differences in project management model, function, purpose, and design of the two buildings offer a rich context for examining the relationship between early phase activities and use value in the occupation phase.

1.2 Research questions and objectives

This subsection outlines the research questions and objectives that will guide the investigation throughout this journey. The strategic goal of this research is to advance the construction industry by enhancing project outcomes, contributing to their use value, and aligning use value and building performance with initial project ambitions. By achieving this goal, the research will contribute to informed decision-making, optimal resource allocation, and the successful realization of building projects that meet user needs, enhance stakeholder satisfaction, and deliver long-term value.

The purpose of this research is threefold. Firstly, it aims to address the knowledge gap by identifying critical factors and activities in the early phases of building projects that lead to use value in the backend of projects. This will inform the construction industry in incorporating and prioritizing these factors for enhanced project outcomes. Secondly, the research includes a post-occupancy evaluation specifically focused on the ZEB Laboratory building, aiming to assess user satisfaction and experience after two years of occupancy. Initially, the aim was to conduct this evaluation on both case studies (ZEB Laboratory and Energy Academy Europe). However, due to limitations, it was only possible to conduct the evaluation on the ZEB Laboratory building.

By conducting the post-occupancy evaluation, the research seeks to gather valuable insights into user satisfaction and experiences with the ZEB Laboratory, providing valuable feedback for potential enhacements and lessons for future building projects. Lastly, the study aims to delve into the lessons learned from a series of case studies, employing a storytelling approach to capture the experiences and insights shared by informants involved in these projects. By exploring these narratives, the research aims to extract valuable lessons and recommendations that can guide future building projects and contribute to the industry's body of knowledge. The combined findings will ultimately bridge the gap between project ambition and actual building performance, contributing to use value and project success.

Objectives:

- To identify the key activities/facors in early phase of projects that contribute to the value for user and building performance during the occupancy phase.
- To conduct a comprehensive post occupancy evaluation of the ZEB Laboratory, assessing user satisfaction with various aspects of the building's performance
- To draw lessons and recommendations from the case studies for improving early phase activities and enhancing outcomes in the occupancy phase of building projects.
- To contribute to the existing knowledge and understanding of the connection between early phase activities and the results in the occupancy and use phase of buildings, aiming to bridge the gap between project ambition and actual building performance.

Research Questions:

- What are the key activities in early phases that contribute to the successful realization of building projects, specifically in terms of value for users and building performance in the occupancy phase?
- To what extent do the results of the post-occupancy evaluation of the ZEB Laboratory indicate user satisfaction with the building's performance and overall use value in ZEB laboratory?
- What lessons can be learned from the case studies, focusing on the experiences and insights shared by the informants involved in these projects?

These questions and objectives establish the framework, and provide a clear direction for the research.

1.3 Scope and limitations of the study

The research topic of this thesis is "From Ambition to Occupancy", focusing on the early stages of building projects, and the occupancy phase, to identify the activities that contribute to the overall use value of the projects. By examining two case studies, namely the Energy Academy Europe in Groningen and the ZEB Laboratory in Trondheim, the research aims to provide valuable insights into enhancing project outcomes and achieving optimal performance and value for users. The topic holds significant relevance to the field of project management as it advances the understanding and implementation of effective practices in the early phases, ultimately bridging the gap between project ambition and the actual use value of buildings.

This study is focused on the user experience of the buildings and is a qualitative study. As such, it does not delve into technical details about the construction or engineering aspects of the ZEB laboratory or the Energy Academy Europe building when it comes to the analysis and discussion parts. Furthermore, this study is limited to the two case studies of the ZEB laboratory at NTNU and the Energy Academy Europe building in Groningen. While these case studies offer valuable insights into the relationship between early phase activities and use value in the occupation phase, the findings may not necessarily be applicable to other buildings or contexts. Moreover, it is important to note that both universities, NTNU and Groningen, have a strong commitment to sustainability and are moving towards building more sustainable buildings. While this study can offer insights and recommendations for future projects, it is not intended to be prescriptive or definitive in terms of best practices for sustainable design and project management.

1.4 Overview on thesis structure

The thesis consists of several sections that provide a comprehensive exploration of the research topic.

The theory section (2) delves into the concept of value, examining its definitions and different perspectives. An integrative framework for divergent values is presented, along with a focus on value in the construction industry. The section also explores value for stakeholders, including users, clients, and suppliers. Value creation, value capture, value slippage, and value blueprint are discussed in detail. Additionally, key activities in the early phases of building projects, value measurement, post occupancy evaluation, and building performance evaluation are examined.

In the methods section (3), an introduction to the research methodology is provided. The data collection methods employed in the study, including two case studies (ZEB Laboratory and Energy Academy Europe), are described. The data analysis procedure is outlined, and the rationale for methodological choices is discussed. Ethical considerations related to the research are also addressed.

Results section (4) presents the findings of the case studies. Case study 1 focuses on the ZEB Laboratory, including project objectives, technical characteristics, collaborative project delivery model, interview findings, post occupancy survey results, and walkthrough findings. Case study 2 examines the Energy Academy Europe, covering its context, location, project objectives, technical characteristics, interview findings, and other relevant details.

The discussion section (5) analyzes the interview findings, identifies key patterns, and explores themes related to early phase activities that contribute to use value. It also presents a value blueprint for the ZEB Laboratory and discusses the results of the post occupancy evaluation. Lessons learned from the case studies are highlighted, with specific insights from both the ZEB Laboratory and Energy Academy Europe.

In the Conclusions section (6), a summary of the findings is provided, addressing each of the research questions. The evaluation of research outcomes is discussed, and the broader implications and contribution of the study are examined. Limitations of the research are acknowledged, and potential avenues for future research are suggested. The section also includes a reflection on the research process.

The appendices include additional supporting materials and information. Appendix A contains the interview questions, while Appendix B presents the interview transcripts. Appendix C includes the post occupancy evaluation survey used for the ZEB Laboratory case study. Appendix D consists of the walkthrough plan, specifically for the ZEB Laboratory. Lastly, Appendix E contains the NSD consent form, ensuring ethical compliance in obtaining participants' consent.

CHAPTER

TWO

THEORY

2.1 Definition of value

Creating value for people, organizations and society, the term value is “widely used but barely understood” (Bos-de Vos, 2020). There exists a multitude of definitions for value that vary across different fields and disciplines.

The discussion about defining value can be traced back to Aristotle. Aristotle formulated the theories of value and emphasized on use as a value creating element. According to Aristotle the use is twofold: for example, a shoe has two uses; its “wear” and its “use in exchange”. In this utility theory of value, there is an objection that even a shoe can have no value in free exchange unless there is a demand for it, and it fulfills a human need. This shows that demand should be considered too (Johnson, 1939).

Value is often associated with monetary value, which represents the economic view of market exchange value. However, value can also be researched from a philosophical point of view which to a great extent complicates the conception of value (Thyssen et al., 2010). Value can be considered as subjective or objective, intrinsic or time and context dependent and etc.

While defining value, Perry argues that value consists of the fulfilment of interest. Interest here means a subject’s liking or disliking, and therefore he showed value is subjective (Perry, 1914). However, there are many arguments against the subjective value, for example; one could argue that goodness and beauty are objective values of which nobody could disapprove. This shows a dependency of human interests in considering what is good. On the other hand, objective viewpoint argues that it should be possible to ascribe the goodness to the object itself (Thyssen et al., 2010).

According to Ben Bradley, Intrinsic value is a kind of value such that when it is possessed by something, it is possessed by it solely in virtue of its intrinsic properties. Intrinsic value is a kind of value such that when had by something, that thing would continue to have it even if it were alone in the universe (Bradley, 2006). To put it simply, extrinsic value is defined as value that is not intrinsic value. Extrinsic value has often been associated with instrumental value which is the value that something has in terms of being a means to an end, such as money (M. J. Zimmerman and Bradley, 2019).

In conclusion, the literature suggests that value can be viewed through two main lenses: 1) value as guiding principles, and 2) value as qualities with worth. These perspectives are interdependent and continuously influence each other. Scholars have referred to these perspectives as 'values as ideals' versus 'values as worth' or the plural form 'values' (i.e. ideals) versus the singular form 'value' (i.e. worth) (Martinsuo, Klakegg, and van Marrewijk, 2019).

2.1.1 Considering values as guiding principles, values

One of the primary perspectives towards value is to consider the values of actors as guiding principles. Scholars in various fields, such as psychology, sociology, anthropology, and philosophy, use the term "value" to refer to the ideals that people hold. According to them, values are the criteria or guiding principles that individuals use to evaluate and choose their behavior, and give significance to what they deem important in life. This perspective suggests that values should be taken into account when designing products or services that align with the ideals and principles of the users (Bos-de Vos, 2020).

Researchers categorized various motivationally unique values that individuals use as guiding principles for their behavior and activities. These values include enjoyment, security, achievement, self-direction, social power, and maturity. They referred to these universal types of values as "human values," which originate from people's individual biological needs, the demands for interaction with others, and the needs of groups to survive and prosper (Schwartz and Bilsky, 1987).

Values that people use as guiding principles may not only stem from their personal needs but can also originate from their social relations. For instance, 'cultural values' are shared values among nations, regions, professions, organizations, and teams, such as autonomy, egalitarianism, and harmony, that shape and justify the beliefs, actions, and goals of individuals and groups, making them part of a certain culture. According to Schwartz, shared values that have the same underlying assumptions are easier to affirm and act upon simultaneously, emphasizing their importance in shaping behavior and decision-making processes (Schwartz and Bilsky, 1987).

2.1.2 Considering values as qualities with worth, value

In contrast to viewing values as guiding principles, some scholars conceptualize value as a quality that has worth and can be realized through design. This perspective is shared by economists, management scholars, and certain design scholars. These scholars view values as qualities inherent in objects, projects, or ideas that represent a certain amount of worth. Worthiness can be monetary or non-monetary, such as use value, social value and ecological value. However, the worthiness is perceived differently by individuals since people value different things. It is also dynamic and influenced by multiple factors, which constantly change through the interaction of diverse actors (Bos-de Vos, 2020).

The concept of 'economic value' refers to the worthiness of a product, service, or idea in monetary terms. Another term, 'economy value', is used by some scholars to describe the economic benefits that a product, service or idea may bring. Scholars in economics and management commonly use the term 'exchange value' to indicate the price that a consumer pays for a set of qualities inherent in a purchased product or service. Although these scholars primarily focus on commercial firms' pursuit of monetary worth through the exchange of goods or services, economic value is also significant at the individual, group and societal levels. For instance, individuals may strive for a good salary (Bowman and Ambrosini, 2000).

Classical economists and strategic management scholars use the term 'use value' to describe a customer's subjective perception of the qualities or usefulness that a company's products or services provide. However, this view is considered too narrow because use value is not just created for customers. Instead, it may also have worth for other entities like organizations, citizens, and society as a whole. It is essential to understand the broad spectrum of values that underlie the concept of use value. The use value of is not limited to mere 'utility value' expressed in values such as functionality, convenience, efficiency, or durability. A design can also lead to benefits that arise from its quality, such as contributing to well-being, having symbolic significance, or evoking emotions (Bowman and Ambrosini, 2000).

Another way that worth can be achieved is through social value. Scholars define social value as the value that society places on a resource and is recognized by most, if not all, people. This value includes benefits like clean air and water that are crucial to human health. In the field of management, Thompson and MacMillan's study (2010) discussed how businesses can contribute to societal wealth improvement by creating social value. They suggested that businesses could open up new markets by addressing issues related to poverty and human suffering (Thompson and MacMillan, 2010).

Lastly, 'ecological value' and the more general term 'environmental value' pertain to the worthiness that is produced for the physical world. Ecological value is usually considered from a comprehensive viewpoint that also encompasses people's social connections. Nonetheless, to prevent misunderstandings, ecological value is defined in this context as the value generated for the planet. Ecological value is frequently motivated by goals of environmental prosperity or the preservation of the planet, and the values that may be relevant include emission reduction, the utilization of existing materials, and sustainability (Bos-de Vos, 2020).

2.2 An integrative framework for divergent values

In this section, a framework which is developed by Marina Bos-de Vos, is introduced. The framework, represented in figure 2.2.1, originally aimed to assist stakeholders in facilitating and participating in processes of designing for divergent values. It encourages conversations and reflections about the values in a project, and provides examples of values that may be relevant to the project. The framework is structured as a matrix, allowing users to focus on specific parts that are relevant to them while being aware of the bigger context they leave out (Bos-de Vos, 2020).

The vertical axis of the framework is divided into two sections: 'value as guiding principles' and 'values as qualities with worth.' The former section distinguishes between guiding principles related to human nature and social interaction. The latter section includes values to be co-created for people and the planet. These two sections are interconnected, as actors' guiding principles continually influence their actions and decisions related to co-creating worth (Bos-de Vos, 2020).

On the horizontal axis, the framework is divided into three degrees of value specificity: overarching value dimensions, underlying motivational goals, and specific value examples. This allows stakeholders to recognize and discuss connections between higher-level value-related issues and the specific design opportunities and constraints of a project. The framework helps students and practitioners to select, develop, and customize the parts that are relevant to them based on concrete examples of values. Although some scholars argue that specification of values may not always be necessary or beneficial, the framework provides a comprehensive basis for understanding which values to discuss in a project (Bos-de Vos, 2020).

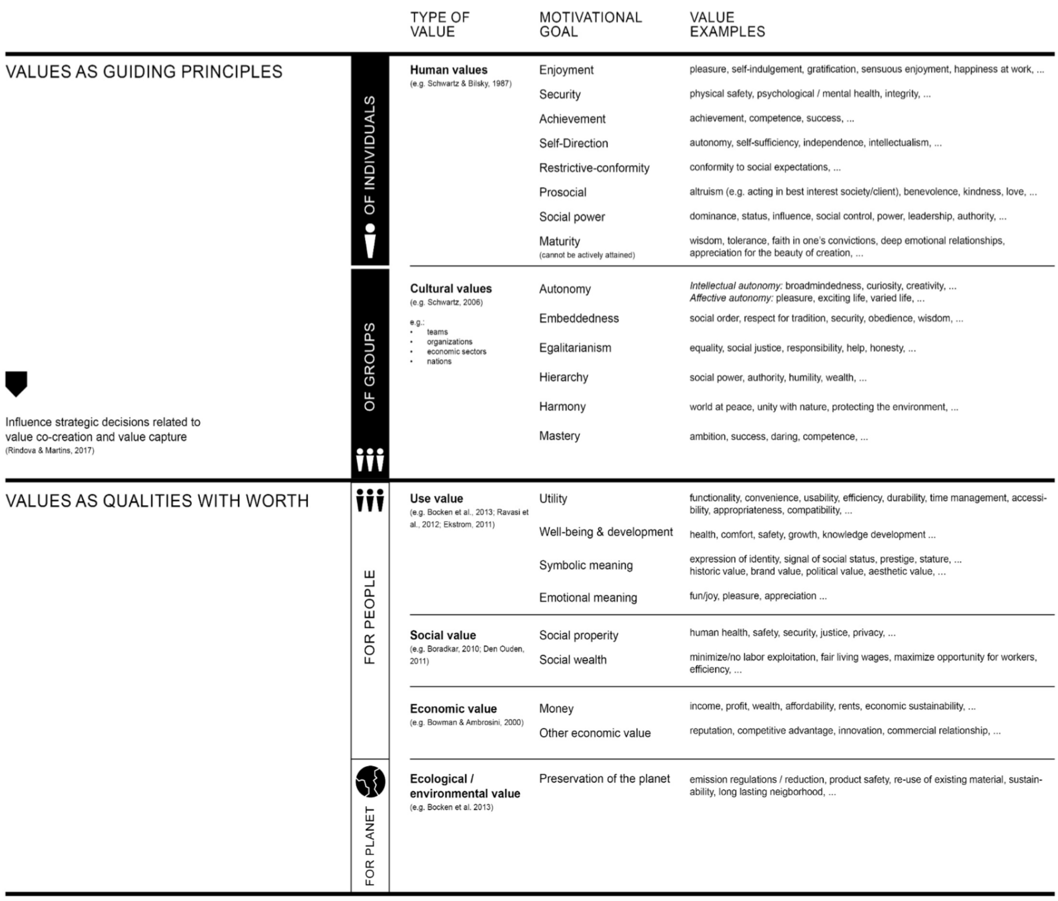


Figure 2.2.1: Framework as a basis for designing for divergent values. (Bos-de Vos, 2020)

2.3 Value in construction industry

One of the first attempts to define value in construction was made by the Roman architect Marcus Vitruvius Pollio. He was of the opinion that all architecture should possess strength, utility and beauty or firmness, commodity and delight. He also mentioned the importance of considering 'the nature of the place' or suitability to surroundings which highlights the range of value concept in construction (Thyssen et al., 2010). However, nowadays, the definitions of value are more mathematical.

A typical economical perspective of value is the willingness to pay for a product or service. However, value in construction projects is more complex (Hjelmbrekke, Klakegg, and Lohne, 2017). As mentioned before, different people perceive value differently due to their interests, and value is a context-based subject which will vary between projects. Traditionally, efficiency in time and cost aspects were of great importance in projects. Whereas efficiency (cost management) seeks 'to do a thing right', Value management seeks 'to do the right thing', i.e. effectiveness.' No matter how efficiently a product or service is provided, it will not be successful unless it is wanted.

Brian R. Norton and William C. McElligott defined value management as a systematic, multi-disciplinary effort directed toward analysing the functions of projects for the purpose of achieving the best value at the lowest overall life cycle project cost. In this definition, the purpose is to increase value and it is not to decrease the cost. As it is shown in the figure 2.3.1, cost is just one element relative to value on a construction project. Two other important aspects are time and function or quality. In order to achieve value, it is necessary to achieve a proper balance between all the important aspects (Norton and McElligott, 1995).

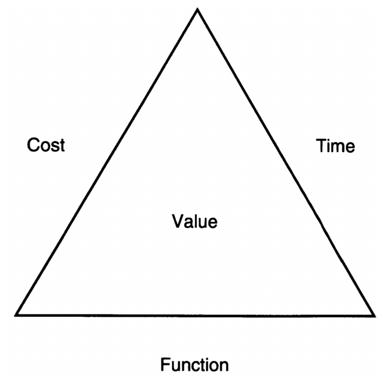


Figure 2.3.1: Elements of value (Norton and McElligott, 1995)

In other studies, value creation in construction projects is divided into external and internal efficiency. Internal efficiency is considered as time, cost and resources used to achieve the given function or quality described in the project. High internal efficiency is when a minimum of resources, time and costs are used to achieve a specific result. External effectiveness is expressed as the project's ability to satisfy the customer's or user's goals, requirements and priorities. Furthermore, internal efficiency (time and cost) can be a component that contributes to external efficiency (function or quality) in the form of better quality or reduced costs for the client (Allen Tadayon, 2022).

While defining value in Oscar project, a list of characteristics was derived from a literature review and sorted in four main groups, economy, social (people and organization), environmental and physical (space and infrastructure), while the unacceptable situation of the last one will affect the others negatively (Anne Kathrine Larssen, n.d.).

Marcos Fuentes and his colleagues also argued that value goes beyond engineering outputs, and it is linked to the functionality and usefulness created by the project particularly for the client in the medium- and long-term. This form of functional value is referred to as value-in-use. This functional perspective of value gives rise to the concept of considering projects as rendering a service (in singular) in the long-term (Fuentes, Smyth, and Davies, 2019).

The British Commission on Architecture and Built Environment (CABE) conducted research to identify and map various value characteristics in building projects. Different types of value for buildings are shown in the figure according to their book (Macmillan, 2006).

Type of value	What does it mean?	How is it measured?
Exchange value	The building as a commodity to be traded, whose commercial value is measured by the price that the market is willing to pay. For the owner, this is the book value, for the developer the return on capital and profitability. Also covers issues such as ease of letting and disposability.	Book value Return on capital Rental Yield
Use value	Contribution of a building to organisational outcomes: productivity, profitability, competitiveness and repeat business, and arises from a working environment that is safe in use, that promotes staff health, well-being and job satisfaction, that encourages flexible working, teamwork and communication, and enhances recruitment and retention while reducing absenteeism.	Measures associated with occupancy, such as satisfaction, motivation, teamwork. Measures of productivity and profitability, such as healthcare recovery rates, retail footfall, educational exam results, occupant satisfaction.
Image value	Contribution of the development to corporate identity, prestige, vision and reputation, demonstrating commitment to design excellence or to innovation, to openness, or as part of a brand image.	Public relations opportunities Brand awareness and prestige The recognition and 'wow' factors.
Social value	Developments that make connections between people, creating or enhancing opportunities for positive social interaction, reinforcing social identity and civic pride, encouraging social inclusion and contributing towards to improved social health, prosperity, morale, goodwill, neighbourly behaviour, safety and security, while reducing vandalism and crime.	Place making Sense of community, civic pride and neighbourly behaviour Reduced crime and vandalism.
Environmental value	The added value arising from a concern for intergenerational equity, the protection of biodiversity and the precautionary principle in relation to consumption of finite resources and climate change. The principles include adaptability and/or flexibility, robustness and low maintenance, and the application of a whole life cost approach. The immediate benefits are to local health and pollution.	Environmental impact Whole-life value Ecological footprint.
Cultural value	Culture makes us what we are. This is a measure of a development's contribution to the rich tapestry of a town or city, how it relates to its location and context, and also to broader patterns of historical development and a sense of place. Cultural value may include consideration of highly intangible issues like symbolism, inspiration and aesthetics.	Critical opinions and reviews Professional press coverage Lay press coverage.

Figure 2.3.2: Types of value (Macmillan, 2006)

According to this research, exchange value is the commercial value of building which can be measured by the price that the market is willing to pay. The use value of a building is related to whether it fits its intended purposes or not. This is achieved by having a safe working environment, promoting well-being and job satisfaction, good air quality, and suitable privacy as well as minimizing maintenance and refurbishment costs. This type of value can be measured by comparing productivity, absenteeism, or occupant satisfaction across comparable buildings in order to identify the best and worst performers. The image value represents the built environment's ability to convey powerful visual messages. This can be seen in he London Eye, Central Park, the Sydney Opera House, and the Eiffel Tower, for example, that symbolize particular cities. Social value is concerned with how places and buildings encourage people to interact in ways which lead to trust, mutual understanding, shared values and supportive behavior. Social value can be measured by indicators which allow comparisons to be made between neighborhoods to identify areas. Surveys before and after a project and social surveys in existing neighborhoods help to identify and compare this type of value (Macmillan, 2006).

Environmental value expresses how well a building's impact on the environment is minimized. Energy efficient, low-maintenance long-life materials, and flexible and adoptive building will add to the environmental value of buildings. The BRE Environmental Assessment Method (BREEAM) and similar tools provide a way of assessing a building's effect on the environment. Cultural value is the legacy created by building for future generations. This is one of the contributions to culture and shows the society we want to create. Cultural value is a matter of a development's contribution to the culture of a town or city, how it relates to its location and contributes to local distinctiveness or becomes part of modern design canon (Macmillan, 2006).

2.4 Value for stakeholders

Different stakeholders define value from their own viewpoints. The long-lasting life cycle of buildings and constant changes in users' needs suggest that the emphasis in defining value should be towards the users and the owners of the buildings. In fact, these stakeholders are the reasons why the building is built. It is believed that the real value of a goods of service can only be defined by the ultimate customer in economics, and the ultimate customers in a construction project are the owner and the users. The owner is considered to be the suppliers' customer and the ultimate customer is the user. In addition, every stakeholder has its own value perception which cannot be neglected (Haddadi et al., 2016).

Haddadi, Temeljotov-Salaj, Foss, and Klakegg emphasized the importance of three main roles whom their needs should be assessed in construction projects; i) the owner, ii) the suppliers iii) the users. Value creation in owner's perspective can be summarized in profitable/optimal operation of the building and fulfilling the customer's needs. The suppliers require minimizing the waste-nonvalue creating activities- and to fulfill the customer's (owner and user) needs. The ultimate goal of the project should then be to fulfill user's needs in order to increase the "customer's perceived value". During the last decades, most successful projects which fulfilled customers' known or unknown needs udes innovative solutions during the project to increase the user's perceived value after the project. These innovations can be in different phases of projects. This shows that not only is it necessary to involve users actively to define the value but also the owner and suppliers' contribution is of great significance (Haddadi et al., 2016). This is summarized in the figure 2.4.1.

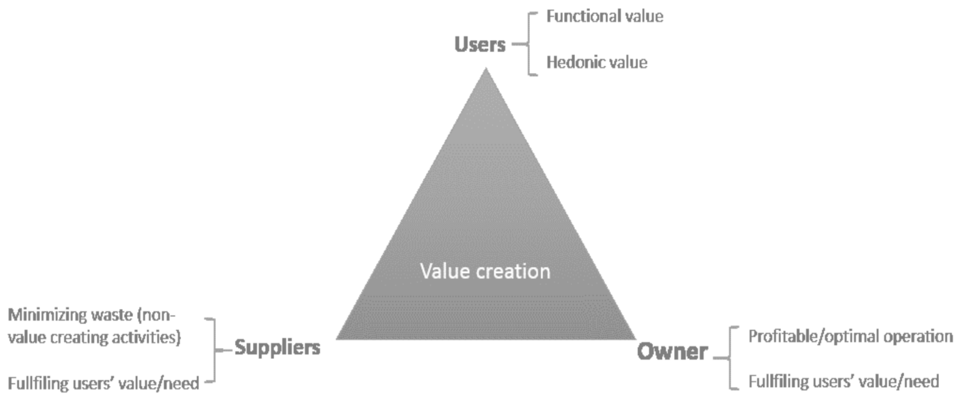


Figure 2.4.1: Construction project's main roles and their needs to be fulfilled for creating value (Haddadi et al., 2016)

2.4.1 Value for users

Holbrook defined consumer value as an interactive relativistic preferential experience in his book of consumer value in marketing. By interactive, he means that consumer value entails an interaction between some subject (a consumer or customer) and some object (a product) (Holbrook et al., 1999).

This is an intermediate position, while on one hand extreme subjectivism holds that value depends entirely on the nature of subjective experience or that "beauty is in the eye of the beholder", and on the other hand extreme objectivism holds that value resides in the object itself as one of its properties and that "beauty" is "a formal property of [the] beautiful". In marketing, extreme subjectivism assumes that a product has value only if it pleases some customer—in other words, that customers and no one else are the final arbiters of consumer value, and extreme objectivism assumes that by virtue of certain resources, skills, or manufacturing efficiencies, producers have managed to put value into their offerings (Holbrook et al., 1999).

Along similar lines, Karl Marx subscribed to a labor theory of value according to which the value of an object depends on the amount of work invested in producing it. However, the intermediate interactionist perspective maintains that value depends on the characteristics of some physical or mental object but cannot occur without the involvement of some subject who appreciates these characteristics (Holbrook et al., 1999).

By relativistic, he means that consumer value is (a) comparative (involving preferences among objects); (b) personal (varying across people); and (c) situational (specific to the context). Furthermore, By relativistic, he means that consumer value is (a) comparative (involving preferences among objects); (b) personal (varying across people); and (c) situational (specific to the context) (Holbrook et al., 1999).

This definition also embodies a preference judgment which is aligned with the so-called "interest theory of value" which includes a wide variety of value-related terms prominent in various disciplines and including (but not limited to) such terminologies as affect (pleasing vs. displeasing), attitude (like vs. dislike), evaluation (good vs. bad), predisposition (favorable vs. unfavorable), opinion (pro vs. con), response tendency (approach vs. avoid), or valence (positive vs. negative) (Holbrook et al., 1999).

Finally, by experience, he means that consumer value resides not in the product purchased, not in the brand chosen, not in the object possessed, but rather in the consumption experience(s) derived therefrom. In this regard, all marketing is "services marketing" which places the role of experience at a central position in the creation of consumer value (Holbrook et al., 1999). As articulated long ago by Abbott (Abbott, 1955):

> "What people really desire are not products but satisfying experiences. Experiences are attained through activities. In order that activities may be carried out, physical objects or the services of human beings are usually needed.People want products because they want the experience-bringing services which they hope the products will render."

Therefore, according to different definitions of value, the end users perceived value is complicated to define due to the fact that it is a situation-specific experience which tends to change under different circumstances during time. So, assessing such value must be an ongoing assessment as users evolve. This shows the important of life cycle assessment in projects. However, according to the findings in Oscar project, the scope of unfortunate technical solutions, detailed design and materials are remarkably large, even within new building which leads to high operating - and maintenance cost, increased replacement rate and negative impact on core business, in terms of disruption and in the worst cases HSE related issues (Anne Kathrine Larssen, n.d.).

According to the research done by Larssen and Bjorberg, a large proportion of the buildings, 31%, is evidenced as inefficient in use from an operational level (poor usability) and any refurbishment is too expensive (Larssen and Bjørberg, 2013). All this will influence project life time and value for users who are stuck with the project and the resulting outcomes.

2.4.2 Value for client

The client group comprises multiple stakeholders with conflicting goals and values. Clients can be experienced/inexperienced, public/private, or short term (developers)/long term (owners), which all represent different perspectives. In addition, clients often comprise end-users, society, law makers, advisors, funding parties and the organization who manages the project for the owner, who have different roles and their involvement may change during the project. In addition, change is one of the inseparable parts of the construction projects as a result of the uncertainties associated with the development process, the temporary multiple organization, task fragmentation, changes in the environment, and resource availability which creates a gap between expectations and reality. This gap can be influenced by a client's ability to cope with it and handle uncertainty. Also, psychological aspects and human emotions add to the uncertainty chain (Anne Kathrine Larssen, n.d.).

Another challenges is that the delivery team which is responsible for understanding and delivering client value is made of different parties with different goals. This is also more challenging since primary stakeholders are not engaged in the early phases sufficiently which results in an outcome of inadequate project definition leading to misunderstanding of client values in design and delivery phase. This results in not fulfilling client expectations or multiple project alternations during the project process which leads to additional cost, delay and frustration among the stakeholders (Thyssen et al., 2010).

Hjelmbrekke and his colleagues concluded that many projects easily end up as a motherless child and fail due to three reasons: (a) client does not manage to translate her strategy into tangible project requirements, (b) a project team is torn between different loyalties and (c) user requirements rarely comes to prevail (Hjelmbrekke, Hansen, and Lohne, 2015).

Marcos Fuentes and his colleagues also believed that client organizations face the challenge of generating and delivering value outcomes in the medium and long-term for a wide range of stakeholders and value outcomes should be anchored to the client as the main stakeholder. They were in the opinion that while the value outcomes start to appear in the latter stages of a project, they have a link back to the early phases, where value outcomes can be purposely designed for the long-term (Fuentes, Smyth, and Davies, 2019).

From an owner perspective, the aim of planning and executing a project is to produce relevant value, in most cases defined as a strategic value. To enable owners (clients) and executing parties (suppliers) to communicate effectively concerning exactly what value the project is intended to create, the nature of the intended value needs to be clear and well understood by the parties involved. (Hjelmbrekke, Klakegg, and Lohne, 2017). Therefore, it is of great significance to conceptualize the value and establish a mechanism to identify the client values and ensure involvement from different parties in the early stages.

2.4.3 Value for suppliers

Haddadi and his colleagues described value for suppliers as correlated with deliverables or results for having a successful project, for instance minimizing non-value-creating activities to achieve a "perfect" process (Haddadi et al., 2016).

The British Commission on Architecture and Built Environment (CABE) categorized the supplier in design and construction team, for whom the main incentive is to receive profits when delivering value to the customers and enhancing the chance of getting more projects and reputations (Macmillan, 2006).

In addition, depending on the procurement and contract format, the main contractor may have different points of interest. The supplier should perceive both the client and the end users of the building as its customers, and try to meet the end users' needs in order to increase the perceived value (Allen Tadayon, 2022).

2.5 Value creation

The concept of value creation is an important topic in the field of management and organization literature, which is studied at both micro level (individual, group) and macro level (organization theory, strategic management). However, despite its significance, there is a lack of consensus on what value creation exactly means or how it can be achieved (Lepak, Smith, and Taylor, 2007).

First, this is because the field of management is multidisciplinary, which introduces significant variability in the targets or users for whom new value is created and in the sources or creators of value. Scholars from different areas such as strategic management, marketing, or entrepreneurship may prioritize creating value for business owners, stakeholders, or customers. Meanwhile, researchers focusing on human resource management or organizational behavior may emphasize creating value for individual employees, employee groups, or teams. Scholars from sociology or economics may focus on creating value for society or nations. The plurality in both the targets and sources of value creation poses challenges to scholars, such as developing a common definition for the term (Lepak, Smith, and Taylor, 2007).

A second challenge in understanding value creation is that it refers to both the content and process of creating new value. Questions such as what is valuable, who values it, and where value resides highlight the complexity of understanding value creation. Moreover, value creation is often used to refer to the underlying process of creating value, how value is generated, and the role of management in this process. The last source of difficulty in understanding value creation is the confusion between the processes of value creation and value capture/retention. These processes should be viewed as separate because the party that creates value may not necessarily capture or retain it in the long run (Lepak, Smith, and Taylor, 2007).

Normann, in his book "Reframing Business", argues that the most crucial competence of business companies in the 21st century is the ability to organize value creation. He suggests that while production and relationship competencies are still important, they are now subordinate to the overarching competency of organizing value creation. According to Normann, the new strategy paradigm involves a significant conceptual change and a shift in how we view customers. The customer is no longer just a passive recipient of products or services, but an active participant in co-producing and co-designing value creation (Normann, 2001).

According to Normann, one effective way of changing our perspective on companies is to prioritize the customer as the primary stakeholder and think of ourselves as a part of their business. While many may pay lip service to this idea, few truly embrace it. This shift in mindset requires moving away from the traditional view of customers as outputs of our production system and instead seeing them as inputs in their own value-creating process. To achieve this, companies must understand their customers' business and use it as a framework for defining their own business. This involves identifying the customers' major stakes, which are often tied to their relationships with their own customers (Winter and Szczepanek, 2008).

Therefore, a genuine focus on the customer requires going beyond the direct relationship between the company and its customers to understand the relationship between the customers and their own customers, also known as the "second-level customer relationship" (as shown in Figure 2.5.1). Using Normann's model in figure 2.5.1, we can consider a project or program as the "we" element with two levels of customer relationship - the first-level customer relationship and the second-level customer relationship, as shown in Figure 2.5.2. The first-level relationship focuses on creating the actual product/deliverable, while the second-level relationship focuses on creating value and benefits for the customer (Winter and Szczepanek, 2008).

Some practical implications can be derived from this model: First, being value-centric rather than product-centric, implies a more strategic approach to the front-end definition and phases of projects and programmes. Moreover, Normann's value creation logic presents the need for a more holistic view of projects, one that includes both relationships and disciplines. Traditionally, projects have been categorized based on specific disciplines like engineering, construction, IT, or human resources. However, the image in Figure 2.5.2 suggests that projects and programmes should be approached in a multidisciplinary manner (Winter and Szczepanek, 2008).

Finally, the model depicted in Figure 2.5.2 represents an image of projects, including various perspectives, such as value creation, change processes, and temporary organizations, whereas some authors argue that projects are temporary production systems. Using multiple images can offer a greater understanding of projects, for they are multifaceted, and multiple images can reveal insights that might not otherwise be apparent (Winter and Szczepanek, 2008).

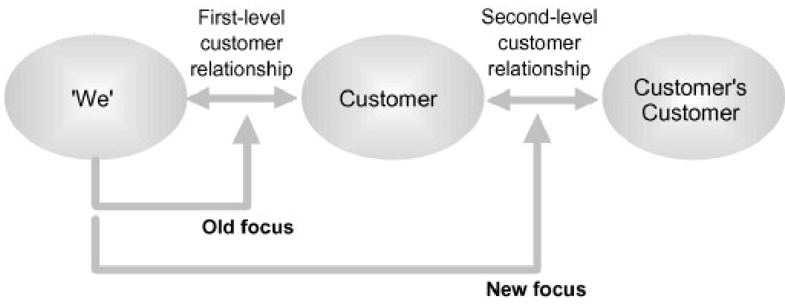


Figure 2.5.1: second-level customer relationship (Winter and Szczepanek, 2008)

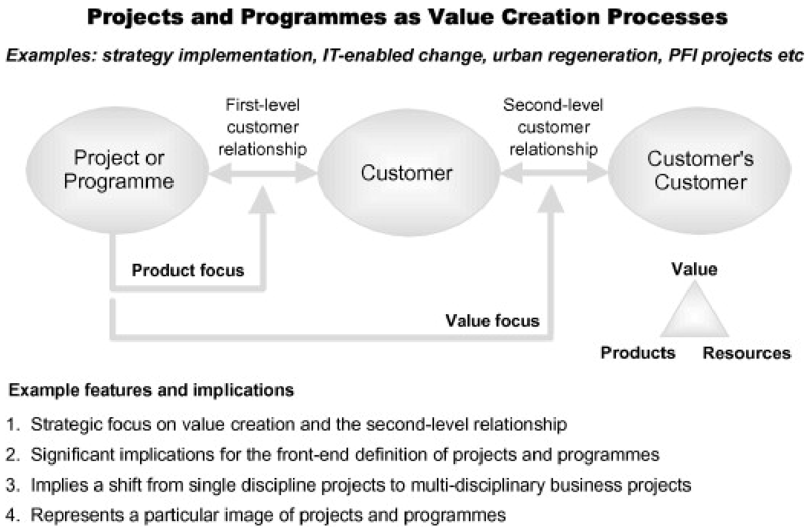


Figure 2.5.2: Projects and programmes as value creation processes (Winter and Szczepanek, 2008)

According to Lepak et al, there are different ways to approach the process of value creation which requires defining the source and targets of value creation and the level of analysis. At the organizational level, value creation is impacted by innovation and invention activities, where firms invent new ways of doing things through new technologies, methods, or raw materials. In addition, innovative organizations introduce new products or services or adopt new management practices. Social connections within organizations provide access to greater information and knowledge, which can be combined and exchanged to create new organizational knowledge, and social networks focused on identifying the needs of customers and product/service users may have greater potential for generating novel and appropriate innovations (Lepak, Smith, and Taylor, 2007).

Furthermore, strategic human resource management practices have been found to enhance employee skills and motivation towards organizational value creation. The value creation process at the organizational level involves any activity that offers novel and appropriate benefits to target users or customers that are willing to pay for them, and it involves enhancing the consumer's valuation on the benefits of consumption through innovation (Lepak, Smith, and Taylor, 2007).

Research results revealed that having a strong owner governance is of great necessity to bring value and goals throughout the execution process until delivery (Anne Kathrine Larssen, n.d.). Ole Jonny Klakegg suggested better practices in three areas: project governance, front-end planning and project execution to secure value creation in projects. He was of the opinion that keys to improvements can be done by implementing a clear governance framework; consistently using evaluation criteria that explicitly focus relevance and sustainability; organizing projects with a role responsible for both investment and operations; and keeping focus on use value in project execution(Klakegg, 2015).

According to Larsen and her colleagues, there is a coherence between how buildings are designed, how they are operated, and maintained and what values they create for using, managing and owning the space, so it is essential should be based on extended knowledge of core business activities, physical environment as well as taking consideration for future changes (technical or social) as well as the whole life cycle (LC) of the building and thereof life cycle cost (LCC) (Anne Kathrine Larssen, n.d.).

In Oscar project, some characteristics of value creation are indicated. They have found out that owners should define clear goals (values) that can be operationalized into (measurable) indicators that show whether owners and users reach and meet their goals in governance level. Also, a distinct implementation strategy must be in place and should consist of a tender-, construction- and contract model. The implementation strategy affects responsibility, risk allocation, organization, information flow, and forms the framework for interaction between project participants. Incentives can be used as a means to improve effectiveness and productivity based on measurable criteria that motivate all actors towards common goals and to prevent suboptimization (Anne Kathrine Larssen, n.d.).

Structured decision-making in the early phases is crucial since decision making in the early phase of a project is most effective for long-term value creation for the owner and user. In this phase it is also crucial to have the widest possible range of expertise in various subjects combined with good project management. Experience of users and owners from previous completed projects are also helpful in early stages. Furthermore, involving facility management (FM) in the early phases increases the potential for improvement regarding achieving value for both users and owners in the use phase (Anne Kathrine Larssen, n.d.).

Several frameworks have been proposed to increase the value for builders in construction projects. These frameworks are strongly related to value management approaches and have been developed to increase the understanding of how client values are implemented and assessed in the design process of construction projects (Allen Tadayon, 2022).

Value management term is used to describe a management process where the focus is on creating and capitalizing on the opportunity to improve value. The ultimate aim of VM is to deliver the best value or ensure value for money from a project. The Achieving Excellence Procurement Guide states that(Perera, Hayles, and Kerlin, 2011):

> "It (VM) enables stakeholders to define and achieve their needs through facilitated workshops that encourage participation, team working and end-user buy in. The focus of VM is on function and value for money, not reducing cost."

SMART value management is one of the methods which was suggested by Green. This approach has its roots in decision analysis, it is primarily concerned with decision structuring rather than decision making. SMART value management consists of simple decision-modelling techniques to facilitate dialogue and negotiation among the various project stakeholders. SMART value management is applied by means of a series of two one-day workshops during the concept and outline proposal stages of a project (figure 2.5.3) (Green, 1994).

The timing of the workshops is dictated by the existence of two strategic decision milestones in the design process where significant client input is required. They are invariably linked to the financial approval procedures of the client body. The first workshop (known as VM1) is held when a construction project is first proposed as a solution to a problem. The goals are to verify the need for the project and to promote agreement on what the design objectives should be. The second workshop (VM2), is held at the point where the client must choose between a range of outline design solutions presented by the design team. The purpose of the workshop is to ensure that this choice is made in a rational manner and that the chosen solution meets the defined objectives (Green, 1994).

SMART value management is consistent with the current trend towards client participation in building design. It enables client interest groups to gain a better understanding of their own requirements and to communicate them effectively to the design team. The workshop structure also helps team building and communication among the project team. It brings any conflicts and inconsistencies out into the open and it encourages their resolution. This approach has been used on more than 200 UK construction projects (Green, 1994).

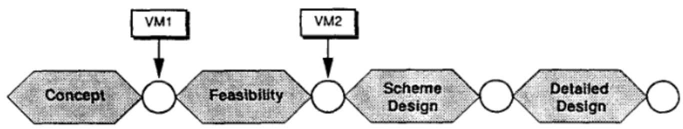


Figure 2.5.3: Timing of SMART value management workshops (Green, 1994)

Hjelmbrekke and his colleagues focused on how business models and project management of the design can increase value creation in construction projects. They believed that governance is essential in order to secure value creation in projects. Governance is fundamentally about monitoring, incentive, leadership selection and control systems. They considered governance as functions for developing strategies, overseeing needs and objectives, making decisions concerning projects and following up on performance across the organization. In other words, governance includes relations and structures which make it possible to establish goals and choose instruments(projects) for achieving the goals. Thus, projects are justified based on an organization's business strategy (Hjelmbrekke, Klakegg, and Lohne, 2017).

Based on the owners' conception of the users' needs and the strategic business outcomes, project governance should secure alignment between the project goals stemming from corporate governance on one hand and the suppliers' goals on the other hand. Business models and corresponding value proposals are the tools to achieve this. Therefore, the basic elements of value creation in projects, from the owners' perspective is shown in the figure2.5.4. They have also developed a governance framework (figure 2.5.5) to support their research. This framework focuses on the front-end phase where the most critical problems are found and the basis for success is developed (Hjelmbrekke, Klakegg, and Lohne, 2017).

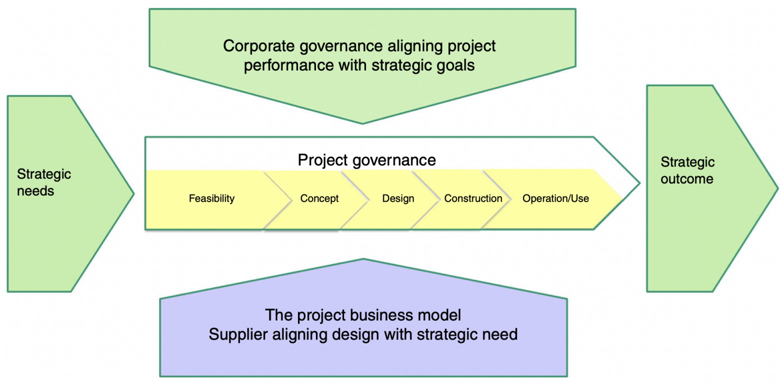


Figure 2.5.4: The basic elements of value creation in projects, seen from the owners' perspective (Hjelmbrekke, Klakegg, and Lohne, 2017)

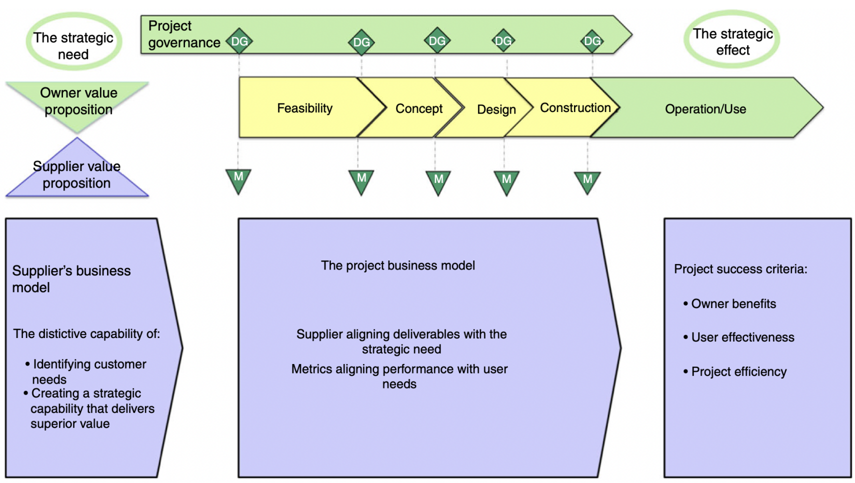


Figure 2.5.5: The generic governance framework model (Hjelmbrekke, Klakegg, and Lohne, 2017)

Savolainen, Saari, Männistö, and Kähkonen believed that believed that design management plays a significant role in value creation in a construction project. They were of the opinion that the clients can forecast quality performance by evaluating the management procedures already during the project instead of waiting until the end of project. The indicator system also provides societal impact as it guides the clients to use the kind of managerial practices that improve the ability to create value in projects that are difficult to evaluate in money terms. To prove this, they used user satisfaction as a quality indicator, and they sought explanation for satisfaction level by qualitative analysis (Savolainen et al., 2018).

In addition, they argued that the collaborative ways of working have been considered promising in improving productivity and quality in the construction industry. Collaboration in temporary project organizations is described as an activity of multi-disciplinary groups and teams that are held together by legal contracts and the desire of participants to achieve a shared objective. However, collaborative design is considered as an upper-level term that includes the sub-concepts of participatory design (PD), integrated design (ID) and concurrent engineering (CE) (Savolainen et al., 2018).

In PD, the users' role as influential member of a designing team is embraced. In ID, the integration between designing disciplines and utilization of BIM as common designing tool are emphasized, and in CE, the collaboration between designers and contractors is embraced. Each sub-concept has a dedicated stakeholder group whose prime objective the collaboration serves. For instance; PD is dedicated to enhancing the ability to maximise value-in-use, ID is dedicated to enhancing designers' ability to coordinate design work and to produce as accurate information as possible, and the role of CE is to find a cost-efficient design solution through collaboration between designers and builders (Savolainen et al., 2018).

Throughout this process, there are some indicators that can bring mutual benefits to stakeholders; communication within each stakeholder group; communication between stakeholder groups; interactions concerning user value creation; and interactions concerning alternative solutions analysis. The problem with traditional collaboration is the fact that the customer (user) often has a responsive role instead of an equal one, and hence, only the construction professionals act as active participators (Savolainen et al., 2018).

Considering a project consisting of four main stages; concept development, technical design, implementation and using and testing, in concept development phase the purpose of the PD is to act as a communication platform to enhance users' articulation and contextual understanding about what is appropriate for the work and for the organization's activities and, thus, bring up and elaborate ideas outside the set of traditional solutions. PD is closely related to the concept of co-creation, which means that the producer and customer are co-creating value-adding solutions by utilizing the customer's know-how. To do that, there must be dialogue between these two and mutual accesses to sufficient data and mutually conducted risk assessment, and the relationship must be conducted in a transparent manner (Savolainen et al., 2018).

When entering the technical design phase, the focus shifts form the conceptualization of customer needs towards the technical solutions. The means of collaboration shifts from PD towards ID as the role of technical discussions within the designers increases. In implementation phase, the value perspective is an essential part of CE as it seeks to cut costs by eliminating non-value-adding activities, reducing production times and improving quality. After project hand over, post-occupation evaluation of designing is a good way to support decision-making and continuous improvement in user value creation and alternative solutions analysis are essential parts of a working customer relationship also after the project is handed over (Savolainen et al., 2018).

2.6 Value Capture

Value capture refers to the process through which companies retain a portion of the value they generate. It is also known as value appropriation (Amit, Zott, et al., 2010). In an organizational context, Pitelis defines value as "the perceived worthiness of a subject matter to a socio-economic agent that is exposed to and/or can make use of the subject matter in question (Bailey, Pitelis, and Tomlinson, 2018)." So far, most of the research on organizational value capture has been conducted in the field of strategic management, focusing on profit generation by goods-producing or entrepreneurial firms. In these studies, value capture is commonly defined as the difference between a firm's revenues and costs, conceptualized as the exchange of the utility of a good or service for money at a certain moment in time. This is often referred to as the exchange of 'use value' (i.e., the customer's subjective perception of the qualities or utility of a product or service) for 'exchange value' (i.e., the price paid to the firm) (Bos-de Vos, 2018).

While the value created by the firm consists of a certain quality and utility, the value captured by the firm is monetary. In the field of project management, value capture has only recently gained attention as an important phenomenon to study. Scholars have explicitly called for more research on value capture in a project context, as the process is distinct from the process of value creation and may provide new insights into the understanding of value-based processes in projects and how project-based firms operate. Value capture studies are also relevant because project-based firms often encounter difficulties when attempting to capture value in their projects (Bos-de Vos, 2018).

According to scholars in service-dominant logic and service logic, value is considered to be created only when a firm's products or services are perceived as valuable by the client, user, or other stakeholders. In this perspective, value is always co-created or co-destructed through interactions among multiple heterogeneous actors (Grönroos and Ravald, 2011). Therefore, in project-based environments, value capture becomes a complex and dynamic social process involving multiple stakeholders with different and sometimes conflicting goals (Bos-de Vos, 2018).

In project-based settings, value capture revolves around intangible values that continue to evolve throughout the project lifecycle. At the beginning of a project, the value that can be captured is often highly uncertain and unpredictable. Certain aspects of project delivery may only become valuable over time or even after project completion. This creates challenges in achieving a "healthy" balance between use value and exchange value from the perspective of various actors, especially since they pursue different goals in the project and have different perceptions of worth (Bos-de Vos, 2018).

2.7 Value slippage

Due to the complexity and dynamics involved in the process, value can easily slip from one actor to another. Lepak et al. (2007) introduced the concept of "value slippage" to explain why actors are not always able to capture the monetary equivalent of the value they co-create. Value slippage occurs when the use value created is high, but the exchange value is low. In such situations, clients or other stakeholders may benefit from the utility of a product or service without providing adequate payment (Lepak, Smith, and Taylor, 2007). In line with Lepak et al. (2007), other scholars described value slippage as "a phenomenon that occurs when value is created but not captured (by the firm)." Value slippage can be detrimental to a firm that co-created value in a project, as the firm bears the costs of value generation without being able to benefit from it financially. Hence, appropriate management of value capture is necessary to prevent "value slippage" (Bos-de Vos, 2018).

According to Marina Bod de Vos and her colluegues, project-based firms often face the challenge of balancing different values when pursuing value capture in their interactions with clients. This is because the goals of value creation and value capture can sometimes diverge at various levels within the organization. Within the firm itself, projects serve not only as a means to generate financial revenues but also as a way to achieve other strategic objectives, which may sometimes compete with one another. It is crucial for firms to consider non-monetary dimensions of value in order to ensure long-term organizational sustainability. These dimensions include project quality, client satisfaction, learning and knowledge development, knowledge sharing, societal influence, and enjoyment. To navigate these trade-offs and reconcile different values, project-based firms must develop value capture strategies that effectively address and integrate various value dimensions within and across their projects (Bos-de Vos, 2018).

The process of capturing value in project-based settings is complex and dynamic, often resulting in value slipping from one actor to another. This phenomenon, referred to as "value slippage", occurs when actors are unable to fully capture the monetary equivalent of the value they co-create. Value slippage arises when the use value created is high, but the exchange value remains low (Bos-de Vos, 2018).

According to the Lepak, the concept of "value slippage" refers to the situation where value created by one source or level of analysis may be captured at another level. For instance, an individual who develops a new method to perform a task in the workplace may create value, but the organization or even society may benefit more from it. Similarly, organizations that introduce new products or processes may not fully capture the value, as it may spill over into society as a whole. Combining discussions of value creation and capture has also contributed to disagreements and confusion among scholars regarding the concept of value creation (Lepak, Smith, and Taylor, 2007). In such situations, clients or other stakeholders may benefit from the utility and quality of a product or service without providing adequate payment (Bos-de Vos, 2018).

The strategic management literature has shed light on how certain strategies enable firms to capture monetary value from their products and services while safeguarding against value slippage. Scholars distinguished four types of value capture strategies that firms may employ (Bos-de Vos, 2018):

- Field-level strategies aimed at establishing and maintaining barriers to entry for new firms (e.g., absolute cost advantages, economies of scale, product differentiation strategies),
- Firm-level "generic strategies" aimed at reducing competitive forces (e.g., cost leadership, differentiation, niche strategies),
- Inter-firm-level strategies focused on generating efficiency or market power (e.g., integration, cooperation, diversification strategies), and
- Firm-wide differentiation strategies aimed at creating a competitive advantage by leveraging the firm's resources, capabilities, and business model strategies.

While empirical evidence has demonstrated that firm-wide differentiation strategies can indeed be instrumental in value capture, it has also been recognized that they can involve value slippage (Zott and Amit, 2010). For example, Somaya and Mawdsley (2015) argue that entrepreneurial, skilled, or creative individuals enhance a firm's ability to capture financial value but may also exploit their unique position to appropriate parts of the value captured, resulting in value slippage for the firm (Mawdsley and Somaya, 2015).

A recent study on value capture by highly professionalized firms operating in projects highlighted that the value capture strategies employed by these firms often involve trade-offs between different dimensions of value . In their study, the interaction between use value and exchange value is complemented by the concept of "professional value." Professional value refers to the perceived qualities or utility of a firm's products or services that are important for achieving the firm's professional goals, such as building and maintaining a reputation, further developing the organization, or realizing work satisfaction. The study emphasizes that projects are not only the primary means through which project-based firms generate financial revenues, but also serve to accomplish other strategic objectives. Therefore, it is important for firms to develop value capture strategies that can strike a balance between the different values they aim to capture in a project (Bos-de Vos, 2018).

Marina Bod de Vos and her colleagues conducted a research with the aim of examining how project-based firms employ strategies to capture multiple dimensions of value in projects. Figure 2.7.1 provides an overview of their findings and how value capture strategies employed by architectural firms largely center around addressing value slippage in their study. One such strategy is the postponement of financial revenues in a project, where firms aim to benefit financially and professionally by accepting the risk of financial value slippage throughout the project's lifecycle. They compensate for the loss of financial revenues across projects by ensuring that they profit from another project. Additionally, the strategy of rejecting a project demonstrates how project-based firms may choose to decline or disengage from certain projects to avoid a potential decline in professional value (Bos-de Vos, 2018).

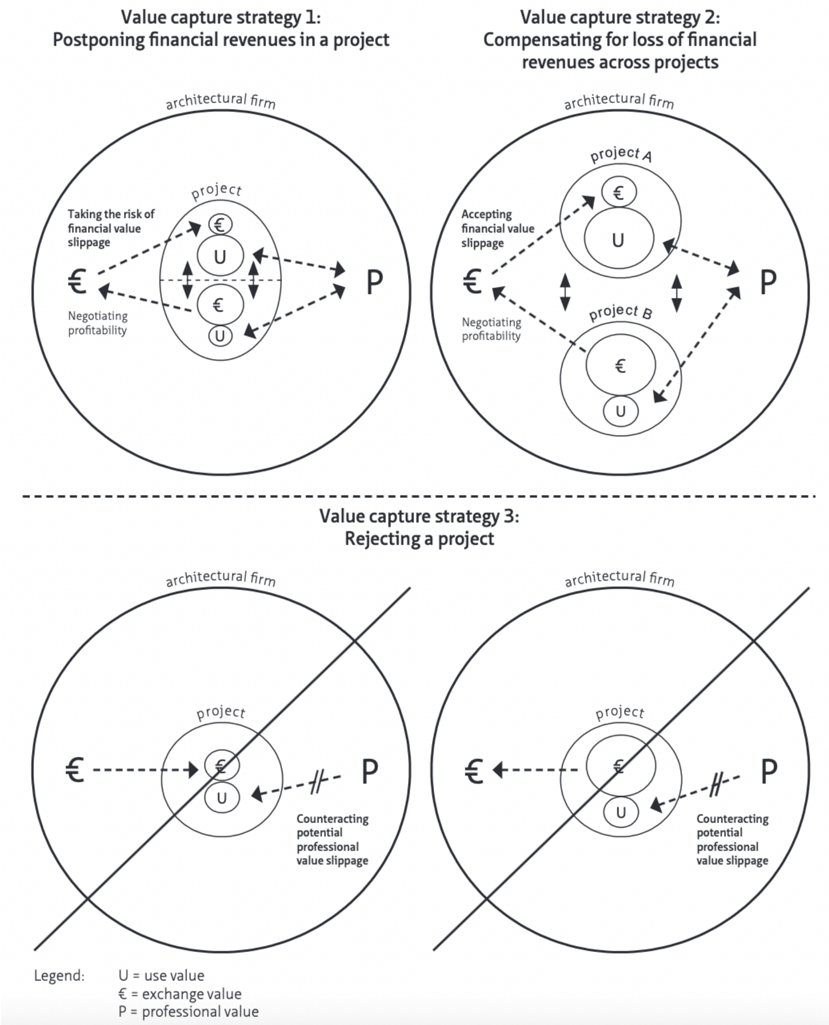


Figure 2.7.1: Overview of value capture strategies (Bos-de Vos, 2018)

2.8 Value blueprint

The Project Value Modelling Blueprint, developed by Marina Bos de Vos, is a tool that helps determining the value of a project. The process involves answering a set of questions that guide stakeholders through the different aspects of the project. This model is shown in a octagon in which each side will be filled with specific information (figure 2.8.1) (Vos, n.d.).

- Step 1 - Value for others: The first step is to consider the value that the project will bring to others. This includes identifying the quality or utility that the project will offer the client, users, society, and other stakeholders. It is essential to differentiate your offering from that of your competitors to ensure that your project stands out in the market.

- Step 2 - Value for yourself: In this step, you need to identify what you would like to gain financially and professionally from the project. Financial values include revenue, profits, and return on investment, while professional values encompass aspects such as status, reputation, skill development, and work pleasure.

- Step 3 - Professional expertise: Identifying your professional expertise and other crucial resources is crucial to realizing the aspired use values. You need to assess your skills, knowledge, experience, and other resources that will help you deliver the project successfully.

- Step 4 - Risks: Identifying and managing risks is crucial in any project. This step requires you to consider the financial and professional risks you are willing to take and those you want to avoid. You also need to identify risks that could affect the value you bring to others and the project's overall success.

- Step 5 - Partners: In this step, you need to identify the partners or types of partners you need to realize the aspired use and financial/professional values. Partnerships may include suppliers, vendors, contractors, investors, and other stakeholders.

- Step 6 - Activities: Identifying the activities required to realize the project's aspired values is essential. This step requires you to assess the activities that you need to undertake to deliver value to others and achieve your financial and professional goals. You also need to identify activities that you have no interest in and can delegate to others.

- Step 7 - Collaboration agreements: Collaboration agreements with partners are critical to the project's success. In this step, you need to identify the formal or informal agreements that enable you to realize the aspired use and financial/professional values. You also need to ensure that all stakeholders have the same goals and understand their roles in the project.

- Step 8 - Revenue model: A revenue model is crucial to link the project's benefits to an appropriate revenue stream for you, the client, and your partners. In this step, you need to identify the project's principal costs, how and when you can cover them, and when the client can pay you. You also need to identify how you can earn from your expertise, how you will recoup your investment, and how the project can generate income. Additionally, you need to identify financial agreements that will enable you to cover your costs and safeguard your earnings while persuading other stakeholders to adopt the right revenue model.

By following these steps, a comprehensive plan can be created that takes into account the value stakeholders bring to others, their financial and professional goals, the necessary resources and expertise, risks, partnerships, activities, collaboration agreements, and revenue model to ensure the project's overall success.

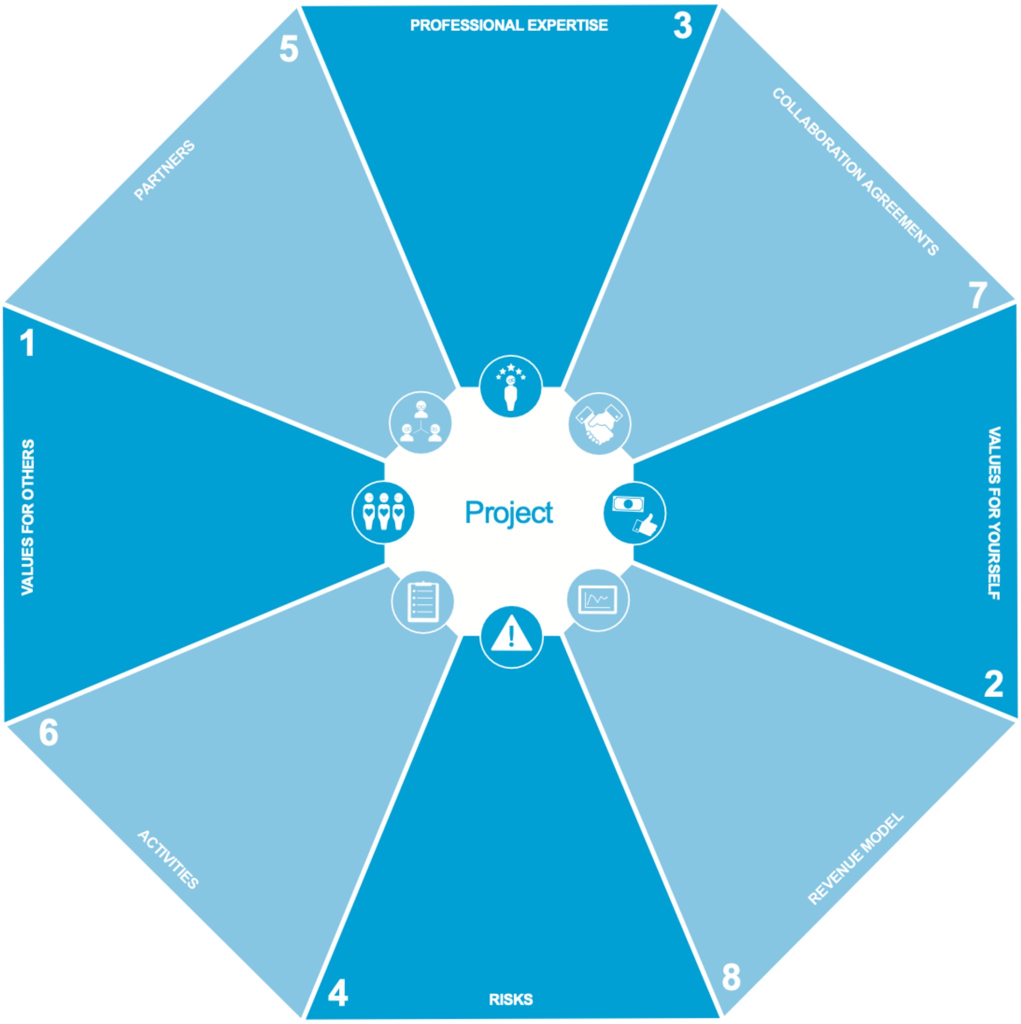


Figure 2.8.1: Project Value Modelling Blueprint (Vos, n.d.)

2.9 Key Activities in the Early Phases of Building Projects

This section aims to explore the key activities in the early phases of building projects that are instrumental in achieving successful outcomes. Specifically, the value they bring to users during the occupancy phase will be examined, based on previous research and the work of prominent scholars. The number of research studies focusing on the identification of key activities in the early phases of projects that generate use value is relatively limited. Despite the importance of this topic, it appears that only a small body of literature has specifically explored this area. In my search among various articles, I have made a concerted effort to find the most relevant studies that address this specific subject matter. By examining these selected articles, we can gain valuable insights into the activities that play a significant role in generating value during the early phases of projects. This highlights the need for further research and exploration in this field to uncover additional key activities and contribute to a more comprehensive understanding of value creation in project development.

In an study condcuted by Bjørn Johs Kolltveit and Kjell Grønhaug, the interests of the Norwegain construction and building industry in the early project phase were examined through a survey involving 26 experts in a case study. The participants were asked whether they believed that a more effective execution of the early phase could lead to increased value generation. The responses were analyzed and categorized into three groups based on the participants' perceptions. Fifty percent of the observations clearly indicated that more effective execution of the early phase could positively influence project value generation, while another fifty percent gave vague indications of the same. Interestingly, none of the experts stated that the early phase had no influence on project performance. They also emphasized the potential for increased value generation through more effective execution of the early phase. Statements from the experts highlighted the importance of utilizing the early phase to define project objectives, utilize existing competence, and avoid failures caused by mistakes (Kolltveit and Grønhaug, 2004).

In addition, a range of activities in the early phase of projects were identified. They catagorized the activities into two dimensions: "degree of traditional execution" and "seeking opportunities." Among the data related to traditional execution, several activities were emphasized. These activities included focusing on risk reduction, applying risk analyses in the early phase, providing a well-prepared basis for contracting, and establishing criteria for choosing alternatives. Informants also highlighted the importance of establishing breakdown methods that enable thorough discussions between project managers and estimators (Kolltveit and Grønhaug, 2004).

Moreover, it was noted that some parties, despite opting for traditional execution, actively sought opportunities for increased value generation in the early phase. Activities in this regard involved establishing methods to manage uncertainties, recognizing the relationship between interfaces and opportunities, and accepting uncertainty as an inherent factor. A small portion of the data indicated an untraditional execution of the early phase to optimize project value generation. Informants mentioned activities such as managing the opportunities presented by uncertainties, acknowledging that interface owners are also owners of opportunities, and embracing the acceptance of uncertainty (Kolltveit and Grønhaug, 2004).

Hisham Said and his colleagues emphasized the significance of the eco-charrette process, which takes place during the predesign phase, to set the sustainability goals and objectives for the entire project. Their study acknowledges that constructing sustainable green buildings involves additional work and documentation throughout the project life cycle, with a crucial step being the eco-charrette process. During this process, major project stakeholders, including the owner/client, designer/architect, and representative group of building users, converge to make informed decisions about the targeted level of building sustainability certification. This collaborative approach ensures that the project's sustainability goals are established and translated into the desired certification level for the green building. Furthermore, the study recognizes the challenges in selecting the project sustainability goals and objectives during the predesign phase due to the limited information available at that stage. It highlights the use of green-building rating systems, such as BREEM, to go beyond basic code requirements and improve building performance. These rating systems focus on key impact categories, including site, water, energy, materials, and indoor environment which affects use value. (Said et al., 2014).

In another study, Mauger and his colleagues highlighted the challenges faced by the Construction Industry, including quality, cost, and delay problems, which directly impact customer satisfaction, particularly the satisfaction of users. These issues are often attributed to the briefing process, which is the conceptual phase of a project where the project framework and expectations are defined through the statement of customers' requirements. The conceptual phase is considered crucial in the development cycle of engineering projects as decisions made during this stage significantly affect the performance, reliability, safety, and cost of the final product. Also, the cost of making changes increases as the project progresses, making the conceptual phase the prime opportunity for improvement (Mauger et al., 2010).

Various industries have developed tools to effectively manage this key phase, and the construction industry has its own practices. However, these existing approaches have been deemed lacking comprehensiveness. Researchers have attempted to address these shortcomings by adopting methodologies from other engineering domains. Notable works include the Client Requirements Processing Model (CRPM) using Quality Function Deployment (QFD) and the Functional Analysis (FA) and Value Management (VM) approaches. While these attempts have shown promise, practical applications have been limited. In addition, one of the key drivers of improvement identified in their case studies on the Construction Industry is "a focus on the customer". The study also underscores the need for a frameworks that prioritize customer-focused approaches. While adaptations of existing frameworks have been attempted, the specific context of each country and project may require tailored solutions (Mauger et al., 2010).

According to a study conducted by Michele Caroline Bueno and her colleagues, user involvement approaches are regarded as essential in aligning users' needs and preferences with building design, as users are considered "experts on their own experiences". This involvement not only supports users' satisfaction but also helps prevent design changes, frustration to designers, and additional costs related to the design process. this aligns with the idea that users should have a direct influence on matters concerning their work and the built environment. User involvement can take various forms and occurs at different levels, representing the relationship between users and service providers (Caixeta, Tzortzopoulos, and Fabricio, 2019).

The level or degree of user involvement is crucial in determining the range of influence users or their representatives have over the final product and decision-making mechanisms. In the field of architectural design, the notion of user involvement represented by two opposing poles: exclusive decision-making by architects and user decision-making without the intervention of architects. The stages between these poles represent different forms of user participation or levels of involvement, such as representation, questionnaire, dialogue, co-decision, and self-decision (figure 2.9.1) (Caixeta, Tzortzopoulos, and Fabricio, 2019) .

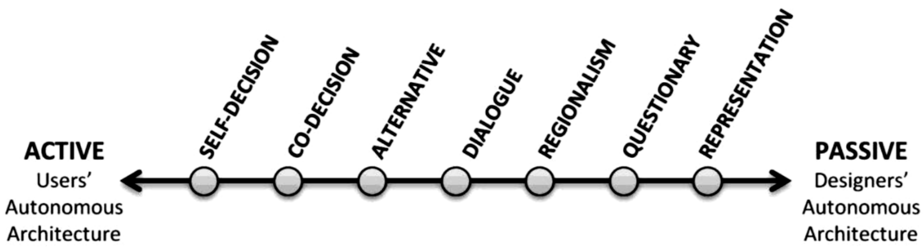


Figure 2.9.1: Forms of user involvement in the design process. (Caixeta, Tzortzopoulos, and Fabricio, 2019)

Moreover, this study highlights the distinction between user-centered design and co-design. User-centered design involves researchers observing and interviewing users to inform designers, considering users as passive objects of study. On the other hand, co-design positions users as partners, actively participating in knowledge development and idea generation. Co-design aims to create shared knowledge among multidisciplinary teams and seeks to improve products or services through collaboration with users (Caixeta, Tzortzopoulos, and Fabricio, 2019).

According to another study conducted by Tae Wan Kim and his colleagues, Involving users, their preferences, and their knowledge in architectural, engineering, and construction (AEC) projects has gained increasing importance in recent years. Researchers have identified significant gaps between user demand and the designs provided by architects, as well as the challenges of achieving usability in condensed workspaces. Consequently, user involvement has emerged as a key factor in enhancing the usability and functionality of buildings. The concept of user involvement has been discussed in the AEC industry since the 1960s, encompassing various theories such as user-oriented research, user-centered theory, user participation, and participatory design. These theories converge the understanding that user involvement aims to develop a suitable product that meets users' needs (Kim, Cha, and Kim, 2016).

Architects often lack comprehensive knowledge about users, emphasizing the necessity of involving them in AEC projects. Extensive evidence supports the benefits of user involvement, such as enhancing product development performance, improving the quality of requirements, and fostering positive user attitudes toward the project and the architect's work. User involvement can take two forms: direct and indirect. While user-centered design requires a deep understanding of users, it does not always necessitate their direct participation in the design process. Indirect user involvement methods may still capture user insights effectively. A variety of approaches, including quality function deployment (QFD), post-occupancy evaluation (POE), and ergonomic design, have been developed to facilitate both direct and indirect user involvement in AEC projects. These methods offer avenues for incorporating user feedback and preferences into the design process, enabling architects to create user-centric solutions (Kim, Cha, and Kim, 2016).

They also argued that architects require a framework that enables them to compare and select appropriate user involvement methods, such as QFD or POE, based on their project's unique requirements. This comprehensive framework should consider both direct and indirect user involvement approaches and incorporate the concept of involving virtual users to encompass evolving design practices. To address this need, they have developed a framework with two key dimensions that characterize user involvement in AEC (Architecture, Engineering, and Construction) projects: the degree of user involvement and the time span covered by each involvement method (Kim, Cha, and Kim, 2016).

Degree of User Involvement: The degree of user involvement dimension focuses on the extent to which real or virtual users are actively engaged in a project and participate in decision-making processes. While traditional classifications, such as "design for," "design with," and "design by," have been used, they have expanded upon them to incorporate both indirect and direct user involvement categories (Kim, Cha, and Kim, 2016).

- Production for users: This category involves architects speculating or gathering information about users and their preferences without their direct input during the decision-making process. Architects rely on informative user involvement methods, such as representation and participation through questionnaires, to inform the project. However, it lacks the benefits of user feedback and cooperation.

- Production with virtual users: In this category, real users are not directly involved, but virtual users—modeled to behave like real users—participate autonomously in the project. Architects can receive feedback on design alternatives from these virtual users, allowing them to predict the success or failure of different design options before the building is constructed and used by real users.

- Production with real users: This category entails direct involvement of real users who provide architects with feedback on different design alternatives. It involves consultative methods where users react and engage in dialogue with architects, enabling a comprehensive understanding of user preferences. However, proper visualization methods may be necessary for users to fully comprehend design alternatives.

- Production by users: This category represents the highest level of user involvement, where users have the opportunity to choose among different design alternatives or even contribute their own designs. Participative methods empower users to actively participate in decision-making, offering the most comprehensive benefits of user involvement. However, coordination challenges and user motivation and time constraints can pose obstacles to effective implementation.

Time Span of User Involvement: The time span dimension considers the phases or stages of an AEC project when user involvement methods come into play. By aligning user involvement methods with specific project phases, architects can effectively integrate user input throughout the project lifecycle. This dimension consists of the following categories (Kim, Cha, and Kim, 2016):

- Programming – Developing user profiles: User involvement methods in this phase contribute to gathering knowledge about users and developing user profiles that inform the core aspects of the building production process. This includes identifying users' functional needs, psychological preferences, and attitudes.

- Programming – Developing design requirements: During this phase, user involvement methods facilitate the translation of user profiles into specific design requirements. Architects can leverage user input to guide the development of design solutions, including space types, sizes, numbers, location, adjacency, temperature controls, and lighting.

- Design – Developing a design solution: User involvement methods in the design phase enable architects to develop design solutions that align with the identified user requirements. Users are often invited to provide feedback on design alternatives through formal meetings or other interactive sessions.

- Construction – Implementing building production: User involvement methods in this phase focus on developing an implementation plan for the construction process while keeping user needs in mind. Although these methods are more commonly used in renovation projects, considering occupant interactions remains crucial in determining construction schedules and site layouts.

- Occupancy – Gathering real usage data: During the occupancy phase, user involvement methods are aimed at gathering real usage data and understanding the relationship between users and the built environment. This data contributes to knowledge about users' experiences and informs future design and construction practices.

By considering both the degree of user involvement and the time span of user involvement, architects can effectively map and select appropriate user involvement methods for each phase of their projects. This comprehensive framework empowers architects to make informed decisions, taking into account the specific project context and the desired level of user engagement (figure 2.9.2). Furthermore, it is important to note that the framework acknowledges the complexities and challenges associated with user involvement. It recognizes that different methods have their strengths and weaknesses, and architects must carefully consider the trade-offs involved. Factors such as cost, time, user motivation, and the complexity of the building play significant roles in determining the feasibility and effectiveness of different user involvement approaches (Kim, Cha, and Kim, 2016).

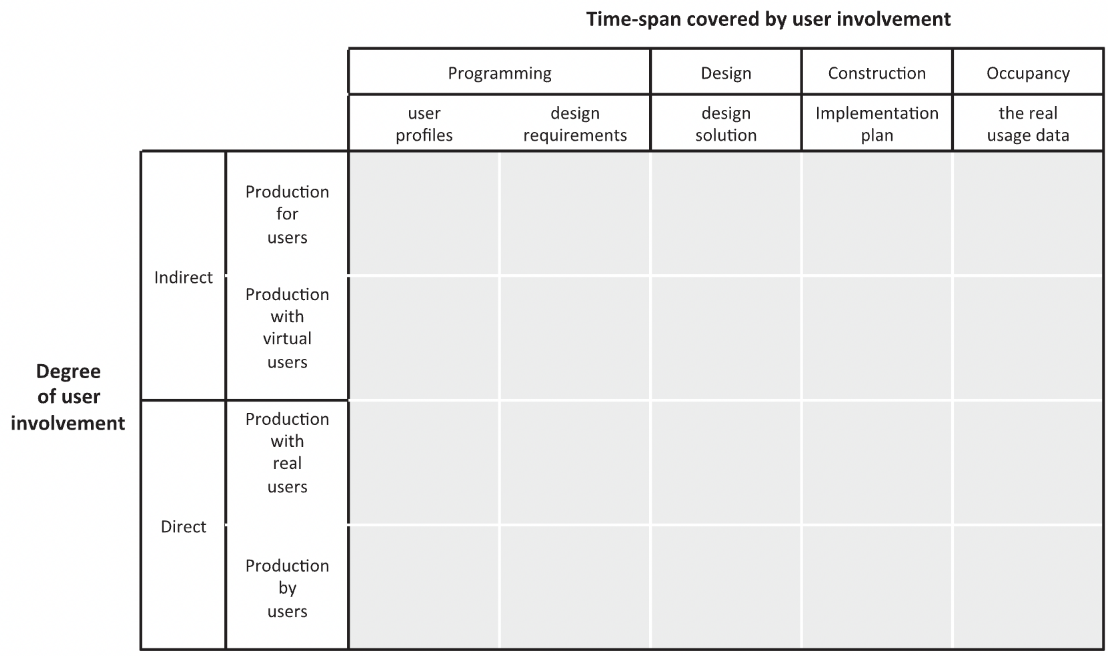


Figure 2.9.2: A framework for user involvement. (Kim, Cha, and Kim, 2016)

They also conducted a comprehensive investigation of various user involvement methods used in Architecture, Engineering, and Construction (AEC) projects. The methods they examined include architectural programming, Quality Function Deployment (QFD), Post-Occupancy Evaluation (POE), ergonomic design, evidence-based design (EBD), workplace planning (WOP), and user simulation (figure 2.9.3). The researchers focused on how well each method aligned with their framework to evaluate its effectiveness. Out of the seven identified methods, four represent users as passive participants without a voice in the decision-making process, while the other three methods involve collecting feedback from users, either real or virtual (Kim, Cha, and Kim, 2016).

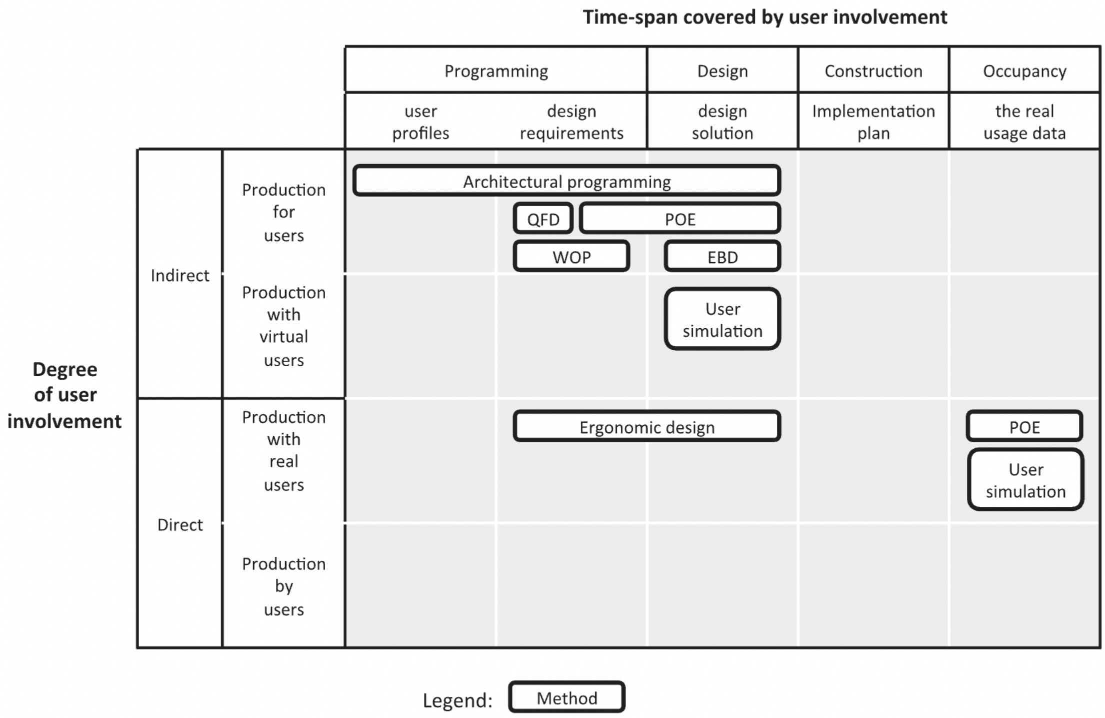


Figure 2.9.3: Mapping of seven user involvement methods onto the proposed framework (Kim, Cha, and Kim, 2016)

Architectural Programming: Architectural programming involves analyzing users and their activities in detail to develop design requirements for a building. It uses techniques like observation, questionnaires, hearings, and interviews to define target users and their profiles. Design requirements are then established based on the function, form, economy, and time perspectives of the project. However, architectural programming falls under the category of "production for users" as it primarily relies on architects to determine user profiles and design requirements without significant user feedback (Kim, Cha, and Kim, 2016).

Quality Function Deployment: QFD is a method that systematically translates users' needs into design requirements using a framework known as the "house of quality." While QFD is popular among researchers in the AEC industry, it has limitations in handling complex products and conflicting requirements. Like architectural programming, QFD also falls under the "production for users" category as it does not actively involve users in providing feedback or making choices regarding design requirements (Kim, Cha, and Kim, 2016).

Post Occupancy Evaluation: POE involves gathering real usage data after a building is constructed and using that data to continuously improve the building. It offers short-term benefits by improving the current building and long-term benefits by providing insights for future similar projects. POE belongs to the categories of both "production with real users" and "production for users" since it utilizes data from real users and applies it to produce better buildings or inform the design requirements of similar projects (Kim, Cha, and Kim, 2016).

Ergonomic Design: Ergonomic design involves user and ergonomic consultant participation in the programming and design phases. Users and consultants provide feedback by reacting to design representations such as function diagrams, magnetic board layouts, and mock-ups. Ergonomic design aims to improve the quality of design by considering user involvement, human factors, stereotypes, standards, and user measurements. However, it also has limitations, including the time and effort required from architects and the users' lack of familiarity with architectural representations(Kim, Cha, and Kim, 2016).

Evidence-based Design: Evidence-based design (EBD) applies research methods to assist architects in making design decisions, particularly in healthcare facilities, digital libraries, and offices. EBD utilizes various research methods, such as surveys, observations, experiments, case studies, and content analysis, to gather evidence on users and their relationship with a building. However, EBD primarily falls into the "production for users" category as it generally lacks an established process for involving user feedback in the design(Kim, Cha, and Kim, 2016).

Workplace Planning: Workplace planning (WOP) predicts space utilization based on formalized user activities, supporting space programming in the early phases of a project. It applies the value generation concept of lean production theory to define the relationship between user activities and the space program of a building. WOP predicts space utilization to gauge how effectively user activities are accommodated and determines the appropriate number of spaces based on target utilization. Similar to other methods, WOP falls under the "production for users" category as it does not actively model users as autonomous agents providing feedback(Kim, Cha, and Kim, 2016).

User Simulation: User simulation is used during the design phase to predict user behavior and gather feedback from virtual users. With advancements in computing power, architects can simulate user interactions with spaces and obtain valuable feedback before the occupancy phase. User simulation can be applied to emergency evacuation scenarios, occupancy in normal situations, and energy use in buildings. User simulation methods involve modeling the relationship between users and spaces, and they can help architects accurately predict user behavior and make informed design decisions. For emergency situations, user simulation models are developed to simulate evacuation scenarios. These models assist in understanding how users would behave during emergencies and help architects optimize building designs for safe and efficient evacuations. Similarly, user simulation models are used to simulate occupancy in normal situations, allowing architects to assess factors such as space utilization and circulation patterns (Kim, Cha, and Kim, 2016).

By obtaining feedback from virtual users, architects can identify design flaws and make improvements before the construction phase. Energy use simulation is another area where user simulation methods are employed. Predicting energy consumption accurately is crucial for designing energy-efficient buildings. User behavior, such as lighting usage, HVAC settings, and appliance usage, significantly impacts energy consumption. User simulation models consider different user behavior values and their effects on energy use to assist architects in designing sustainable and energy-efficient buildings. User simulation methods are placed in the category of "production with virtual users" since they primarily involve virtual user interactions and feedback during the design phase. These methods leverage advancements in modeling techniques, sensor data, and user profiles to create realistic simulations and enhance the design process(Kim, Cha, and Kim, 2016).

According to a study conducted by Atle Engebø and his colleagues, to achieve a shift towards sustainable construction, the construction industry needs to adopt new project delivery methods and promote collaboration among organizations with different goals and cultures. The integration of stakeholders becomes crucial as projects become more complex. Collaborative project delivery methods involve cross-disciplinary project teams, including contractors, designers, architects, and others, working together from the start to complete complex projects successfully. These methods aim to align the supply chain, develop trust, implement joint approaches, empower participants, and stimulate learning (Engebø et al., 2020).

While limited empirical evidence exists on the delivery of high-performance buildings using collaborative project delivery methods, they provide a framework for integration and can be modified from traditional methods to enhance integration. Early involvement of contractors in the design and constructability reviews, facilitated by contract types like Construction Management at Risk (CMR) and Design-Build (DB), promotes integration. Integration is a continuous collaborative effort by participants throughout the project, facilitating decision-making, requirements alignment, and goal-setting. It improves teamwork and enhances overall team performance. The client's commitment, timing of participants' entry, and selecting a team with appropriate characteristics contribute to achieving integration (Engebø et al., 2020).

In another research conducted by Sina Moradi and his colleague, core success factors for collaborative construction projects has been explored. According to this study, project success is commonly understood as the achievement of technical performance goals and the satisfaction of project stakeholders and is often divided into two components: project management success and product success. Additionally, success can be defined as meeting stakeholder expectations and can be measured through various factors such as time, cost, scope, quality, business success, and stakeholder satisfaction. Traditionally, project success in construction has focused on the project itself, its lifecycle, and efficiency. However, recent research indicates that construction projects also have significant impacts on the local environment, society, and end-users' quality of life (Moradi and Kähkönen, 2022).

Therefore, a holistic view of construction project success is necessary to account for these broader considerations. This holistic view defines construction project success as the achievement of specific project objectives while addressing challenges such as timely completion, staying within budget, meeting quality requirements, stakeholder satisfaction, ensuring safety, minimizing waste generation, and avoiding harm to the local environment and people. Collaborative delivery models, such as alliance, partnering, integrated project delivery (IPD), and lean project delivery (LPD), have been developed to enhance project outcomes. These models involve joint design, planning, control, and management of construction projects with early involvement of key parties, trust-based relationships, open communication, and a fair sharing of risks and rewards. Each model has its specific characteristics and approaches, but they all share common features such as early involvement, joint decision-making, open communication, and multi-party agreements (Moradi and Kähkönen, 2022).

Research on construction project success has evolved alongside changes in project delivery models. Previous studies have focused on both general perspectives and context-specific studies within the collaborative construction context. For instance, studies on alliance, IPD, lean project delivery, and partnering have identified success factors specific to each delivery model. These factors include effective communication, trust, early involvement, shared responsibilities, and appropriate staffing. The study also conducted an analysis of success factors for collaborative delivery models in construction projects. The researchers identified eight common success factors: appropriate and relevant contract, commitment to a win-win philosophy, collaboration and cooperation, equality, incentive system, open communication, mutual trust, and selecting competent people for the project. These factors were found to be applicable across collaborative delivery models such as alliance, integrated project delivery (IPD), and partnering (Moradi and Kähkönen, 2022).

The results showed that the identified success factors were specific to collaborative construction projects and differed from traditional construction projects. The findings aligned with previous research emphasizing the importance of factors such as communication, reasonable contracts, staffing, and cooperation in project success. However, there were notable differences in success factors between collaborative and traditional projects (Moradi and Kähkönen, 2022).

Furthermore, the researchers developed a success model based on the identified commonalities between success factors (figure 2.9.4). The model highlighted the significance of equality and mutual trust as fundamental factors underlying project organization, contractual relationships, and the operational system. Other factors such as selecting competent people, commitment to a win-win philosophy, reasonable contracts, collaboration and cooperation, open communication, and incentive systems were also included in the model. These factors were seen as critical for achieving success in collaborative construction projects (Moradi and Kähkönen, 2022).

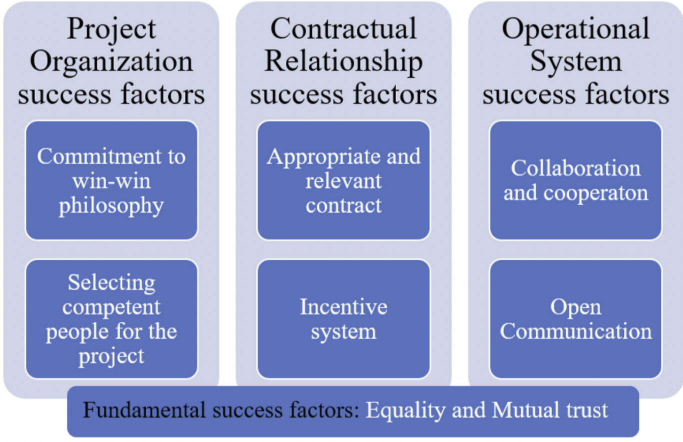


Figure 2.9.4: Success model for construction projects with collaborative delivery models (Moradi and Kähkönen, 2022)

In a research conducted by Gerard Wood and his colleague, they argued that successful implementation of relationship-based procurement strategies hinges on trust, as it acts as the binding force in cooperative relationships. Trust is a complex social phenomenon, viewed as an attitude, personality trait, and vital social lubricant. The focus of this study was on trust within partnering approaches to construction procurement. In this study, trust is defined as the willingness to rely on and be dependent upon the actions of others, making oneself vulnerable to their actions. Some argue that collaboration can be achieved through power or incentives, but the construction industry, despite its extensive subcontracting, has proven resistant to collaborative procurement approaches (Wood, McDermott, et al., 2001).

This study discussed how to progress in an adversarial sector and highlighted that increased cooperation necessitates increased vulnerability, underscoring the need for trust. Their interview data showed that changes are already being made to working practices and processes to foster the development of trust. Establishing a relationship requires a minimum degree of trust, which deepens as parties demonstrate competence, ability to keep promises, open and honest communication, information sharing, and the production of mutually beneficial outcomes. As confidence grows, the relationship becomes closer, more open, and more trusting, creating a virtuous cycle (Wood, McDermott, et al., 2001).

In another study conducted by Albertus Laan and his colleagues on a case study of a rail construction project in the Netherlands, it was emphasized that the relationships between principal and contractor organizations in construction projects are often characterized by conflict and a lack of trust. This holds true for both traditional contracts and newer contractual forms like design-build. Establishing trust between clients and contractors is challenging in the project-based nature of the construction industry, where time constraints limit extensive interaction and trust-building processes (Laan et al., 2011).

As a result, independent organizations with limited familiarity must collaborate on complex and uncertain projects, often leading to conflict and unsatisfactory outcomes. Efforts to improve construction project performance often emphasize increased cooperation between clients and contractors. Partnering approaches, particularly for high-risk and complex projects, are advocated because they have been shown to foster more cooperative and trusting relationships. In the project-based construction industry, organizations come together temporarily to achieve specific project goals within a defined timeframe. The success of a project relies heavily on the coordinated efforts of all participants. Given the ever-changing temporary collaborations in this industry, the development of trust becomes crucial (Laan et al., 2011).

They argued that trust is influenced by uncertainty and risk, and it involves both trusting intentions and trusting beliefs. Trust can be influenced by someone's disposition to trust, which assumes that others are generally trustworthy. Trust can also have calculative and non-calculative elements, and it encompasses the expectation that trustees will not engage in opportunistic behavior. The development of trust in construction projects is influenced by the performance of the project and the quality of the relationship between the partnering organizations. The behaviors of the representatives from each organization play a crucial role in building trust. Unlike traditional contracts, where one party may refrain from action in the face of risks, the efforts demonstrated in addressing challenges serve as a significant source of trust in project alliances. This study showed that successful trust-building efforts can contribute to improved project outcomes and better collaboration between clients and contractors (Laan et al., 2011).

In a research conducted by Şeyda Emekci, the concept of "appropriate technology" was defined. They argued that over the past few decades, there has been a rapid introduction of high-tech solutions into our daily lives, leading to significant advancements in building technologies. These advancements, particularly in energy storage, efficiency, and conversion, have given rise to the possibility of buildings generating more energy than they consume annually. However, these developments have predominantly occurred in technology-oriented sectors, often neglecting a holistic approach. As a result, sustainability in architecture has become largely associated with technology-driven solutions. This raises the question of whether sustainability in architecture can be achieved through low-tech approaches. While high-tech approaches in architecture offer enhanced comfort, control, and efficiency, low-tech approaches propose a more conservative use of resources with potentially lower environmental and social impacts. Low-tech approaches also prioritize a human-centered perspective, whereas high-tech approaches often prioritize technological solutions. Before the industrial revolution, architecture was characterized by vernacular design, utilizing local materials and adapting to local climatic conditions. However, with the advent of industrialization, building design became more uniform and less sensitive to the environment (Emekci, 2021).

Vernacular architecture is rooted in the experiences of people living in different climatic conditions and incorporates design and construction techniques based on the local environment, culture, and history. Studies have shown that employing vernacular techniques in modern buildings can improve energy efficiency, cost-effectiveness, and sustainability. Factors such as building shape, orientation, and material choice play crucial roles in energy conservation. On the other hand, high-tech solutions aim to enhance the quality of life by providing new services and better control and management of existing services. However, buildings relying heavily on technology often contain materials that are difficult to recycle or reuse, consume significant energy, and require frequent maintenance and updates. There are concerns about increased energy consumption and electronic waste associated with technology-driven buildings(Emekci, 2021).

To address the drawbacks of both approaches, it becomes essential to combine high and low-tech solutions to achieve truly sustainable buildings. This concept of "appropriate technology" involves striking a balance between the advantages and challenges posed by high and low-tech approaches. By integrating adequate technology with vernacular architectural techniques, it is possible to create energy-efficient buildings while considering the availability and sustainability of resources (Emekci, 2021).

In a research conducted by Rui de Klerk and his colleagues, it is argued that sketching, whether through hand drawing or digital modeling, is widely recognized as a valuable conceptual activity in architectural design. It facilitates the exploration of relevant concepts and is particularly useful in the early stages of the design process. Recent advancements in augmented and virtual reality (AR/VR) technologies, particularly portable head-mounted displays, have the potential to revolutionize architectural practice. These technologies, leveraging gesture-based spatial interactions, promise to enhance the architectural design process. They enable architects to create sketches at different scales in the early design stages, allowing for the externalization of ideas and the evaluation of early-stage designs. The use of VR systems for buildings offers a more immersive and expeditious alternative to physical models and detailed 3D renderings. It facilitates the testing of spatial hypotheses, provides insights into design problems, and encourages exploration of design alternatives(de Klerk et al., 2019).

In another research conducted by Shakil Ahmed, they explained that decades ago, creating a virtual model of a construction project before its physical realization was a daunting task. However, with the advancement of virtual reality (VR) technologies, it is now possible to build virtual project models that provide a realistic preview of the project before it begins. These visualization models offer parametric information that surpasses what is achievable with 2D CAD models and serve as a comprehensive information resource for all departments involved in the construction team. VR technologies enable individuals to navigate and explore the entire project, both inside and outside, with a heightened sense of real-world immersion. They are particularly useful in the planning phase, facilitating effective decision-making within time constraints. VR also aids consultants and contractors in designing projects with consideration for constructability. Furthermore, after the construction phase, VR technologies streamline maintenance and facilities management processes, reducing effort and costs(Ahmed, 2018).

According to the editorial board of the 7th International Building Physics Conference, IBPC2018, the importance of Building Physics research lies in its focus on the significant impact buildings have on people's health, well-being, carbon emissions, energy efficiency, and overall environmental quality. However, challenges arise in designing and constructing buildings that fulfill multiple performance goals while considering factors such as energy conservation, human health, and individual occupant needs. The field grapples with quantifying the benefits of Indoor Environmental Quality (IEQ) and determining appropriate criteria for IEQ control (J. Zhang et al., 2019).

Building Physics research also spans various spatial and temporal scales, requiring an understanding of how different systems interact and affect energy and mass flows. Addressing these challenges necessitates an integrated, multiscale approach to urban climate analysis and the development of strategies that consider multiple scales of the built environment and energy systems. Moreover, incorporating occupant behavior into building design and operation becomes crucial for optimizing performance and achieving occupant satisfaction, energy efficiency, and well-being. Various environmental control methods, such as hybrid ventilation and personalized environmental control, are explored to enhance building performance. The field of Building Physics continues to evolve, aiming to integrate technological advancements with social, economic, cultural, and policy developments to create sustainable and high-performing built environments(J. Zhang et al., 2019).

Khwla A.M.H. Alaraji and his colleagues asserted that incorporating more options and choices in the physical environment can enhance users' sense of control and overall well-being. This highlights the crucial role of flexibility in building design. Previous studies have explored the elements and features that should be flexible in building and house design, ranging from user involvement in selecting furniture and fixtures to active participation in redesigning the entire house. Various principles and applications of flexibility, including demountable walls and flexible furniture, have been suggested. It is essential to consider users' perspectives on flexibility, as they play a significant role in customizing and personalizing their homes. Modifiability and long-term adaptability are considered the responsibility of the investor client, but users may have different needs and expectations beyond what designers anticipate (Alaraji and Jusan, 2015).

According to a study by David M. Spatz, the construction industry relies heavily on teamwork for successful project completion. Teamwork is crucial at all levels and is deeply ingrained in the industry's culture. Effective teamwork in construction leads to increased efficiency, adherence to schedules, meeting deadlines, improved employee morale, and customer satisfaction. Examples of effective teamwork can be observed during project formulation, planning, and various construction phases. Construction teams are known for their specialized knowledge and skills, understanding of each other's roles, and the ability to coordinate activities to meet tight schedules and performance standards (Spatz, 2000).

Team-based cultures in construction foster effective communication, exchange of ideas, and collaboration among employees and managers. Trust, respect, and open honest communication are essential values that contribute to successful teamwork and employee satisfaction. When these basic human needs are met, other incentives such as salary increases become less important to employees. Implementing team-based strategies in construction requires thoughtful planning and establishing clear values. Companies often reorganize into fully functional teams aligned with their core businesses. Hierarchical management structures are replaced with a team organizer who helps select appropriate individuals, coaches team processes, and promotes effective teamwork. In team-based environments, skills transfer, knowledge is shared, and collaboration is encouraged, leading to improved project flow and quality(Spatz, 2000).

In conclusion, the literature review on the identification of key activities in the early phases of projects that generate value provides valuable insights into this critical aspect of project development. While the number of research studies specifically focusing on this topic is limited, the existing body of literature highlights the importance of understanding and implementing these key activities to ensure successful project outcomes. Through an in-depth analysis of relevant articles, valuable knowledge can be gained regarding the activities that contribute to value creation during the early phases of projects.

2.10 Value measurement

In order to explain the relationship between the value creation and value capture of a construction projects, we need to focus on use value. Use value refers to specific qualities of the product (an asset or a building) as perceived by customers in relation to their needs, for example, hospitals aim to support health care. This is considered as the first-order effects of a project which is difficult to measure, but will provide value through use and operations. From a strategic point of view, use-value is considered to be second-order effect, for instance, hospitals improve overall health of the population (Hjelmbrekke, Klakegg, and Lohne, 2017).

As it was discussed before, social value is one of the values in construction projects. Hemanta Doloi developed a framework for an accurate understanding and assessment of the social performance and value creation of public infrastructure projects based on stakeholders' networks and their influences in the project in Australia. Sustainable development should be characterized as articulating political and economic differences and introducing social justice in addition to environmental issues and financial concerns. In other words, social sustainability should be equally important as ecological sustainability within the concept of sustainable development (Doloi, 2012).

As the community becomes increasingly aware of environmental and social impact of projects, social sustainability and the measurement methods has been more and more emphasized. In society, there are three independent functional systems involved in social sustainability: Economic system, Political system, and Cultural system. In addition, within a project, social performance requires the project to produce immediate benefits for stakeholders rather than simply the creation of shareholders alone (Doloi, 2012).

Figure 2.10.1 illustrates a resulting conceptual framework for social performance evaluation in infrastructure projects developed by Hemanta Doloi . As seen, the beginning of the evaluation process, the project management team is asked to identify stakeholder categories in the project. For each stakeholder category identified, individual stakeholders are then selected to conduct an interview. The interviewees are requested to identify the relationship with other stakeholders, as well as their evaluation of social value in the project. Social network analysis is conducted subsequently to quantify the influence of stakeholders in the network (Doloi, 2012).

The overall social performance of the project is then derived by integrating the social value perception of individual stakeholders and their influence in the network. This method also demonstrated by a case study. SNA analysis provided meaningful insights in terms of stakeholders influence in project development contexts.This method is applicable for social performance evaluation with complex multiple stakeholders, as it brings precision and deeper understanding in social relations (Doloi, 2012).

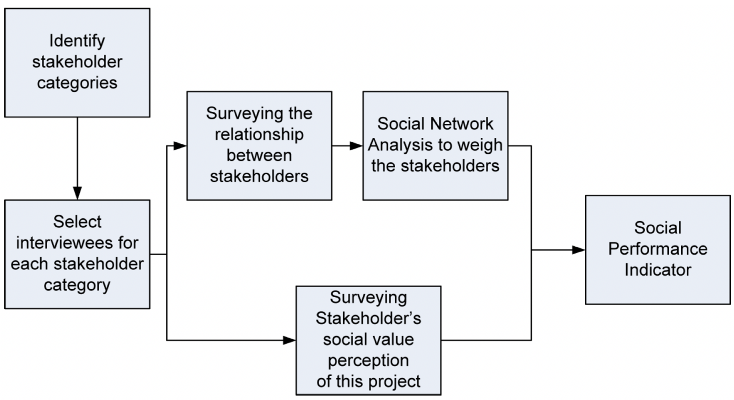


Figure 2.10.1: Framework of social performance assessment in capital project (Doloi, 2012)

Zhang conducted aresearch on whether Building Information Modeling (BIM) can present building properties, thus creating an opportunity to perform value analysis based on BIM automatically. The article proposed a method for value-focused modeling and extraction of design information from a BIM model. Relevant stakeholder values (human-centered values) which were used for validation is shown in the figure 2.10.2 (L. Zhang, 2016).

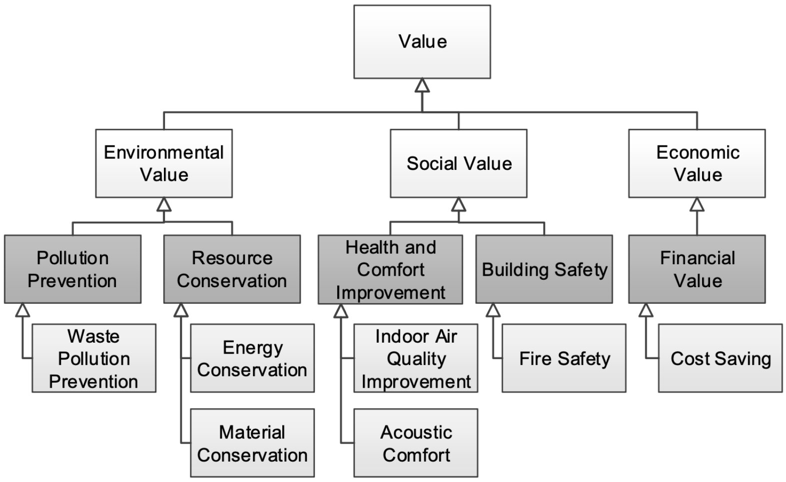


Figure 2.10.2: Relevant stakeholder values used for validation(L. Zhang, 2016)

In another research, a framework was developed to assess value creation for municipalities through adaptation of the Lean Project Delivery System and Post Occupancy Evaluation (POE). The framework is shown in the figure 2.10.3 . It was also argued that It is impor-tant to make sure that the project fulfills all the users' needs and values, which in turn must be guaranteed by standards and regulations (Brioso et al., 2018).

Frequently, it was referred to use-value when talking about value for stakeholders since users are the end customers in the construction process and key value for the clients also lies in the buildings' proper operations and user satisfaction. As discussed, different value measuring methods were suggested by many researchers. In this report, the Post Occupancy Evaluation method is used to measure value in construction projects and will be explained in the following sections.

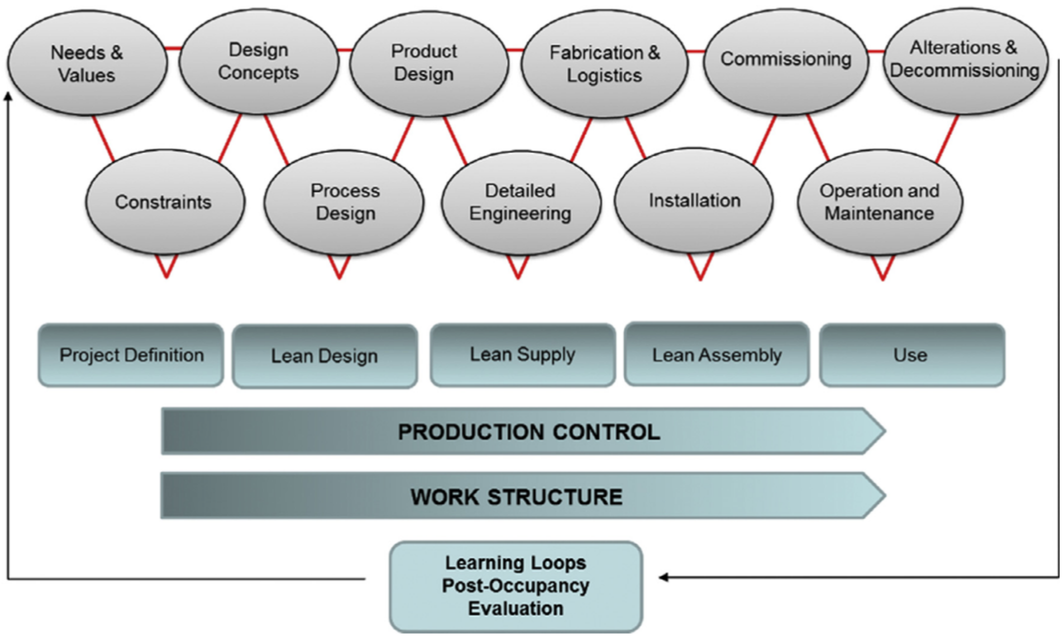


Figure 2.10.3: Lean project delivery system(Brioso et al., 2018)

2.11 Post occupancy evaluation

Post-occupancy evaluation (POE) is a systematic method to evaluate buildings' performance after buildings have been occupied for some time, it originated in the United States and has been widely used worldwide since the 1960s. The POE activities promote the participation of building occupants, the end- users, focus on their requirements of buildings in the aspects of health, safety, convenience, amenity, psychological comfort, living quality, and satisfaction.

2.11.1 History

The first precursors to post occupancy evaluation started in Us in the late 1960s with evaluating dormitories. Van der Ryn and Silverstein conducted case study evaluations of dormitories at the university of California, Berkeley. At that time, the aim was not carrying out POE, however, they had the intention of assessing building performance from users' perspective. The term 'post occupancy evaluation' was used in scientific publications in January 1975 for the first time in the AIA journal. The authors of the article, Herb McLaughlin and a group of consultants, Conducted POE on hospitals in Utah and California (Hardy, Schramm, and Preiser, 2018).

In 1970, AIA Research Corporation developed a methodological review of POE methods, and by the late 1980s, POE became known and carried out around the world. At that time publicly owned buildings were the major focus of studies. The first book on POE was published in 1988 by Preiser, Rabinowitz, and White. Research, methodologies and framework of POE continue to evolve (Hardy, Schramm, and Preiser, 2018).

2.11.2 Definition

Post occupancy evaluation is a systematic inquiry aimed at discovering and documenting how a building, product or service has worked within its intended use (Becker, 1989). POE is an approach to obtain feedback about a building's performance in use, including energy performance, indoor environment quality (IEQ), occupants' satisfaction, productivity, etc (Li, Froese, and Brager, 2018). In fact, a post-occupancy evaluation (POE) feeds data back into the design process as a measurement of the gap between planned and actual performance of a building. The most common application is to evaluate the performance of a facility once it is occupied. The army calls this post evaluation "ground truth, "an assessment of what happened in the field differently from how the strategy was planned (Parshall and Fonseca, 2018).

2.11.3 POE methods

POE methods differ in different building types in terms of purpose and methodology. POEs of residential buildings often focus on occupants' experience and use of facilities, and therefore, almost every project would use an occupant survey or interview as the research method. POEs of office buildings are typically interested in occupants' comfort and productivity, and the more sophisticated of these would utilize both a survey and physical measurements of IEQ (indoor environmental quality). POEs of university building are variable but, depending on the objective, could be similar to the POEs of either office or residential buildings (Li, Froese, and Brager, 2018).

POEs of kindergartens and schools usually focus on the efficiency of teaching activities, sometimes including the analysis of children's behaviors, and thus, observation is the key component of the methodology. POEs of medical buildings are typically quite distinct from other POEs: on one hand, they use variable methods to evaluate the general user experience (e.g., accessibility and way finding); on the other hand, medical buildings have strict requirements (for example, sound insulation and indoor air quality) (Li, Froese, and Brager, 2018).

According to Preiser, building performance criteria are an expression and translation of client goals and objectives functions and activities, and environmental conditions that are required in three performance level (figure 2.11.1) (Preiser, 1995):

- Health/safety/security level;
- Functionality/efficiency level;
- Social, psychological, cultural and aesthetic level

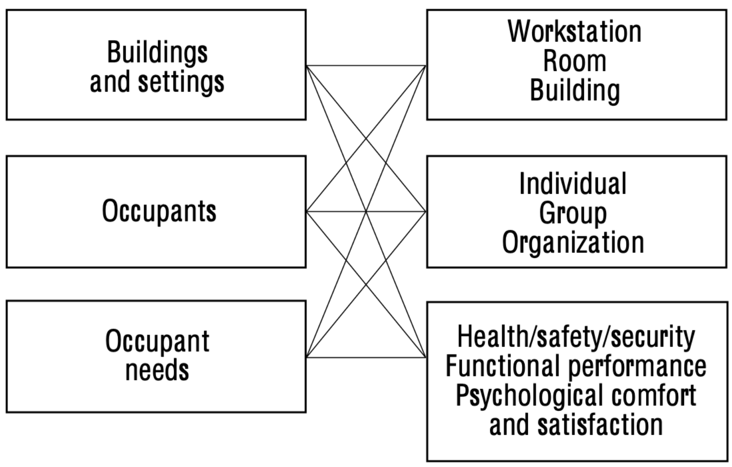


Figure 2.11.1: Elements and levels of building performance (Preiser, 1995)

Preiser initially classified three levels of POE: indicative, investigative and diagnostic. Indicative POE includes "quick walkthrough evaluations involving structured interviews with key personnel, group meetings with end users as well as inspections". Investigative POE are considered to be more in-depth analyses, utilising interviews and questionnaires, usually across a number of buildings of the same or similar type. Diagnostic POE tend to have a broad, system wide focus on a number of comparable facility types, focusing on a broad range of technological and anthropological areas of research (Preiser, 1995).

Preiser suggested that this type of in-depth POE produces “high validity and generalisability of data collected has the potential of being transformed into guidelines” for use in the public guidelines (Preiser, 1995). However,many years after, Hadjri and Crozier stated that “the overarching notion of the purpose of POE is to facilitate the accumulation of information/knowledge that can be subsequently utilized to improve the procurement of buildings to the benefit of all the stakeholders involved” (Hadjri and Crozier, 2009).

The most common focus of a POE evaluation is on the occupant, followed by IEQ, energy, design and facility. POE methods include energy and water assessment, IEQ physical measurements, occupant survey questionnaires, focus group meetings, structured interviews, visual records, walkthroughs, and technical measurement of building structure, services and systems. In a few cases, window opening sensors or GPS-enabled mobility tracking were used to study occupant behaviors (Li, Froese, and Brager, 2018).

According to the study by Peixian and his colleagues, subjective methods including occupant surveys, interviews and walkthroughs were the most popular methods and physical measurements including IEQ in thermal, lighting, IAQ (indoor air quality), acoustics, energy and water came into consideration in the second place. To enhance the feedback to owner and occupants, BIM (Building Information Modelling) and GIS (Geographic Information Systems) are sometimes used to show the spatial mapping of occupant satisfaction and IEQ (Li, Froese, and Brager, 2018).

"Usability - methods and tools" research project was conducted at NTNU in 2009 to develop methods and tools for mapping and evaluating the quality of use of buildings by focusing on qualitative methods. In this project, the emphasis is on the usability of buildings which is dependent on how well buildings support users need and satisfaction and it is defined as quality of use or according to ISO 9241 as "the extent to which a product/system can be used by specified users to achieve specified goals in a particular context, with the best possible efficiency, value creation and satisfied users" (Hansen, Blakstad, and Knudsen, 2010).

Use-tool is developed to assess usability by focusing on efficiency, value creation and satisfaction of the user which contributes to achieving the specified objectives (Hansen, Blakstad, and Knudsen, 2010). Use tool method consists of five stages which is show in the figure 2.11.2.

- *Defining the purpose and scope of the evaluation*
  In the first step, the purpose of the evaluation is defined. This decision must be taken by bisiness that uses the building, or by the owner/manager of the building which make it clear whether the purpose is a general survey of business/building mass for benchmarking, evaluation with a view to improving existing premises/buildings or for input into planning and programming of new buildings. Therefore, appropriate ways to dedicate knowledge needs and resource use can be used.

It is also recommended to create a comprehensive description of the user company's visions, strategies, objectives and how the business is organized and physically located and document them using different methods like interviewing with user operations and the management of the administrator. Planning and anchoring the evaluation process will be based on the purpose and focus area of the evaluation, defining which activities must be carried out, when these must take place and which resources are needed to carry out the activities in terms of time, costs and people.

- *Mapping quality of use*
  The aim of the work at this stage is to establish an overall picture of the quality of use including obtaining facts regarding the building, original functional/ program requirements that are linked to the business, activities and work patterns for all or parts of the building based on a set of predefined parameters which is done by conducting a structured group interview, as well as collecting already available information like gross land use per person, the building's use and program area and any gross/net factor for example the number of square meters per employee or per workplace, meeting rooms per employee, number of groups per student etc. It is recommended that data be obtained from any other conducted searches such as HSE, user surveys, customer satisfaction for supplementing and comparing information.

  Next step in this stage involves carrying out one or more structured group interviews with selected user groups. The aim of the work at this stage is not to carry out as much data collection as possible, but to carry out enough interviews to have a good enough basis for further analysis. In general, the respondents should represent different user groups based on experience that the quality of use is assessed from the individual's point of view and context. It is recommended that the participants are sent a list of the relevant topics that will be dealt with in the group interview in advance. Finally, the results are recorded and documented for further process.

- *Walkthroughs, inspection the quality of use*
  The purpose of this step is to obtain user experiences for selected topics from previous step, and to gain a better understanding of why solutions work well or poorly. Based on the mapping, a picture of "where the shoes should be pressed" or special topics to obtain in-depth knowledge will be defined which can be explored further by means of a walk in this step. Walk-through is a common term for a method of inspecting a building to assess various aspects of the building's usability. There are different variants of how the walk can be carried out. It ranges from a completely open form of evaluation based on spontaneous and subjective assessments by random participants then and there, to predefined stopping points, evaluation criteria and selected participants.

An important effect of walking as a method is the learning effect in that the various participants gain an insight into each other 's requirements and needs, and assessment of the quality of use related to concrete physical solutions. Then, a walk is carried out as an inspection, where the group take a walk through the building (and stop at selected places) with selected users and ask for their experiences from use in relation to the topic in question. Both the number of participants and the type of stakeholder group that will take part in the walk are selected based on the purpose of the walk and selected focus areas and themes. It is recommended that the number of participants does not exceed 8-9 people and It is therefore important to select participants based on different user perspectives. Participants should be chosen from the user group who actually use the premises/building on a daily basis. It may be relevant to supplement the group with experts and consultants or others where this is relevant. It is also possible to take several walks with different themes, or several walks with the same theme, but where different people are represented.

Stopping points on the walk are chosen in collaboration with the company's management, based on the focus areas and theme defined in step 1 and step 2 and should provide good information about the theme chosen. It is recommended that the number of stopping points does not exceed 8. A high number of stopping points, combined with many participants, is time-consuming and can provide a large amount of information. It should be decided upon whether it should be a quiet walk, discussion along the way or a combination before the walk. In a quiet walk, the participants make notes on their own forms. Finally, the results from the walk are compiled in an appropriate and systematized by stop, theme and user perspectives containing the reasons why certain solutions work or do not work in relation to function and users. Combining text and images from the various stop pest sites provides useful and rich documentation that is easy to pass on.

- *Workshop with the business*
  A workshop is an organized form of work where people from different backgrounds work together in relation to a given theme or issue. The aim of the work at this stage is to discuss the findings from stages 2 and 3 of the survey in relation to the company's overall visions, strategies and objectives. The choice of participants should therefore reflect the purpose of the survey and the purpose of the workshop. The company's management, local FM and representatives of users should be represented at the workshop. It is important that the workshop begins with a presentation of the purpose of the entire evaluation, the business's overall visions, strategies and goal settings and the results from steps 2 and 3. Furthermore, the purpose of the workshop itself and the roles and responsibilities of the participants must also be conveyed.

An important purpose of the workshop will be the review and discussion of results from the evaluation up to overall objectives. The purpose is to initiate reflections on selected topics from mapping and walking. An important purpose here is to get answers to why things work or don't work, and that an assessment of the quality of use is related to the strategic level of the business. It is important that the discussion is well led and structured. The discussions about why physical solutions work well/less well provide a basis for identifying knowledge that has transfer value to other buildings. The first phase of the workshop should be open.in which different points of view and perspectives are allowed to come forward freely. In this phase, the purpose is not to arrive at a common position, but rather to illuminate the topic in the best possible way. The workshop will focus on points / areas about which you more knowledge is needed, and it is important to get both positive and negative aspects related to quality of use.

Different techniques for scoring, weighting, mapping and analyzing the strengths and weaknesses of processes and projects can be used such as SWOT analysis. In order for the results from the workshop to be useful for further work with an action plan, knowledge development or transfer of experience, the discussion must be managed and elements that emerge systematized so that they can be used further in the process. Finally, the workshop can have different purposes, but primarily this should provide a basis and input for the preparation of an action plan.

- *Develop action plan*
  The aim of this step is to document and summarize the most important experiences based on the evaluation process. This step starts with a review of the reports and analyses carried out earlier in the process. Mapping of quality of use is based on assessment from different user perspectives, and the results from the evaluation will therefore be influenced by the respondents' role, tasks and responsibilities, place of work, preferences etc. In this step, it is important to analyze the results from the evaluation in relation to overall objectives, taking into account relevant experiences and assessments. In particular, the results from the workshop can be an important basis for drawing up the action plan.

  If the purpose of the evaluation is to obtain new knowledge about buildings in use, a final report will be a relevant format. However, if the purpose of the evaluation is improvements in existing buildings, or input into the programming of new buildings, an action plan would be a better format. For an action plan to function effectively, the plan must be structured and realistic with regard to the implementation of various measures. The measures should also be prioritized so that there is agreement in terms of importance, time and costs. The action plan must describe necessary measures, responsibilities, necessary resources, priorities and any assumptions or dependencies that must be taken into account and point directly back to the purpose of the mapping and the company's visions, objectives and strategies.

Figure 2.11.2: Use tool methodHansen, Blakstad, and Knudsen, 2010

In general, POE, provides a method of gathering and disseminating information that is of value to all stakeholders within a building life cycle, with specific elements of this information being of benefit to particular stakeholders, in different ways; for instance POE has specific benefits for facilities management. It also provides a knowledge base of “lessons learned” from users in completed projects which could then be utilised to either improve spaces in existing buildings or form a programming platform for future buildings (Hadjri and Crozier, 2009).

Green and Moss also suggested that it is essential for organisations to create learning cycles specifically in relation to the organisations facilities management. In this situation “the design of the workplace must be viewed not as a finite process which end on completion of a new building, but as an ongoing process which extends to the upgrading and refurbishment of buildings in occupation (Green and Moss, 1998).

Alex Zimmerman and Mark Martin examined benefits and barriers of POE. According to their study, benefits from using POE include: a feedback loop to enhance continuous improvement processes, improved fit between occupants and their buildings, the optimization of services to suit occupants, the reduction of waste of space and energy, validation of occupants' real needs, reduced ownership/ operational expenses, improved competitive advantage in the marketplace. The barriers to implementing POE are found to include: fragmented incentives and benefits within the procurement and operation processes, lack of agreed and reliable indicators, potential liability for owners, and exclusion from current delivery expectations. (A. Zimmerman and Martin, 2001).

2.12 Building performance evaluation

Traditionally, project(building) delivery models was considered as a linear process. For example, for architects, the design of a building was the beginning of a project and the hand-over of keys were the end. This perspective, eliminates the occupancy and future re-use phase of the building life cycle. On the other hand, the client wants a project to be built to get a problem solved, and the opening of a project is not the end of the process where we can decide whether or not it was a successful project or not. Maintenance costs, functionality, user satisfaction and well-beings are important factors that should be considered during the life cycle. Also, holistic perspective includes a reflection about building's re-use transformation and potential future demolition (Hardy, Schramm, and Preiser, 2018).

In 1997, the concept of POE was expanded as an integrated framework of building performance evaluation (BPE). BPE focuses on the entire life of the building, from planning, programming, design, construction, occupancy, to adaptive re-use or recycling (Li, Froese, and Brager, 2018).

By taking holistic perspective in mind, building life cycle consists of six phases: strategic planning, programming, design, construction, occupancy, and adaptive re-use/recycling. In addition, in order to have a bigger picture, the evaluation part expands into five phases with the goal of continuous quality improvement of buildings. This goal, feed-forward, is of great importance since it provides a database of findings which can be helpful in planning, programming, design, construction, and building management in the next similar projects (figure 2.12.1). Six phases of this method are (Hardy, Schramm, and Preiser, 2018):

- *Phase I: Strategic planning- effectiveness review*
  The starting point of the building life cycle is the strategic plan, which establishes medium- and long-term needs of an organization through market/needs analysis,and is based on strategic goals. In feedback loop, outcomes of strategic planning are reviewed in terms of their effectiveness in regards of organization's goals, such as corporate symbolism and image, visibility, innovative technology,flexibility and adaptive re-use, initial capital cost, operating and maintenance cost, and costs of replacement and recycling.

- *Phase II: Programming - program review*
  After strategic planning, cost estimating and budgeting has performed, programming can begin for a building project. A building program defines the client's needs, aims, resources, and context for the project. Programming takes place between key stakeholders, including representatives of future building occupants with building specialists. At the end of this phase, feedback loop involves the client, the programmer, and representatives of occupant groups in reflecting on the program document containing performance criteria and other outcomes of strategic planning. The review process allows the program to be evaluated step-by-step and to be modified in response to requirements or new priorities.

- *Phase III: Design - design review*
  In the design process, schematic design is the initial phase of building design, during which a range of alternative solutions are developed, translating the programming parameters into one or more building solutions. Design development is the second stage of building design, wherein one of the alternatives is chosen and elaborated on in order to address the program in more detail. Finally,construction contract documents are produced for the selected design. In feedback loop of this stage, design review, or troubleshooting is performed by involving the architect, the programmer, and client and/or user representative(s). Digital tools like computer aided design (CAD) techniques and building information modeling(BIM) can be used in this stage to evaluate solutions during the earliest phases of design.

- *Phase IV: Construction - commissioning*
  Once design review is completed with satisfactory outcomes, building construction can begin. In this phase, construction managers and architects work together to assure contractual compliance. In addition, national standards and codes, as well as local regulations need to be met. Failure to complete the previous phases can result in unforeseen change orders during construction, as some new requirement is identified or budgetary constraints imposed which can also lead to change in the cost of building construction. At the end and during of the construction phase, inspections take place, which result in listing the items that need to be completed prior to acceptance and occupancy of the building by the client. This feedback loop is aimed to insure that owners'expectations, as well as obligatory standards, are met in the constructed building. This feedback loop is a reality check which ensures that the builder fulfils her contract, specific building performance criteria, and relevant standards.

- *Phase V: Occupancy - post occupance evaluation*
  This phase is the longest of all, depending on building type. To occupy a building is the original goal of a client when they decide on a building project and in this phase the client obtains the architectural solution to the initial problem. During feedback loop in this phase, BPE is activated in the form of POEs that provide feedback on what works in the facility and what needs improvement. POEs also test some of the hypotheses behind key decisions made in the programming and design phases.The results can be

used to identify issues and problems in the performance of occupied buildings and to identify ways to solve these. Moreover, POEs are ideally carried out at regular intervals, 2- to 5-year cycles,especially in organizations with repetitive building programs.

- *Phase VI: Re-use/ recycling - market/needs analysis*
  Recycling buildings for similar or quite different uses towards the end of their useful life has become quite common these days. Some major use changes are as dramatic as constructing a new building. The question of how well a building adapts and can be recycled is very important, not only in the sense of sustainable building practices,but also in the sense of adaptation to new uses. The end of this phase constitutes the end of the useful life of a building, e.g., when the building is decommissioned, re-used, or demolished. Feedback Loop in this phase involves evaluating the market for the building type in question in terms of a prospective client organization's needs. It can mean assessing the rehabilitation potential of a building or the potential of a prospective site in terms of future needs. Thus, in the BPE process model, the end point of this evolutionary cycle is also the beginning point of the next building life cycle.

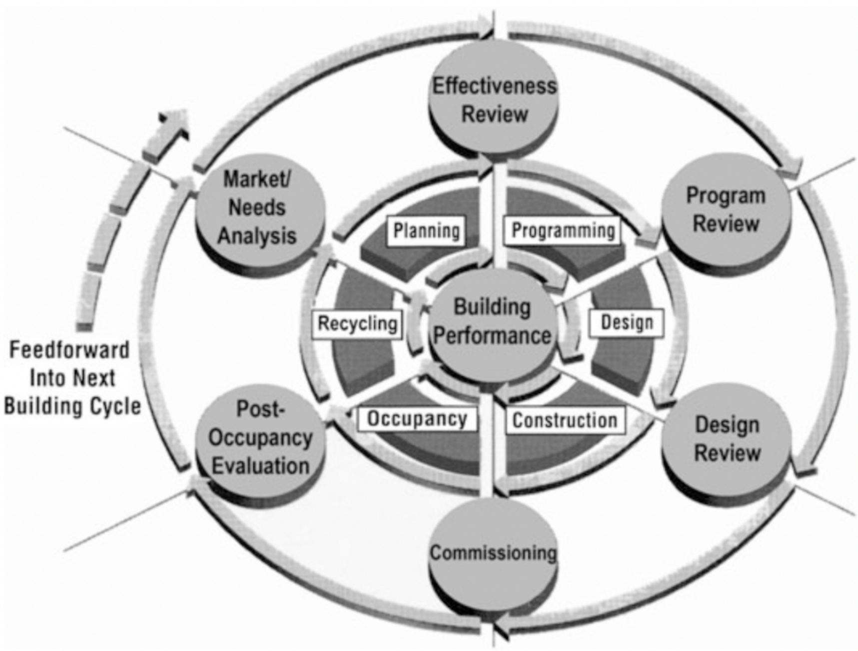


Figure 2.12.1: Building performance evaluation (BPE) process model Hardy, Schramm, and Preiser, 2018

CHAPTER

THREE

METHODS

3.1 Introduction to methodology

This chapter outlines the methodology used in conducting the research for this thesis. The primary aim of this study is first, to identify critical factors and activities in the early phases of building projects that lead to use value, informing the construction industry for better project outcomes, second, to conduct a post-occupancy evaluation of the ZEB Laboratory building to assess user satisfaction and gather insights for potential enhancements and future building projects, and finally, extract valuable lessons and recommendations from case studies to guide future building projects and contribute to the industry's knowledge, bridging the gap between project ambition and building performance.

To achieve these, a mixed-methods approach was employed, combining both qualitative and quantitative data collection methods. The study focused on two case studies: the ZEB Lab building in Trondheim, Norway, and the Energy Academy Europe building in Groningen, the Netherlands.

These two buildings were selected as case studies because they both have high energy efficiency goals and have implemented innovative energy-saving technologies. Additionally, both buildings have been designed to showcase sustainable building practices and serve as teaching facilities for students and researchers. Despite their similarities in energy efficiency and sustainability goals, the two buildings differ in terms of their size, location, construction materials and procurement process.

The following sections will describe in detail the research design and approach, participant selection, data collection methods, data analysis procedures, and ethical considerations and limitations of this study.

3.2 Data collection methods

For both case studies, a combination of qualitative data collection methods was employed to gather information. The following methods were used:

3.2.1 Case Study 1 - Zeb Laboratory

Interviews: Key personnel involved in the Zeb Laboratory project, including the project manager from the owner side, designer, and project manager of the contractor, were interviewed. The interviews were conducted face-to-face, or through teams meetings and a semi-structured approach was used to ensure consistency and allow for follow-up questions.

Survey: A post-occupancy survey was distributed to the occupants of Zeb Laboratory to gather their feedback on the building's performance and usability. The survey was administered online and included both open-ended and closed-ended questions.

Walkthrough: A walkthrough of Zeb Laboratory was conducted to observe and document the building's physical characteristics, layout, and functionality. This method involved selecting occupants from different floors and sides of the building to capture diverse perspectives and experiences. The occupants were chosen based on their affiliation with either NTNU or SINTEF, as well as the physical locations of their offices within the building.

3.2.2 Case Study 2 - Energy Academy Europe

Interviews: Advisors and project managers representing the clinet, or the University of Groningen involved in the Energy Academy Europe were interviewed. The interviews were conducted online, and a semi-structured approach was used to ensure consistency and allow for follow-up questions.

Guided Tour: A guided tour of the Energy Academy Europe was conducted to observe and document the building's physical characteristics, layout, and functionality. The tour was guided by key personnel from construction managers of University of Groningen.

The data collection methods used for both case studies were selected based on the specific research questions and objectives, and were aimed at gathering comprehensive and diverse data to ensure a thorough analysis.

3.3 Data analysis procedure

For the Zeb Laboratory case study, the data collected from interviews with the project manager, designer, and contractor and for the Energy Academy Europe project, the data collected from interviews with the the client and advisors were transcribed and analyzed using content analysis. The purpose of this analysis was to identify key themes and patterns in the data.

In this thesis, a manual content analysis technique known as open coding was employed to extract themes and patterns from the transcriptions of the interviews. Open coding allowed me to approach the data without any preconceived categories, providing flexibility and the opportunity for new insights to emerge. I began by thoroughly reading the transcripts and taking note of intriguing ideas, concepts, and phrases. By generating descriptive codes that captured the essence of each segment, I was able to break down the data into meaningful units. As I progressed, I carefully examined the relationships between these codes, identifying connections and developing categories. Through this iterative process, themes and patterns started to organically surface, leading to a comprehensive understanding of the interview data.

The post-occupancy survey results were also analyzed using descriptive statistics to provide an overview of the occupants' satisfaction with the building. In my thesis, I employed descriptive statistics as a method to analyze the survey data I collected. Descriptive statistics allowed me to summarize and describe the main characteristics of the survey responses. Through measures of central tendency, such as the mean, median, and mode, I was able to determine the typical or average response to each survey question. Measures of variability, including the range, variance, and standard deviation, helped me assess the spread or dispersion of the responses. By calculating these statistical measures, I gained insights into the distribution of responses and the variability among participants. Additionally, I utilized graphical representations, such as histograms and bar charts, to visually present the survey data and highlight any patterns or trends. Finally, the walk-through notes were used to support and verify the findings from the interviews and survey.

Both case studies utilized a qualitative approach to data analysis, which allowed for a more in-depth exploration of the themes and patterns identified in the data. The results were then compared and analyzed to draw conclusions about the success of each project and identify similarities and differences between them. Additionally, in both cases the observations made during the guided tour of the buildings were used to support and verify the findings from the interviews.

It is important to note that data analysis is an ongoing process that involves constantly revisiting and re-evaluating the data to ensure that the findings are accurate and reliable. This iterative approach to data analysis was employed in both case studies to ensure that the conclusions drawn were well-supported by the data.

3.4 Rationale for Methodological Choices

The chosen data collection methods were driven by the specific research questions and objectives of the study. Interviews were conducted with key personnel involved in the building projects, including project managers, designers, contractors, advisors, and client representatives. These interviews provided valuable insights into the factors and activities that contribute to use value in the early phases of building projects. The semi-structured approach ensured consistency and allowed for follow-up questions, facilitating a deeper exploration of the subject matter.

In addition to interviews, surveys were distributed to the occupants of the buildings to gather their feedback on the building's performance and usability. Surveys offered a structured and standardized approach to collect data from a larger sample size. By incorporating both open-ended and closed-ended questions, the survey provided a combination of qualitative and quantitative data. Open-ended questions allowed respondents to express their opinions and provide detailed feedback, while closed-ended questions enabled quantitative analysis and statistical summaries. Surveys were well-suited for capturing occupants' satisfaction levels, identifying areas for improvement, and obtaining a broader perspective on the building's performance.

To complement the interviews and surveys, walkthrough and guided tour were conducted to observe and document the physical characteristics, layout, and functionality of the buildings. These methods allowed for direct experience and assessment of the built environment, providing firsthand knowledge of the buildings' features and their contribution to use value. Occupants from different floors and sides of the buildings were selected to capture diverse perspectives and experiences. Walkthroughs and guided tours added valuable qualitative data that complemented the insights obtained from interviews and surveys.

The selection of these specific data collection methods was guided by their relevance to the research questions and objectives of the study. Interviews, surveys, and walkthroughs/guided tours aligned with the need to explore critical factors and activities in building projects, assess user satisfaction, and gather insights for potential enhancements and future projects. Furthermore, these methods provided a depth and breadth of data by incorporating different types of data (qualitative insights, quantitative data, and qualitative observations), enabling a comprehensive analysis of the research questions and enhancing the validity and reliability of the findings.

Moreover, the chosen data collection methods were suitable for capturing multiple perspectives. Interviews involved key personnel from various roles, surveys captured feedback from building occupants, and walkthroughs/guided tours engaged individuals with direct experience in the buildings. This multi-stakeholder approach ensured a comprehensive understanding of use value and facilitated the identification of diverse insights and recommendations.

Lastly, the chosen data collection methods were deemed feasible and practical within the scope and resources of the study. Interviews, surveys, and walkthroughs/guided tours could be efficiently conducted, considering the availability of key personnel and building occupants.

By employing these specific data collection methods, the study was able to gather a rich and diverse data set that effectively addressed the research questions and objectives.

3.5 Ethical considerations

The necessary permission to process personal data for my master's thesis has been obtained, as the Notification Form for personal data was completed and submitted to the Norwegian Centre for Research Data (NSD). The form outlined the nature of the data processing involved in my research project, specifically the recording of the informants' voices during interviews. Additionally, a consent form was provided to the informants, clearly informing them about the recording and explaining the purpose and use of their personal data. By adhering to these protocols and receiving approval from NSD, compliance with legal requirements and the principles of data protection has been ensured in my research project.

Moreover, informed consent was obtained from all participants involved in the study to ensure that the research was conducted in an ethical manner (appendix E). The nature and purpose of the study were explained to the participants, and they were made aware of their right to withdraw from the study at any time. The confidentiality of participants was also ensured by not disclosing their identities in any publications or reports.

In addition, in the development of this thesis, a portion of the theory section draws upon the knowledge and groundwork established during the Specialisation Project course, which was a mandatory component completed in the previous semester. The purpose of this course was to provide a solid foundation for the subsequent thesis work. Specifically, the theory section of this thesis incorporates and builds upon the theoretical framework established in the previous course. The insights and concepts presented in the corresponding report from the Specialisation Project course have been instrumental in shaping the theoretical underpinnings discussed in the sections 2.1, 2.3, 2.4.1, 2.4.2, 2.4.3, 2.8, 2.9 and 2.10 of this thesis.

CHAPTER

FOUR

RESULTS

4.1 Case study 1: ZEB Laboratory NTNU

The ZEB Laboratory is located in Trondheim at the NTNU Gløshaugen campus and is a living office laboratory. It is designed to accommodate the ZEB-COM ambition level over 60 years. The laboratory is situated near the existing laboratory facilities of SINTEF Community and NTNU Department of Civil and Environmental Engineering. The design process started in 2016, the construction work began on May 7, 2019, and the laboratory was planned to be ready for test operation in August 2020. The test operation period was planned for six months.

ZEB Laboratory had a vision of being an arena where new and innovative components and solutions are developed, investigated, tested, and demonstrated in mutual interaction with building occupants. It aimed to serve as a basis for knowledge development at an international level, as well as for international competitive industrial development. Moreover, it is an example for new and retrofitted zero-emission buildings, a research arena for developing zero-emission buildings, an arena for risk reduction when implementing zero-emission building technologies, and an international resource within the research area (Time et al., 2019).

The ZEB Laboratory is a full-scale office building where building façades, components, and technical systems can be modified and replaced. It forms a living laboratory, which means that it is used by people as an ordinary office building or for educational purposes, becoming a source of continuous experimental data. Demonstrating and investigating new technologies in a full-scale office building is important to reduce risk for the first movers willing to start implementing zero-emission building levels in their designs and constructions. The adaptability of the building/laboratory will make it possible to investigate different building configurations, technologies, and usages (Time et al., 2019). Figure 4.1.1 shows the ZEB Lab as a living office laboratory.

Figure 4.1.1: ZEB Laboratory, Photo taken by the author.

4.1.1 Project objectives

In front end of the project, NTNU and SINTEF set ambitions for the ZEB Laboratory, which are in prioritized order:

- The building should be a model project and achieve ZEB-COM level (simulated over a 60 years perspective) (figure 4.1.2)
- Separate control and measurement systems
- Flexibility in design and use of energy and climatisation systems
- Flexibility in design of working space
- Continuous selection of new materials and improvements by rebuilding parts of the facades
- Adaptation of the building to climate change (*ZEB-laboratoriet Innovasjonskatalog*, 2021)

The ZEB Laboratory is intended to be:

- A laboratory for the development of internationally competitive industry

- A laboratory for knowledge generation at a high international level
- A research arena for the development of climate-adapted zero-emission buildings
- An arena for reducing risk when implementing solutions for zero-emission buildings
- A national resource for all research organizations in the field (*ZEB-laboratoriet Innovasjonskatalog*, 2021)

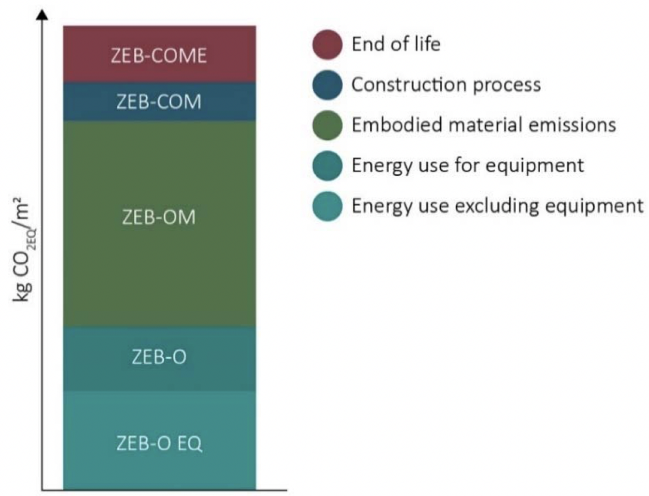


Figure 4.1.2: The ZEB (Zero Emission Building) ambition levels. The illustration shows what is included in the climate gas emission calculation. Local renewable energy production should compensate for emissions related to materials/equipment, construction and use. (Time et al., 2019)

4.1.2 Technical characteristics

The ZEB Laboratory was constructed using loadbearing wood materials. The building featured Glulam columns and CLT elements in floors, elevator shafts, and some stiffening elements. The outer walls are wooden frames insulated with glass wool to keep embodied emissions low and enable the achievement of ZEB-COM. The building was cladded with dark PV-cells located on the roof, the whole southern façade, and part of the other facades. Burnt wooden panels were used elsewhere to achieve a uniform appearance and keep embodied emissions low (figure 4.1.3) (Time et al., 2019).

Figure 4.1.3: ZEB Laboratory, Southern and Western façade, Photo taken by the author.

The south façade of the first floor, including the twin rooms, was designed to allow for the whole façade or window elements to be replaced and rebuilt. This enables the application of new products, components, and technologies to investigate and optimize the building envelope and building performance. This feature allows for investigations of the performance and the effect of products and envelope properties, such as insulation levels, façade configurations, including solar shading and natural ventilation strategies, on energy use and user comfort (Time et al., 2019).

Furthermore, a part of the air cavity below the PV panels (photovoltaic panels) was separated from the rest of the roof to facilitate studies on temperature, relative humidity, and air pressure underneath the PV roofing. This feature also prepared the arena for future experiments that can utilize the heat below the PV panels in the climatization of the building. Additionally, the cavity functions as a solar roof, and experiments can investigate the potential for improving the efficiency of PV panels, the efficiency of performance for the building's heat pump, and direct charging of the building's thermal PCM (Phase Change Material) storage (Time et al., 2019).

Temperature, relative humidity, and air pressure are measured behind the PV and wooden claddings and on the wind barrier on the vertical facades to characterize long-term climate conditions for tapes and barriers. These investigations have provided insights into the building's performance and helped optimize the technologies used to construct and operate the ZEB Laboratory (Time et al., 2019).

The twin rooms on the second floor of the ZEB Laboratory were designed based on the expertise gained from the ZEB Test Cell, which is a small laboratory to investigate how energy use and comfort parameters, including indoor temperature, vary with different active and passive facade solutions (figure 4.1.4). Each of these rooms represents a 66 m2 office space, with independent HVAC systems, a dedicated control room and a larger number of sensors than other spaces in the laboratory (figure 4.1.5) (Time et al., 2019).

All parameters that influence occupants' comfort are monitored, such as temperature, relative humidity, carbon dioxide concentration, air change rates, and illuminance, among others. Siemens provided the data acquisition and control system, which is more robust but less flexible than the system realized in the ZEB Test Cell. This makes the two laboratories complementary facilities, where solutions can be implemented in the ZEB Test Cell and tested on a larger scale in the ZEB Laboratory. Similar to the ZEB Test Cell, the twin rooms in the ZEB Laboratory enable comparative and close to calorimetric studies. This means that the facades' materials and components can be replaced to investigate their effect on energy use and user comfort. The twin rooms offer a valuable testing ground for new products, components, and technologies in a controlled and realistic environment (Time et al., 2019).

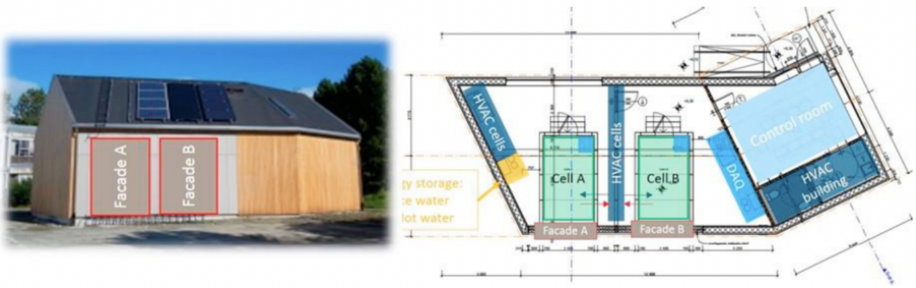


Figure 4.1.4: ZEB Test Cell Laboratory; View from south and Plan of the building (Goia, Schlemminger, and Gustavsen, 2017)

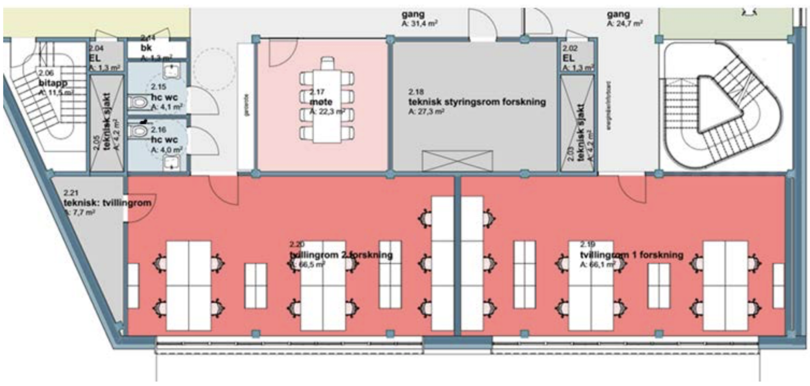


Figure 4.1.5: Plan for the twin rooms on the fourth floor of ZEB Laboratory with separate technical rooms (preliminary) (Time et al., 2019)

The ZEB Laboratory is an advanced facility equipped with building integrated photovoltaic (BIPV) panels and a heat pump that can use various heat sources including heat recovery from service and outside air. The facility provides a unique opportunity to investigate the combinations of available renewable energy production and the centralized electricity grid that meets the zero-emission building requirements. To ensure efficient utilization of the heat pump, a twin phase change material (PCM) heat storage system is installed in the building, which is used to recover thermal energy from the BIPV roof and act as a thermal energy buffer (figure 4.1.7). This system is flexible, allowing for future research and development of PCM-based heat storage systems. The energy balance of the entire system is shown in Figure 4.1.6 (**Nocente2022**).

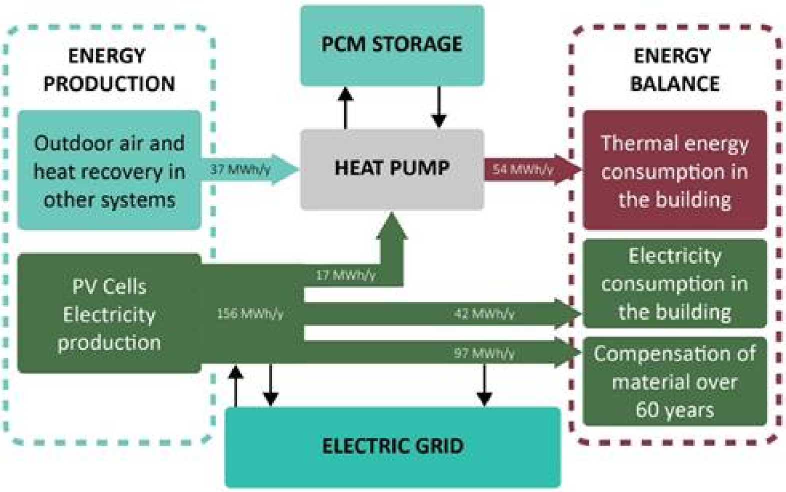


Figure 4.1.6: Schematic view of energy supply and use for the ZEB Laboratory (**Nocente2022**)

Figure 4.1.7: PCM-based heat storage system, Photo taken by the author.

The laboratory's grid integration capabilities allow for experiments on the interface between buildings (ZEBs) and smart power grids, as well as district heating and cooling grids. This feature enables the study of optimal predictive control strategies, load shifting, and energy storage performance. With these advanced capabilities, the ZEB Laboratory provides a unique and versatile environment for research and development in the field of zero-emission buildings (Time et al., 2019).

The building has been equipped to test various ventilation strategies while monitoring the user's satisfaction and energy consumption. The ventilation options include natural ventilation, mechanical ventilation, or a combination of both (hybrid or mixed-mode ventilation). For natural ventilation, some of the windows in the building can be manually opened, while others are equipped with an automatic opening system. The window design allows for cross ventilation when opened, ensuring effective ventilation throughout the building (Time et al., 2019).

The building's main staircase has been designed to function as an extraction point for both mechanical and natural ventilation air. A fire hatch located on the top of the stairs has been designed to operate as an outlet for natural ventilation, driven by the chimney effect (thermal buoyancy). Additionally, the twin rooms can be ventilated naturally by windows and by extracting air through ducts configured in different ways (figure 4.1.8)(Time et al., 2019).

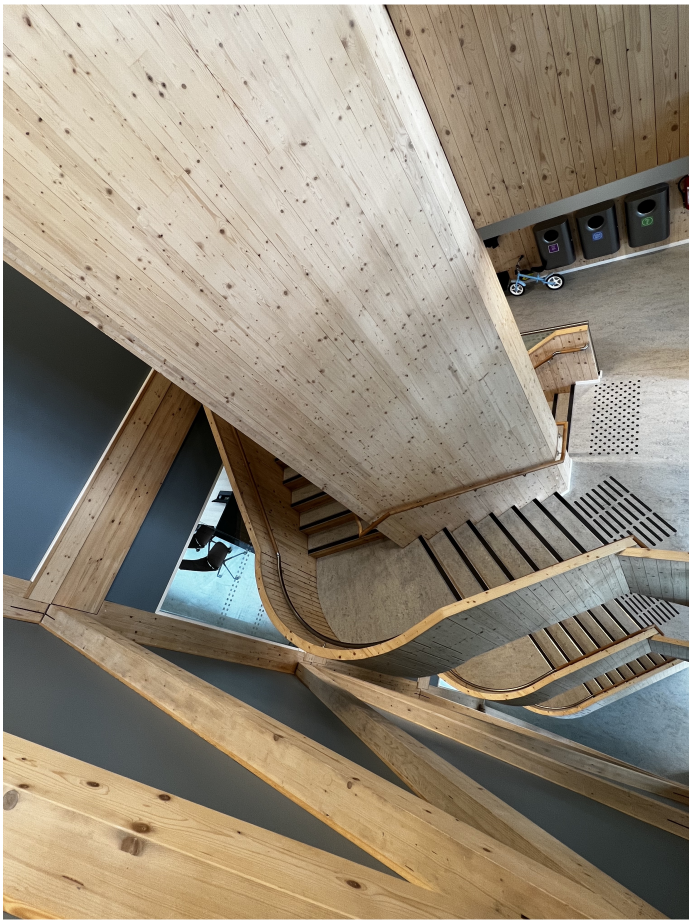


Figure 4.1.8: Main staircase in the ZEB Laboratory, Photo taken by the author.

The building is designed to explore different ventilation strategies with a focus on monitoring user satisfaction and energy use. The building is equipped for natural ventilation, mechanical ventilation, or a combination of both. Natural ventilation is achieved by opening windows manually or automatically. The windows are designed to allow cross ventilation when opened. The main staircase is designed to function as an extract for both mechanical and natural ventilation air, and a fire hatch on top of the stairs serves as an outlet for natural ventilation, driven by the chimney effect (Time et al., 2019).

The twin rooms are equipped with natural ventilation through windows and air extraction via ducts in various configurations. In addition, the building is equipped with a central mechanical ventilation system that relies on the principle of displacement ventilation (Time et al., 2019).

Different air distribution systems were designed for each of the four floors. The ground floor air is supplied through inlet devices in the floor, while the first floor relies on porous ceiling boards in the suspended ceiling, and the second floor uses slots, and the third floor uses wall air terminals placed at floor level. The exhaust includes a heat recovery unit with an annual average efficiency greater than 80%, and the heating is achieved using a central heat pump with the possibility of PCM accumulation. No mechanical cooling system is installed (Time et al., 2019).

The twin rooms are specially equipped with their technical rooms and independent HVAC systems, including dedicated Air Handling Units (AHUs) for preprocessing the air before entering the room. The twin rooms have the option of applying both heating and cooling to the internal environment via heating/cooling batteries connected to the central water-based system and additional electric heating batteries. The twin rooms are also equipped with an abundance of sensors to monitor and control systems for indoor climate, energy supply, ventilation strategies, cooling, space heating, lighting, and window shading (Time et al., 2019).

The building is equipped with an advanced indoor positioning system developed by Siemens that enables real-time tracking of occupants, known as ZEB app (figure 4.1.9). The system uses wireless sensors mounted on the ceiling to establish a communication network with the occupants' smartphones, allowing for precise location detection through triangulation algorithms. The data collected from the system, including occupancy and position information, is stored on the SINTEF API server and can be used for research purposes. The system also offers a range of services to the occupants, which can be accessed through a mobile app or browser. These services include locating colleagues, equipment, meeting rooms, and exits within the building. Additionally, users can choose to make their location visible or not, depending on their preferences. The system is designed to be flexible, allowing for modifications to be made to address changes in building management or experimental requirements. Overall, the indoor positioning system enhances the building's functionality and provides valuable data for research purposes (Time et al., 2019).

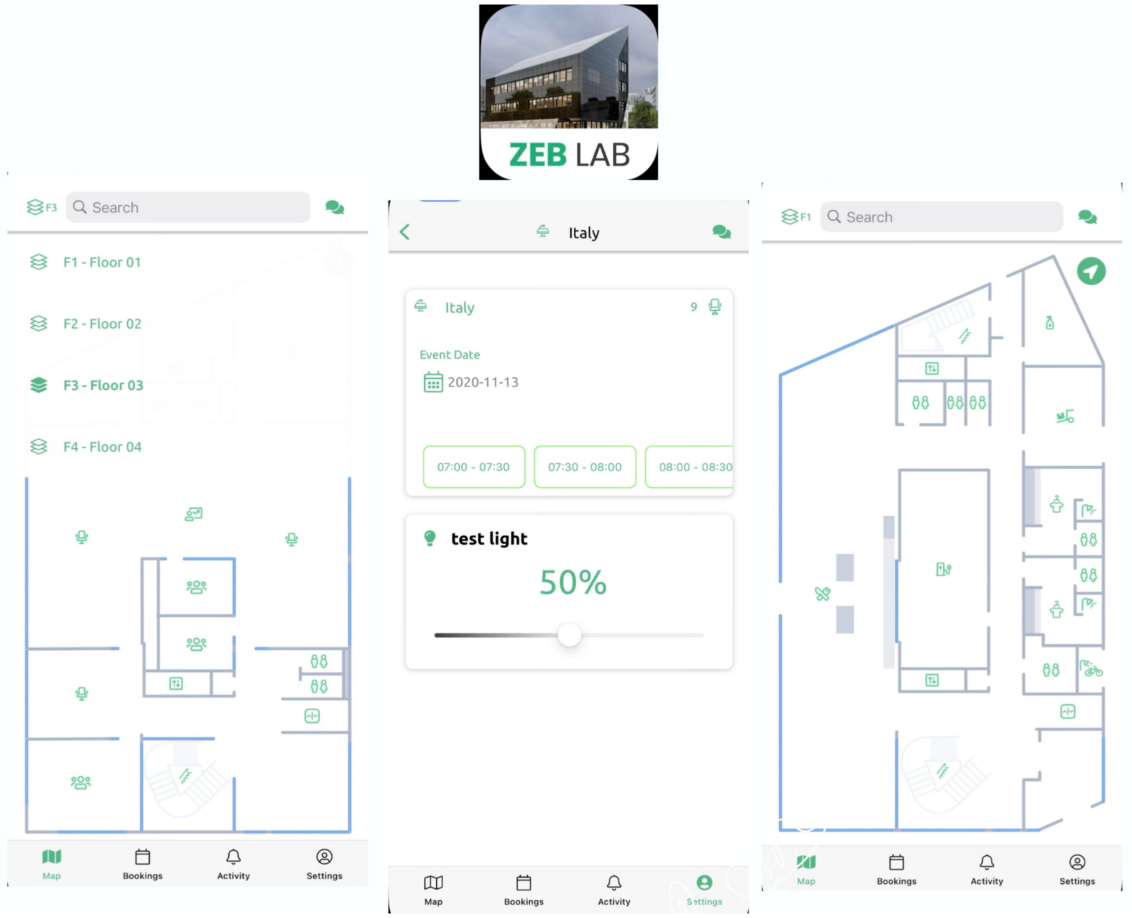


Figure 4.1.9: ZEB App (App Store)

The building is equipped with an advanced system consisting of a Building Energy Management System (BEMS) and a time series database system provided by Siemens. This common platform allows for seamless control and monitoring of the physical installations in the building and twin rooms using the same technology. In each of the twin rooms, a Siemens Total Room Control system was installed, enabling both research and normal operation (Time et al., 2019).

The building is mainly operated by NTNU Campus Service, requiring connection to the campus' central building energy management system that Campus Service operations already uses. However, researchers can "overtake" the building or parts of it, and operate it using their own algorithms through a research simulation server. This offers researchers the flexibility to control the building as needed for their experiments. A schematic view of the control system is illustrated in Figure 4.1.10, depicting the different components of the BEMS (Building Energy Management Systems) and their interaction with the physical installations in the building and twin rooms. The BEMS will collect and store data from sensors, and use this information to control and optimize the operation of the building systems. The time series database system will provide a historical record of the collected data, allowing for analysis and visualization of building performance over time (Time et al., 2019).

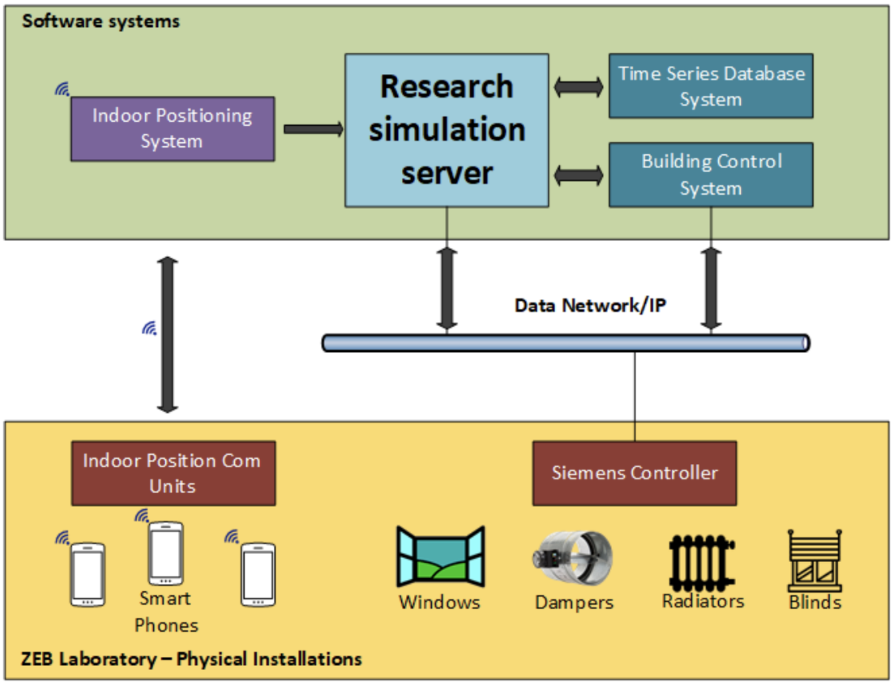


Figure 4.1.10: A schematic view of the monitoring and control system (Time et al., 2019)

4.1.3 Collaborative Project Delivey Model for ZEB laboratory Project

The development of buildings that do not contribute to greenhouse gas emissions through production, operation, and disposal - zero-emission buildings - required rethinking in the construction process. There was a need to develop several new concepts and solutions, as well as new knowledge about processes and strategies for achieving zero-emission buildings (*ZEB-laboratoriet Innovasjonskatalog*, 2021).

The demand for sustainable and high-performance buildings presents challenges across various analytical levels. Firstly, it requires a fresh perspective on delivering buildings that meet these criteria. Secondly, the construction industry, which has experienced significant fragmentation, necessitates greater integration in project delivery. Collaborative project delivery methods have emerged as potential solutions to address this integration gap and help fulfill clients' aspirations of delivering sustainable and high-performing buildings (Engebø et al., 2022) .

The ZEB Laboratory, a cutting-edge facility designed for the development and testing of zero-emission building technologies, was the result of a collaborative effort between a leading contractor and its team of consultants and subcontractors. Unlike traditional building projects where design and solutions are predetermined, the ZEB Laboratory's design and solutions were selected during the design process to best fulfill the high ambitions for the building (Time et al., 2019).

NTNU and SINTEF, along with a group of highly skilled architects, designers, and contractors, worked together to develop the laboratory. In addition, professionals from renowned Norwegian research centers such as Zero Emission Buildings (ZEB), Zero Emission Neighbourhoods (ZEN), and Klima 2050 were included to provide their specialist expertise. The procurement and development of the ZEB Laboratory followed a novel project delivery model, a collaborative contract, which was detailed in the announcement. This approach allowed for a more collaborative effort between all parties involved and enabled the development of a unique and innovative facility (Time et al., 2019).

Collaboration between stakeholders was necessary at the start to develop a project together. In the ZEB laboratory, the ZEB methodology have been developed and integrated into the organizational elements used in the project - Integrated Concurrent Engineering (ICE) - with the co-location of the project team in a physical "Big Room". Then, the building owner and the group met once a week to "crush" the project across organizational and professional boundaries (*ZEB-laboratoriet Innovasjonskatalog*, 2021).

Participants worked both collectively and in thematically divided groups, and in addition, a series of ZEB workshops were developed and conducted. The stakeholders and building owner set common goals and solved problems together, evaluated the process, and gained an understanding that it was the simultaneous, collaborative iterations that over time created value and achieved ZEB goals (figure 4.1.11). This was the first time the ZEB methodology has been integrated into this type of collaboration (*ZEB-laboratoriet Innovasjonskatalog*, 2021).

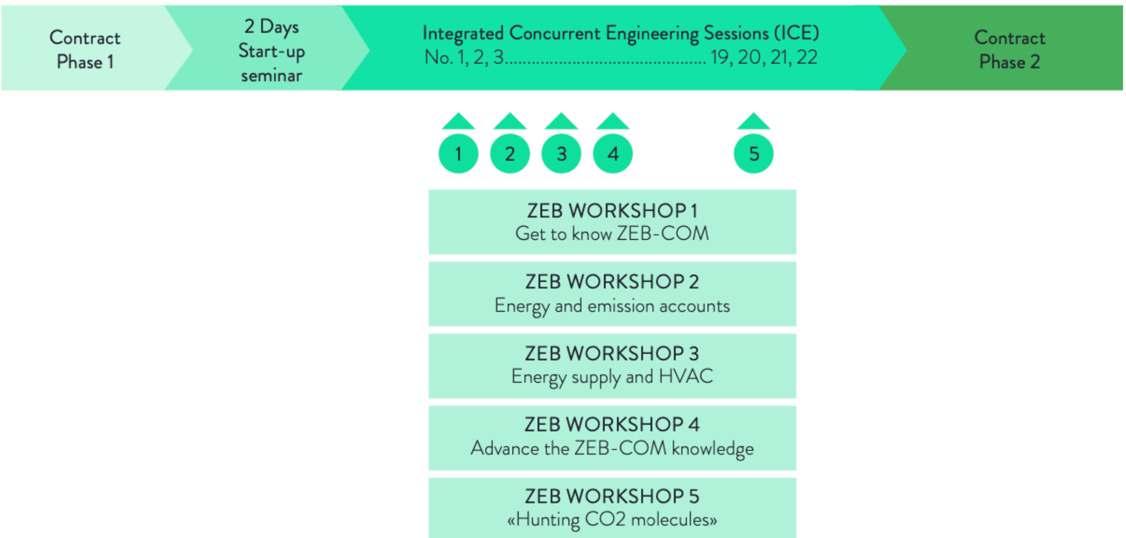


Figure 4.1.11: Collaborative implementation with ZEB methodology (*ZEB-laboratoriet Innovasjonskatalog*, 2021)

Following the tendering process, the client engaged a contractor-led project team on a "fee-for-service" basis, starting from the concept development phase until the approval of the concept (Engebø et al., 2022). In fact, SINTEF/NTNU chose a collaborative approach for the two-stage design-build contract, involving a consortium of contractors, architects, designers, and subcontractors. In the first stage, the consortium had settlement based on time spent, and both parties theoretically had the option to withdraw before the second stage. The client provided the consortium with a set of ambitions as a planning foundation and challenged them to prioritize functionality and thereby value for the users (Atle Engebø, 2020).

In addition, the contractual measures such as early involvement, kickoff seminars, target pricing, and open book are intended to ensure the right expertise at the right time and create an understanding of the function. However, the client believed that these contractual measures were not sufficient to achieve and maintain good collaboration. Therefore, the contractual measures were made flexible enough to allow the actors to influence the collaboration through organizational and cultural means (Atle Engebø, 2020).

After optimization phase of the concept, a design-build contract was signed between the contractor and the client for project execution. The project team comprised the main contractor, the architect, the sub-contractors, and the engineers, all of whom were contractually connected to the main contractor. Each participant in the project team represented a different role within the project. The client, as the organization with a direct contract with the main contractor, had its own designated representatives among the project participants, who actively contributed to the project's progress (Engebø et al., 2022).

After the contract was signed, the project started with a two-day start-up seminar. This seminar played a crucial role in establishing relationships among the participants, serving as a platform for introductions and fostering the initial partnership between the client and the project team. The selection of the contractor-led project team was based on their expertise and track record, ensuring their capability to deliver. Evaluating the team composition as a criterion helped guarantee the right mix of skills and expertise within the project team (Engebø et al., 2022).

The key organizational element utilized in the project was concurrent engineering (Integrated Concurrent Engineering-ICE) with the co-location of the project team in a physical Big Room. In this method, the client and the group met once a week to collaboratively work on the project across organizational and disciplinary boundaries. The participants worked both collectively and in thematically divided groups. The working method had similarities to more traditional processes, but the intention behind the work methodology went beyond weekly status updates. The actors solved problems together and gained an understanding that it was the concurrent, collective iterations that created value for the client over time (Atle Engebø, 2020).

Project team sessions took place every Tuesday from 08:30 to around 14:00 throughout the design phase. The sessions followed a standardized format. They began with the design manager reviewing the agenda, followed by a round table discussion. The team then followed up on tasks from the previous week and the client had its dedicated time for input. Afterward, the team divided into smaller working groups for thematic meetings. At mid-day, the participants shared lunch together, and the day concluded with a summary meeting to define tasks for the following week. The participants involved were: the design manager (contractor), project manager (contractor), BIM-coordinator (con- tractor), project developer (contractor), architect, architect assistant (architect), project manager (client), building physics expert (client), laboratory design expert (client), sustainability expert (client), ventilation expert (client), engineer (structural), engineer (HVAC), engineer (electricity), engin- eer (automation), and the Integrated Technical Building (ITB)-coordinator (Engebø et al., 2022).

The contractual and organizational measures provided the client and the group with a collaborative environment where the focus was on delivering value for the client. However, it is also important for the project to meet the needs of the individuals involved. This involves creating engagement and motivation for the tasks at hand. To succeed in collaboration, individuals need to feel that they gain something beyond financial rewards – for example, being intellectually challenged and having opportunities for personal development. In the case of the ZEB laboratory, the client fostered personal engagement and facilitated professional development through training in zero-emission buildings. The contractual and organizational measures aligned the organizations in the same direction, while the cultural measures aligned the individuals in the same direction (Atle Engebø, 2020).

In the main contract, there were three elements that were not explicitly included: 'Inclusion of architect in the contract', 'Inclusion of sub-contractors in the contract', and 'Inclusion of consultant in the contract'. The formal contractual arrangement was solely between the main contractor and the client. The main contractor then managed separate contracts with the other participants involved in the project. It is noteworthy that despite not being part of the formal agreement between the contractor and client, the participants still felt included. This feeling of inclusion can be attributed to the presence of trustworthy management practices, which created an environment of inclusivity for all participants, irrespective of their involvement in the formal agreement. Additionally, the formal agreement also incorporated a pain/gain mechanism, further contributing to the atmosphere of trust and collaboration among the project stakeholders (Engebø et al., 2022).

The long-term collaboration between different organizations in the Integrated Concurrent Engineering approach can face challenges due to individual commitments within each organization. It was anticipated that some participants would be unable to fully dedicate themselves to the project, resulting in the need for replacements within the team. For instance, the ITB-coordinator had to be replaced temporarily due to parental leave, and the new coordinator faced difficulties integrating into the project group. Another issue observed was the communication barrier faced by the system-integrator engineer, who struggled to convey technical concepts in a language understandable to the rest of the team. As a result, the client couldn't fully appreciate the value of the proposed solutions, leading to strained communication within the team. To address this, the client initiated a series of one-on-one meetings, which resolved the situation (Engebø et al., 2022).

In contrast to traditional design approaches, the client emphasized the importance of seeking innovative solutions that went beyond conventional technical approaches, and they placed trust in the team's ability to deliver on this expectation. However, during the initial stages of the project, some participants displayed hesitance as this approach deviated from prevailing industry norms. The client expressed frustration over the participants' initial reluctance to embrace this mindset. However, through ongoing interactions during the integrated concurrent engineering sessions, the team gradually began to move beyond established industry standards. An illustrative example of this shift was observed when the team had to decide on the preferred HVAC concept. They demonstrated a willingness to take calculated risks in terms of design solutions, project scope, and budget, surpassing the typical level of risk-taking observed in similar processes (Engebø et al., 2022).

Furthermore, it was notable that the project participants demonstrated a fair and understanding attitude towards each other when expectations were not fully met, such as instances where prerequisite tasks were unfinished before the Big-Room sessions. Among the various interfaces, the relationship between the architect and the contractor posed the most significant challenge. The contractor frequently had to reject suggestions due to cost considerations, which left the architect feeling frustrated and pulled in different directions. Although such iterations could potentially strain trust between the two parties, it is worth mentioning that the architect recognized the commercial realities involved, while the contractor-client made extra efforts to provide the architect with alternative avenues for creative expression (Engebø et al., 2022).

Support from management played a crucial role in the project's success. The design manager, representing the management, played a central role in facilitating a structured and standardized process. The temporary organization comprised a design manager, a project manager from the contractor, and a project manager from the client. The client project manager served as the bridge between the project and the client organization, while the contractor's project manager had overall responsibility for the supply chain. The design manager, on the other hand, was responsible for ensuring technical coordination. However, it was observed that some participants initially struggled to adapt to this hierarchical decision-making structure. This could be attributed to mixed signals from the management team. While the design manager exhibited a supportive leadership style, others relied on their authority and charismatic presence to assert their influence when necessary. This discrepancy in management approaches created a certain level of ambiguity and required participants to navigate through different leadership dynamics(Engebø et al., 2022).

To conclude, Atle Engebø and his colleagues who conducted a research on the design phase of ZEB laboratory believed that given the complexity of sustainable high-performance projects, it is crucial for all parties involved to establish a foundation of trust. This is because the process is characterized by uncertainty and a high degree of interdependence. Therefore, it is recommended that the client and the supplier establish their relationship based on factors beyond just price, such as the composition of the delivery team. Building trust should commence immediately after the contract signing, and team-building activities like a start-up seminar can be instrumental in fostering a sense of trust and collaboration. In addition, the project should be organized in a manner that creates an environment resembling a unified organization. One effective approach is to adopt integrated concurrent engineering, which promotes cross-functional collaboration and enables all stakeholders to work together seamlessly. This integration helps streamline decision-making processes, enhance communication, and facilitate a shared understanding of project objectives (Engebø et al., 2022).

Furthermore, trust-building initiatives through supportive management and a focus on shared interests can yield significant benefits. When participants have confidence that their fellow team members are acting in the best interests of the project and its stakeholders, it frees up time, capacity, and resources that can be directed towards value creation. This collaborative environment enables individuals to focus on their core tasks and contributes to a more efficient and effective project delivery process. Overall, practitioners should prioritize trust-building efforts, encourage a unified organizational structure, and foster an environment of shared interests in order to successfully deliver sustainable high-performance buildings (Engebø et al., 2022).

4.1.4 Interview findings: unveiling perspectives of project key players

The purpose of the interviews conducted for the ZEB Laboratory project was to gather insights and perspectives from key individuals involved in the project, including the contractor, designer, and the client.

For the research on the ZEB Laboratory project, a total of three interviews were conducted. The participants selected for the interviews were representatives from three key roles involved in the project: the client, the designer, and the contractor. The selection criteria for these participants were their active engagement and involvement in the project, ensuring that they possess firsthand knowledge and experiences related to the project. The interview process followed a semi-structured approach, allowing for a combination of pre-planned questions and the flexibility to ask follow-up questions based on the participants' responses.

An interview guide was prepared in advance, which included a set of pre-determined questions relevant to the research objectives. These questions were designed to elicit insights on topics such as the early phase activities, decision-making processes, challenges faced, value acheived and delivered, and lessons learned (Appendix A). During the interviews, the interviewer utilized the interview guide as a reference to ensure coverage of all important areas. However, in a semi-structured format, there was room for the interviewer to ask additional open-ended questions or seek clarification on specific points based on the participants' responses. This approach allowed for a more dynamic and interactive conversation, enabling a deeper exploration of the participants' perspectives and experiences.

The identities of the interviewees have been anonymized to ensure confidentiality, and they will be referred to using coded names. Informant 1N, representing the client, provided valuable insights into the project requirements and expectations. Informant 2A, serving as the Architecture Team Representative, shared their expertise on the design and aspects of the laboratory. Lastly, Informant 3C, the Contractor Team Representative, offered valuable perspectives on the project's implementation and construction. The anonymized transcriptions of the interviews can be found in Appendix B, providing a comprehensive record of the participants' responses while protecting their identities.

4.1.5 Findings from post occupancy survey

As it is discussed in the section 2.8, Post-occupancy evaluation (POE) is a method for measuring building performance in terms of meeting design intent, and identifying any gaps between actual and modelled performances in the of aspects indoor environmental quality (IEQ), occupant satisfaction, energy consumption, etc (Li, Froese, and Brager, 2018).

In this thesis, a structured anonymous POE assessment was conducted in ZEB laboratory at NTNU campus. This study aims to help close the building performance gap, optimize building operation systems, and improve occupants' satisfaction levels as well as helping campus development team to identify important factors for future projects. In this research, the questionnaire survey (Appendix C) investigated the influences of environmental factors on user satisfaction from the main aspects of building overall design, physical environment, acoustics, lightning, thermal comfort, indoor air quality, lighting, building systems, ventilation, amenities, equipment, workspace, its functionality and safety, sustainability features and image, learning opportunities, user engagement in different phases and other non-environmental factors, such as the background information about age, working time in building, and years of experience.

4.1.5.1 background information

The post-occupancy evaluation survey of ZEB Laboratory at NTNU included general questions regarding the demographics of the respondents. The survey collected data on the age, employer, years of work experience, and length of time working in the ZEB laboratory. The data indicated that the majority of the respondents were between the ages of 36 and 45 (46.7%), 26.7% were between 26 to 35, 13.3% between 56 to 56, 6.7% between 46 to 55 and 6.7% between 18 to 25 (figure 4.1.12). The majority of respondents (73.3%) were employed by NTNU, while 26.7% were employed by SINTEF (figure 4.1.13). The respondents had an average of 14 years of work experience (figure 4.1.14). The majority of respondents had been working in the ZEB laboratory for 2 years. In terms of work schedules, the majority of respondents worked in the laboratory from 8:00 to 17:00.

Age

Number of submissions: **15**

Submissions	Count	% of submissions
18-25	1	6.7%
26-35	4	26.7%
36-45	7	46.7%
46-55	1	6.7%
56-65	2	13.3%
66-75	0	0%
76-85	0	0%
86-95	0	0%

Figure 4.1.12: background age information

Employer

Number of submissions: **15**

Submissions	Count	% of submissions
Sintef	4	26.7%
NTNU	11	73.3%

Figure 4.1.13: background employer information

years of work experience

Number of submissions: **15**

Submissions	Count	% of submissions
51-60	0	0%
41-50	0	0%
31-40	2	13.3%
21-30	1	6.7%
11-20	6	40%
6-10	3	20%
0-5	3	20%

Figure 4.1.14: background work experience information

Analysis and discussions: The demographic characteristics of the survey respondents in the post-occupancy evaluation of the ZEB Laboratory have provided valuable insights into the user base and their experiences within the office building. Understanding the demographics of the respondents helps us contextualize the survey findings and better interpret the results.

The age distribution of the respondents revealed that the majority fell within the 36 to 45 age range, comprising 46.7% of the participants. This finding suggests that the ZEB Laboratory primarily caters to individuals in their late thirties to mid-forties. The presence of a significant proportion of respondents in the 26 to 35 age range (26.7%) indicates a younger demographic within the user base. These age demographics may influence the preferences, needs, and expectations of the users, as different age groups may have varying workplace requirements and comfort levels.

The employment distribution among the respondents showed that the majority (73.3%) were employed by NTNU, while 26.7% were employed by SINTEF. This distribution reflects a diverse mix of academic staff, researchers, and industry professionals within the ZEB Laboratory. The involvement of both academia and industry in the survey suggests a multidisciplinary approach to the evaluation, which can enhance the comprehensiveness and applicability of the findings.

The average years of work experience among the respondents were 14, indicating a group of professionals with considerable expertise and knowledge in their respective fields. The level of work experience can significantly influence individuals' perceptions and evaluations of their work environment. Experienced professionals may have developed a refined understanding of their needs and preferences, potentially affecting their assessment of the user experience in the ZEB Laboratory.

The length of time working in the ZEB Laboratory varied among the respondents, with the majority having a tenure of 2 years. This suggests that majority of respondents have been working in ZEB laboratory since the building have been occupied. The different levels of familiarity with the laboratory environment can influence participants' ability to assess the design, functionality, and overall user experience. Those with longer tenures may have a deeper understanding of the space, while newcomers may provide fresh perspectives on the user experience.

The reported work schedule of the majority of respondents aligning with standard office hours (8:00 to 17:00) implies a conventional working pattern within the ZEB Laboratory. This finding has implications for the evaluation of the user experience, as the office environment and its amenities may cater to the needs of individuals working within these typical hours. Understanding the work schedules of the respondents helps identify potential patterns or challenges related to productivity, comfort, and engagement during specific times of the day.

In conclusion, the demographic information obtained from the survey respondents provides valuable context for understanding the user experience within the ZEB Laboratory. The age distribution, employment affiliations, years of work experience, length of time working in the laboratory, and work schedules all contribute to a comprehensive analysis of the survey results. These demographic factors shed light on the diverse perspectives and experiences of the respondents, influencing their evaluations and expectations of the office building. Considering these demographics enhances the understanding of the survey findings and enables more targeted recommendations for optimizing the user experience in the ZEB Laboratory.

4.1.5.2 Physical environment

The post-occupancy evaluation survey of the ZEB Laboratory at NTNU also included questions regarding the physical environment of the laboratory. Respondents were asked to rate their satisfaction with various aspects of the laboratory environment, including lighting, acoustics, access to natural light, access to outdoor spaces, indoor air quality, overall cleanliness and maintenance, ergonomics and comfort of the furniture and equipment, and solar shading. The data revealed that overall, the respondents were satisfied with the physical environment of the laboratory. The overall cleanliness and maintenance and access to the natural light were rated the highest, with 93% of respondents reporting that they were either extremely satisfied or somewhat satisfied with them.

The indoor air quality were rated third highest, with 86% of respondents reporting that they were either extremely satisfied or somewhat satisfied with it. The acoustics, comfort of furniture and equipment and lighting were rated highly, with 80% of respondents reporting that they were either somewhat satisfied or extremely satisfied with each aspect. The solar shading and access to the outdoor spaces were both rated moderately, with 60% of respondents reporting that they were either somewhat satisfied or extremely satisfied with each aspect. The lightning, acoustics, solar shading, the access to the outdoor spaces received the lowest rating, with 30% of respondents reporting that they were either somewhat dissatisfied or extremely dissatisfied with these aspect. The acoustics and solar shading are the only two aspects which have received 6% extremely dissatisfied ratings.

Submissions	Extremely dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Extremely satisfied	Chart
the lighting	0	4	0	2	9	
the acoustics	1	2	0	8	4	
the access to natural light	0	1	0	4	10	
the access to outdoor spaces	0	3	3	6	3	
the indoor air quality	0	2	0	5	8	
the overall cleanliness and maintenance	0	1	0	4	10	
the ergonomics and comfort of the furniture and equipment	0	1	2	0	12	
solar shading	1	1	3	8	2	

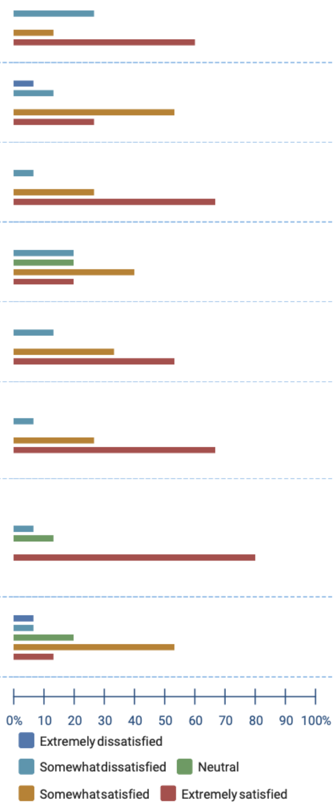


Figure 4.1.15: User satisfaction regarding physical environment

Analysis and Discussions: The results of the post-occupancy evaluation survey provide valuable insights into the respondents' satisfaction with various aspects of the physical environment of the ZEB Laboratory. Understanding the satisfaction levels expressed by the respondents allows us to identify strengths and areas for improvement within the buildings's physical environment.

Overall, the survey results indicate a high level of satisfaction with the physical environment of the laboratory. The aspect that received the highest satisfaction ratings was the overall cleanliness and maintenance, with 93% of the respondents expressing either extreme or moderate satisfaction. This suggests that the laboratory management has been successful in maintaining a clean and well-maintained environment, which is crucial for creating a positive user experience. This is specially essential since the building is considered to be a living laboratory and any malfunctions can possibly affect the data being collected from the building.

Access to natural light was another aspect that received high satisfaction ratings, with 93% of respondents expressing satisfaction. This finding highlights the importance of natural light in the workplace, as it has been linked to improved well-being, productivity, and overall satisfaction. The presence of ample natural light within the laboratory contributes to a pleasant and comfortable working environment, positively impacting the user experience.

Indoor air quality, rated third highest in satisfaction levels, received positive feedback from 86% of the respondents. Good indoor air quality is vital for occupant health, comfort, and productivity. The high satisfaction rating in this aspect suggests that the ZEB Laboratory has implemented effective measures to ensure a healthy and breathable indoor environment, such as proper ventilation and air filtration systems.

The aspects of acoustics, comfort of furniture and equipment, and lighting also received relatively high satisfaction ratings, with 80% of respondents expressing satisfaction. Acoustics play a significant role in creating a conducive work environment by minimizing noise disturbances and ensuring adequate speech intelligibility. The positive ratings in this aspect indicate that measures have been taken to address acoustical concerns within the laboratory. Additionally, the satisfaction ratings for comfort of furniture and equipment highlight the importance of ergonomics in supporting the well-being and productivity of laboratory users. Adequate lighting is essential for visual comfort and task performance, and the high satisfaction ratings suggest that the laboratory provides appropriate lighting levels and quality.

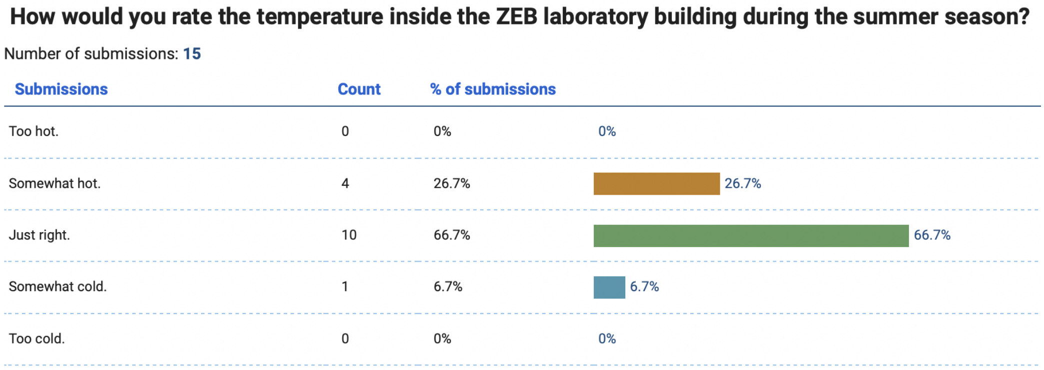
Solar shading and access to outdoor spaces received moderate satisfaction ratings, with 60% of respondents expressing satisfaction. These aspects play a role in providing opportunities for relaxation, connection with nature, and mitigating glare and excessive solar heat gain. While the moderate satisfaction ratings indicate that improvements may be needed in these areas.

It is important to note that the aspects of lighting, acoustics, solar shading, and access to outdoor spaces received the lowest satisfaction ratings, with 30% of respondents expressing some level of dissatisfaction. In particular, acoustics and solar shading were the only aspects to receive extremely dissatisfied ratings from 6% of the respondents. These findings highlight potential areas for improvement and suggest the need for further investigation and action to address the concerns raised by the users.

In conclusion, the survey results indicate an overall high level of satisfaction with the physical environment of the ZEB Laboratory. The positive ratings for cleanliness, access to natural light, and indoor air quality reflect the successful implementation of strategies to create a conducive and healthy workplace. However, there is room for improvement in areas such as acoustics, solar shading, and access to outdoor spaces, as indicated by the lower satisfaction ratings. Addressing these areas of concern can further enhance the user experience within the laboratory and contribute to the well-being and productivity of its occupants.

4.1.5.3 Temperature and air quality

The survey also asked respondents to rate the temperature inside the ZEB laboratory building during the summer season. The data revealed that the majority of respondents (66.7%) rated the temperature as "just right," while 26.7% of respondents rated the temperature as "somewhat hot." Only 6.7% of respondents rated the temperature as "somewhat cold." No respondents rated the temperature as "too hot" or "too cold." These findings suggest that the ZEB laboratory building is generally comfortable during the summer season. However, it is worth noting that a quarter of the respondents reported feeling somewhat hot, indicating that there may be room for improvement in the cooling system of the laboratory during the summer months.



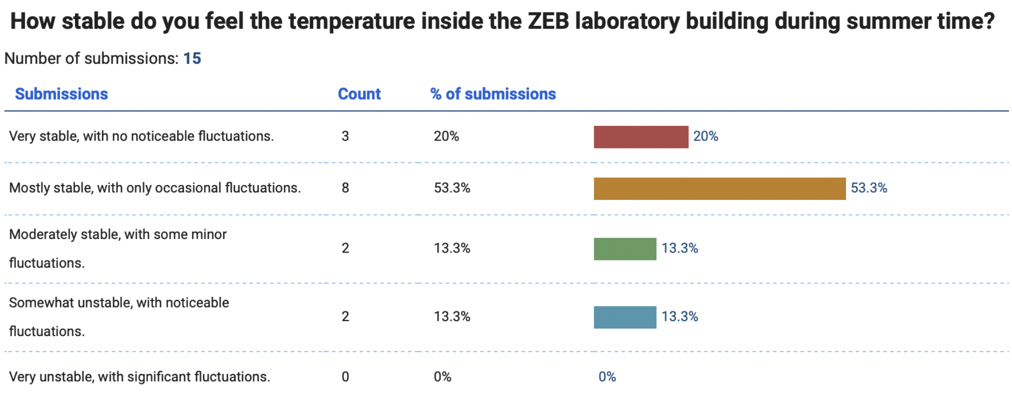
How would you rate the temperature inside the ZEB laboratory building during the summer season?

Number of submissions: 15

Submissions	Count	% of submissions	
Too hot.	0	0%	0%
Somewhat hot.	4	26.7%	26.7%
Just right.	10	66.7%	66.7%
Somewhat cold.	1	6.7%	6.7%
Too cold.	0	0%	0%

Figure 4.1.16: User satisfaction regarding the temperature in summer

The survey also asked respondents to rate the stability of the temperature inside the ZEB laboratory building during the summer season. The data revealed that the majority of respondents (53.3%) rated the temperature stability as "mostly stable, with only occasional fluctuations," with 20% of respondents rating it as "very stable, with no noticeable fluctuations." Another 13.3% of respondents rated the temperature stability as "moderately stable, with some minor fluctuations." Only 13.3% of respondents rated the temperature stability as "somewhat unstable, with noticeable fluctuations," and no respondents rated it as "very unstable, with significant fluctuations." These findings suggest that the temperature inside the ZEB laboratory building is generally stable and consistent, with only occasional or minor fluctuations. This is a positive result, as stable temperature conditions can help to ensure comfort, productivity, and energy efficiency in a laboratory setting.



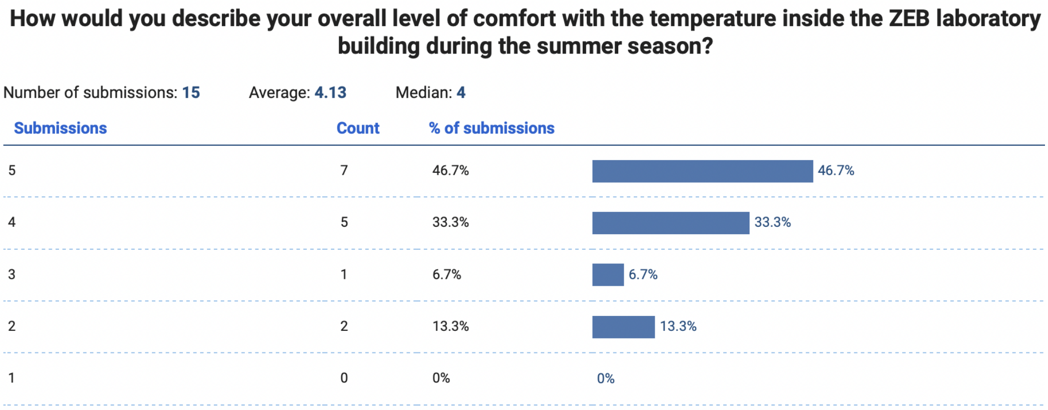
How stable do you feel the temperature inside the ZEB laboratory building during summer time?

Number of submissions: 15

Submissions	Count	% of submissions	
Very stable, with no noticeable fluctuations.	3	20%	20%
Mostly stable, with only occasional fluctuations.	8	53.3%	53.3%
Moderately stable, with some minor fluctuations.	2	13.3%	13.3%
Somewhat unstable, with noticeable fluctuations.	2	13.3%	13.3%
Very unstable, with significant fluctuations.	0	0%	0%

Figure 4.1.17: User satisfaction regarding the stability of temperature in summer

The survey asked respondents to describe their overall level of comfort with the temperature inside the ZEB laboratory building during the summer season. The results show that the majority of respondents (46.7%) rated their level of comfort with the temperature as "5" with another 33.3% rating it as "4." Only 6.7% of respondents rated their level of comfort as "3," and 13.3% of respondents rated it as "2." No respondents rated their level of comfort as "1." These findings suggest that the majority of respondents were comfortable with the temperature inside the ZEB laboratory building during the summer season. This is a positive result, as comfortable temperature conditions can help to ensure the health, comfort, and productivity of laboratory occupants. The average level of comfort rating was 4.13, with a median of 4.



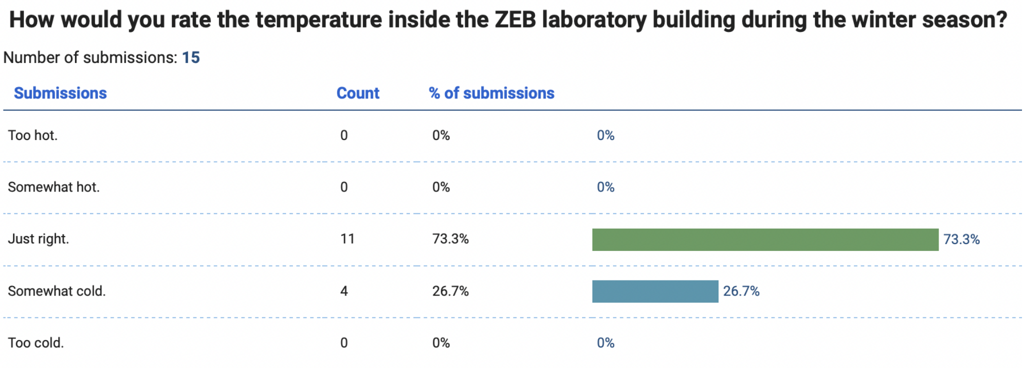
How would you describe your overall level of comfort with the temperature inside the ZEB laboratory building during the summer season?

Number of submissions: 15 Average: 4.13 Median: 4

Submissions	Count	% of submissions	
5	7	46.7%	46.7%
4	5	33.3%	33.3%
3	1	6.7%	6.7%
2	2	13.3%	13.3%
1	0	0%	0%

Figure 4.1.18: Overall user comfort with the temperature in summer

The survey also asked respondents to rate the temperature inside the ZEB laboratory building during the winter season. The majority of respondents (73.3%) rated the temperature as "Just right," while 26.7% rated it as "Somewhat cold." No respondents rated the temperature as "Too hot," "Somewhat hot," or "Too cold." These findings suggest that the majority of respondents were comfortable with the temperature inside the ZEB laboratory building during the winter season. This is a positive result, as comfortable temperature conditions can help to ensure the health, comfort, and productivity of laboratory occupants. It is worth noting that some respondents rated the temperature as "Somewhat cold," which could be an area for improvement in the future.



How would you rate the temperature inside the ZEB laboratory building during the winter season?

Number of submissions: 15

Submissions	Count	% of submissions	
Too hot.	0	0%	0%
Somewhat hot.	0	0%	0%
Just right.	11	73.3%	73.3%
Somewhat cold.	4	26.7%	26.7%
Too cold.	0	0%	0%

Figure 4.1.19: User satisfaction regarding the temperature in winter

The survey also asked respondents to rate the stability of the temperature inside the ZEB laboratory building during the winter season. The majority of respondents (46.7%) rated the stability as "Very stable, with no noticeable fluctuations," while 33.3% rated it as "Mostly stable, with only occasional fluctuations." Only a small proportion of respondents rated the stability as "Moderately stable, with some minor fluctuations" (6.7%), "Somewhat unstable, with noticeable fluctuations" (6.7%), or "Very unstable, with significant fluctuations" (6.7%).

These findings suggest that the majority of respondents felt that the temperature inside the ZEB laboratory building during the winter season was stable and did not fluctuate significantly. This is a positive result, as stable temperature conditions can help to ensure the health, comfort, and productivity of laboratory occupants. However, it is worth noting that some respondents rated the stability of the temperature as less than "Very stable," which could be an area for improvement in the future.

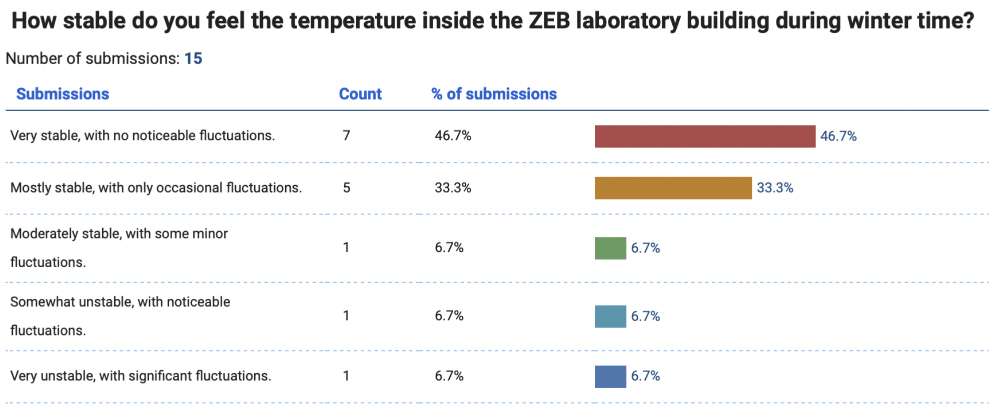


Figure 4.1.20: User satisfaction regarding the stability of temperature in winter

The survey results indicate that the majority of respondents (60%) were highly satisfied with the overall level of comfort with the temperature inside the ZEB laboratory building during the winter season, rating it as a 5 on a scale of 1 to 5. An additional 20% of respondents rated the temperature as a 4, indicating a somewhat high level of comfort. Only 13.3% of respondents rated the temperature as a 2, indicating some level of discomfort, and no respondents rated the temperature as a 1, indicating extreme discomfort. The average rating for overall level of comfort with the temperature during the winter season was 4.27, with a median rating of 5.

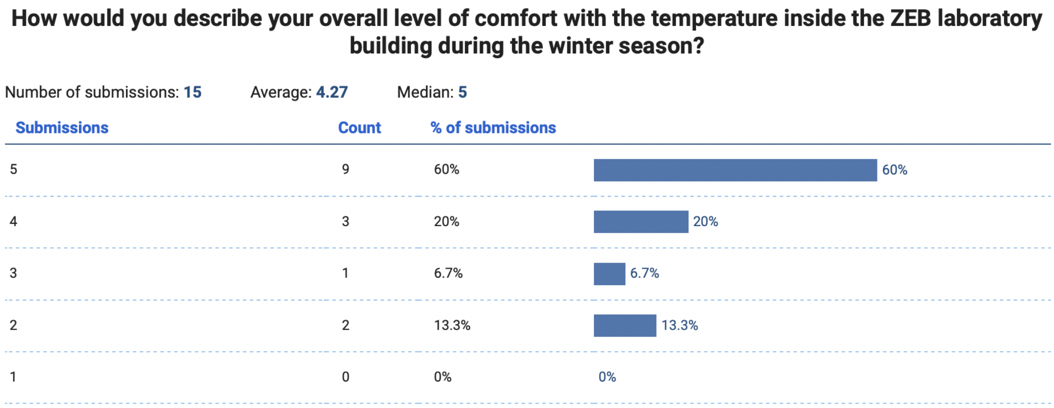


Figure 4.1.21: Overall user comfort with the temperature in winter

The majority of respondents (86.7%) reported no noticeable indoor air quality issues in the ZEB laboratory, while 13.3% reported experiencing some issues. The main issue reported was a feeling of "heavy" air quality and insufficient ventilation, which was mentioned by both respondents who reported issues. One respondent specifically noted that meeting rooms became uncomfortable after a short while.

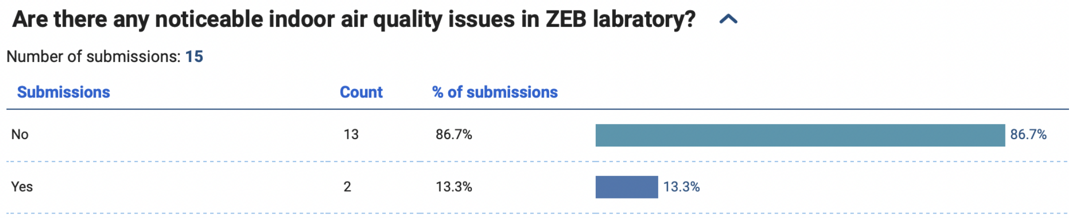


Figure 4.1.22: Overall user comfort with the temperature in winter

Analysis and discussions: The survey results pertaining to temperature and temperature stability inside the ZEB Laboratory during both the summer and winter seasons provide valuable insights into the comfort levels experienced by the respondents.

During the summer season, the majority of respondents (66.7%) rated the temperature as "just right," indicating that the ZEB Laboratory building generally provides a comfortable environment. However, it is worth noting that 26.7% of respondents reported feeling somewhat hot, suggesting that there may be room for improvement to address the concerns of those individuals.

Regarding temperature stability during the summer season, the majority of respondents (53.3%) rated it as "mostly stable, with only occasional fluctuations." This indicates that the ZEB Laboratory maintains a relatively consistent temperature, which is favorable for occupant comfort and productivity. Additionally, 20% of respondents rated the temperature stability as "very stable, with no noticeable fluctuations," further confirming the positive condition of temperature control within the laboratory.

The overall level of comfort with the temperature during the summer season was generally positive, with the majority of respondents (46.7%) rating it as a 5 on a scale of 1 to 5. Another 33.3% of respondents rated their comfort level as a 4, indicating a high level of satisfaction. Only a small proportion of respondents (6.7%) expressed some level of dissatisfaction, rating their comfort level as a 2. These findings suggest that the majority of respondents felt comfortable with the temperature inside the ZEB Laboratory during the summer season.

Turning to the winter season, a significant majority of respondents (73.3%) rated the temperature as "just right," indicating a comfortable indoor environment. No respondents reported the temperature as "too hot," "somewhat hot," or "too cold." However, it is worth noting that 26.7% of respondents rated the temperature as "somewhat cold," suggesting a potential area for improvement to address the concerns of those individuals.

Regarding temperature stability during the winter season, a majority of respondents (46.7%) rated it as "very stable, with no noticeable fluctuations." This indicates that the ZEB Laboratory maintains a stable temperature, contributing to occupant comfort and satisfaction. However, a smaller proportion of respondents (6.7%) rated the stability as "somewhat unstable, with noticeable fluctuations," suggesting that further attention could be given to addressing fluctuations in the temperature during the winter season.

The overall level of comfort with the temperature during the winter season was generally positive, with the majority of respondents (60%) rating it as a 5 on the scale. An additional 20% of respondents rated their comfort level as a 4, indicating a relatively high level of satisfaction. Only 13.3% of respondents rated their comfort level as a 2, indicating some discomfort. These findings suggest that the majority of respondents felt comfortable with the temperature inside the ZEB Laboratory during the winter season.

Regarding indoor air quality, the majority of respondents (86.7%) reported no noticeable issues. However, 13.3% of respondents mentioned concerns about "heavy" air quality and insufficient ventilation, with some specific mention of discomfort in meeting rooms. These findings suggest that improvements in ventilation and air quality management could enhance the overall user experience in the ZEB Laboratory, particularly addressing the reported issues.

In conclusion, the survey results indicate that the ZEB Laboratory generally provides a comfortable temperature environment during both the summer and winter seasons. The majority of respondents expressed satisfaction with the temperature and rated it as "just right." However, there were some individuals who reported feeling somewhat hot or cold, indicating potential areas for improvement in the cooling and heating systems. Additionally, temperature stability received positive ratings, but some respondents mentioned minor fluctuations, which could be addressed to provide an even more stable environment. The majority of respondents also expressed a high level of comfort with the temperature, indicating overall satisfaction with the thermal conditions inside the ZEB Laboratory.

During the summer season, it is recommended to further investigate and address the concerns of the respondents who reported feeling somewhat hot. This could involve adjusting temperature set-points, or providing additional cooling measures in specific areas of the laboratory where heat accumulation may be more pronounced like offices in the south part of the building.

Similarly, during the winter season, attention should be given to addressing the concerns of respondents who reported feeling somewhat cold. This could involve improving insulation, adjusting heating systems, or providing localized heating solutions to ensure a more comfortable environment for all occupants.

Regarding temperature stability, while the majority of respondents felt that fluctuations were minimal, it is important to consider the feedback from those who reported noticeable fluctuations. This feedback highlights the need for ongoing monitoring and fine-tuning of the systems to maintain a consistent and stable temperature throughout the ZEB Laboratory.

In terms of indoor air quality, the majority of respondents did not report any issues. However, the concerns raised by a portion of the respondents regarding "heavy" air quality and insufficient ventilation should be addressed. Increasing ventilation rates, ensuring proper air circulation, and implementing air quality monitoring systems can help improve the overall air quality and ensure a healthier and more comfortable indoor environment for laboratory occupants.

To further enhance the user experience in the ZEB Laboratory, it is recommended to conduct regular assessments and post-occupancy evaluations to continually monitor and address any issues related to temperature, temperature stability, and indoor air quality. Additionally, gathering feedback from occupants and involving them in the decision-making process regarding environmental conditions can foster a sense of ownership and improve user satisfaction.

Overall, the survey results indicate a positive user experience regarding the physical environment, temperature, and indoor air quality within the ZEB Laboratory. The findings provide valuable insights for facility managers, architects, and designers to identify areas of improvement and optimize the laboratory's conditions, ultimately enhancing occupant comfort.

4.1.5.4 Building systems

The post-occupancy evaluation survey of the ZEB Laboratory at NTNU also included questions regarding the building systems of the laboratory. Respondents were asked to rate their satisfaction with various aspects, including HVAC systems, electricla systems, plumbing system, the speed of maintainance and repairs and the effectiveness of maintainance and repairs. The data revealed that overall, the respondents were satisfied with the building systems of the laboratory.

The plumbing system was rated the highest, with 93% of respondents reporting that they were either extremely satisfied or somewhat satisfied with them. The electrical system was rated second highest, with 86% of respondents reporting that they were either extremely satisfied or somewhat satisfied with it. The HVAC systems were rated highly, with 80% of respondents reporting that they were either somewhat satisfied or extremely satisfied with each aspect. The effectiveness and the speed of maintenance and repairs were both rated moderately, with 60% of respondents reporting that they were either somewhat satisfied or extremely satisfied with each aspect. The HVAC systems and electrical systems received the lowest rating, with 10% of respondents reporting that they were somewhat dissatisfied with these aspect. None of the aspects received extremely dissatisfied ratings.

Submissions	Extremely dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Extremely satisfied	Chart
the HVAC (heating, ventilation, and air conditioning) system	0	2	1	3	9	
the electrical system	0	1	1	1	12	
the plumbing system	0	0	1	2	12	
the speed of maintenance and repairs	0	0	6	1	8	
the effectiveness of maintenance and repairs	0	0	5	2	8	

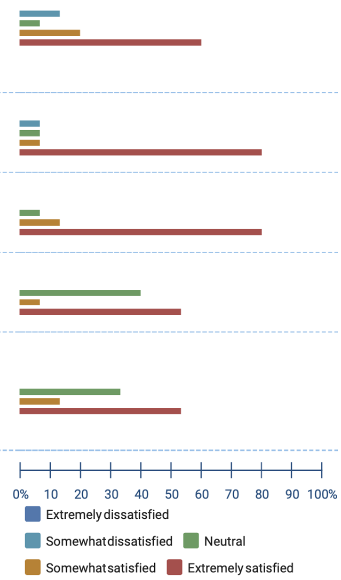
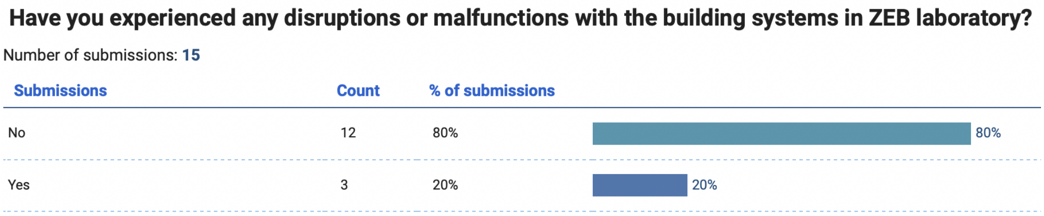


Figure 4.1.23: User satisfaction regarding building systems

According to the survey results, 80% of respondents reported that they have not experienced any disruptions or malfunctions with the building systems in ZEB laboratory, while 20% reported that they have experienced such issues. Among those who reported experiencing disruptions or malfunctions, a range of issues were mentioned. One respondent noted that the HDMI input to meeting room screens has been a frequent and known problem for a long time. Another reported that the ZEB app doesn't work most of the time, preventing users from adjusting lighting, temperature, and window blinds. Additionally, heat pumps and window screens were also mentioned as systems that have stopped working. These issues with the building systems can be problematic for occupants of the ZEB laboratory, as they can lead to interruptions in work and decreased comfort levels. Addressing these issues and ensuring that the building systems are functioning properly is important for maintaining a productive and comfortable work environment.


Have you experienced any disruptions or malfunctions with the building systems in ZEB laboratory?

Number of submissions: 15

Submissions	Count	% of submissions	
No	12	80%	80%
Yes	3	20%	20%

Figure 4.1.24: malfunctions with the building system

Analysis and Discussions: The findings from the survey indicate that overall, respondents were satisfied with the building systems of the ZEB Laboratory. The high satisfaction ratings for the plumbing system and electrical system suggest that these aspects are functioning well and meeting the expectations of the occupants. This is important as reliable plumbing and electrical systems are essential for the smooth operation of a laboratory facility.

The HVAC systems, which play a critical role in maintaining comfortable indoor temperatures and air quality, also received positive ratings from the majority of respondents. However, it is worth noting that a small percentage of respondents expressed some level of dissatisfaction with these systems. Further investigation and analysis may be required to identify the specific concerns and areas for improvement. It is important to address these concerns promptly to ensure optimal thermal comfort and air circulation within the laboratory.

The survey also revealed that the effectiveness and speed of maintenance and repairs were rated moderately by the respondents. While the majority of respondents expressed satisfaction with these aspects, there is room for improvement in terms of addressing maintenance and repair issues promptly and efficiently. The feedback from respondents who reported experiencing disruptions or malfunctions in the building systems highlights the need for proactive maintenance practices and effective communication channels between occupants and maintenance personnel. Timely resolution of issues is crucial to minimize any negative impact on productivity and occupant comfort.

The identified issues with the building systems, such as the HDMI input problem, malfunctioning ZEB app, heat pumps, and window screens, should be addressed promptly. These issues can disrupt work processes, hinder user experience, and potentially affect the overall productivity of the laboratory. It is recommended to prioritize the resolution of these issues and establish a system for reporting and tracking malfunctioning ZEB app requests.

In conclusion, while the survey results indicate a generally positive satisfaction level with the building systems of the ZEB Laboratory, there are areas for improvement, particularly in addressing maintenance and repair issues and resolving specific concerns raised by respondents. Proactive measures, including regular maintenance, timely repairs, and efficient communication channels, should be implemented to ensure that the building systems are functioning optimally and meeting the needs of the laboratory occupants. This will contribute to a productive and comfortable working environment, enhancing the overall user experience in the ZEB Laboratory.

4.1.5.5 Amenities

The post-occupancy evaluation survey of the ZEB Laboratory at NTNU also included questions regarding the amenities of the laboratory. Respondents were asked to rate their satisfaction with various aspects, including the availability and access to common areas, the availability of technology and equipment, the quality of technology and equipment, the quality of workspace, the quality of common areas and amenities, plenty pods (quit boxes), the availability of meeting rooms, the quality of meeting rooms and color theme used in the building and amenities.

The quality of common areas and amenities was rated the highest, with 100% of respondents reporting that they were either extremely satisfied or somewhat satisfied with it. The availability and access to common areas, the availability of technology and equipment, the quality of technology and equipment and colour theme used in the building were rated second highest, with 93% of respondents reporting that they were either extremely satisfied or somewhat satisfied with it. The color theme used in the building and amenities was rated with 80% of respondents reporting that they were extremely satisfied with it. The availability of meeting rooms and quality of them were rated either extremely satisfied or somewhat satisfied by 80% of respondents. The silent space, plenty pod was rated moderately, with 60% of respondents reporting that they were either somewhat satisfied or extremely satisfied with each aspect. The quality of meeting rooms received the lowest rating, with 20% of respondents reporting that they were somewhat dissatisfied with these aspect. Also, 13% of the respondents were somewhat dissatisfied with the quality of workspace.

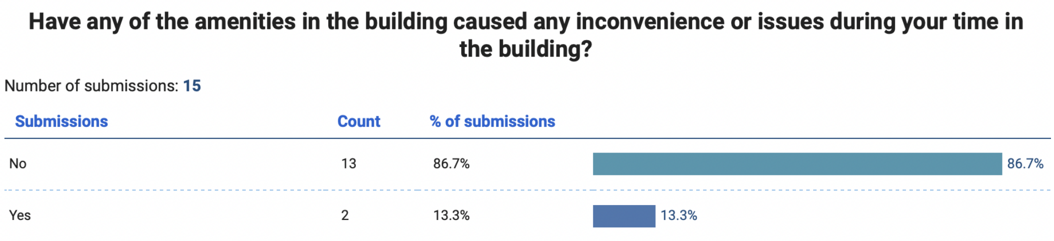
How satisfied are you with

Submissions	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied	Chart
the availability and access to common areas	0	0	1	8	6	
the availability of technology and equipment	0	1	0	4	10	
the quality of technology and equipment	0	1	0	7	7	
the quality of workspace	0	2	0	6	7	
the quality of common areas and amenities	0	0	0	7	8	
the silent space, Plenty Pod	1	0	5	8	1	
the availability of meeting rooms	1	0	2	7	5	
the quality of meeting rooms	0	3	0	3	9	
colour theme used in the building	0	1	1	1	12	

and amenities

Figure 4.1.25: User satisfaction regarding amenities

According to the survey, the majority of respondents (86.7%) did not report any inconvenience or issues with the amenities in the ZEB laboratory building. However, 13.3% of respondents did report some issues. The issues mentioned were related to the elevators not working, difficulties with getting teams working in the "allrom" room on the first floor, and minor inconveniences with rubbish bin placements. Additionally, one respondent mentioned having trouble with the app used to book meeting rooms, which resulted in having to rely on colleagues for assistance.



Have any of the amenities in the building caused any inconvenience or issues during your time in the building?

Number of submissions: 15

Submissions	Count	% of submissions	
No	13	86.7%	86.7%
Yes	2	13.3%	13.3%

Figure 4.1.26: Inconvenience or issues with the amenities

Analysis and Discussions: The survey findings indicate that overall, respondents were satisfied with the amenities provided in the ZEB Laboratory. The high satisfaction ratings for the quality of common areas and amenities, availability and access to common areas, availability and quality of technology and equipment, and the color theme used in the building reflect positively on the user experience. These results suggest that the laboratory offers comfortable and well-equipped spaces for work and collaboration.

However, it is important to note that a small percentage of respondents expressed some level of dissatisfaction with certain aspects. The quality of meeting rooms received a lower rating, with 20% of respondents reporting some level of dissatisfaction. Additionally, 13% of respondents were somewhat dissatisfied with the quality of workspace. These findings highlight specific areas where improvements or adjustments may be needed to enhance user satisfaction.

The survey also identified some issues and inconveniences reported by respondents regarding the amenities. These included elevator malfunctions, difficulties with accessing the "allrom" room on the first floor, minor inconveniences with rubbish bin placements, and challenges with the app used for booking meeting rooms. It is crucial to address these issues promptly to ensure that the amenities function effectively and provide a seamless experience for laboratory occupants. Improving communication channels and addressing technical difficulties with booking systems or other technologies can contribute to a more user-friendly environment.

To enhance the overall user experience, it is recommended to address the concerns raised by respondents who expressed dissatisfaction with meeting room quality and workspace quality. Conducting further assessments and engaging with laboratory occupants to gather specific feedback and suggestions can provide valuable insights for improvement. Additionally, ensuring regular maintenance and periodic updates to the amenities will contribute to their longevity and functionality.

In conclusion, while the survey results demonstrate overall satisfaction with the amenities provided in the ZEB Laboratory, there is room for improvement in certain areas, such as meeting room quality and workspace quality. Addressing the reported issues, such as elevator malfunctions and difficulties with accessing specific areas, will further enhance the user experience. By actively seeking feedback and continuously evaluating and improving the amenities, the ZEB Laboratory can create a more productive, comfortable, and user-centered environment for its occupants.

4.1.5.6 Functionality

The post-occupancy evaluation survey of the ZEB Laboratory at NTNU also included questions regarding the functionality of the laboratory. Respondents were asked to rate their satisfaction with various aspects, including the layout and design, the access to resources and technology, the level of privacy and quitness, the extent to which the ZEB laboratory meets their current work requirements.

The access to the resources and technology was rated the highest, with 86% of respondents reporting that they were either extremely satisfied or somewhat satisfied with it. The extent to which the ZEB laboratory meets their current work requirements was rated second highest, with 80% of respondents reporting that they were either extremely satisfied or somewhat satisfied with it. The layout and design was rated moderately, with 73% of respondents reporting that they were either somewhat satisfied or extremely satisfied with each aspect. The level of privacy and quitness received the lowest rating, with 26% of respondents reporting that they were extremely or somewhat dissatisfied with these aspect. Also, 13% of the respondents were somewhat dissatisfied with the layout and design of the building.

Submissions	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied	Chart
the layout and design	0	2	2	4	7	
the access to resources and technology	0	0	2	4	9	
the level of privacy and quietness	2	2	5	3	3	
with the extent to which the ZEB Laboratory meets your current work requirements	0	1	2	4	8	

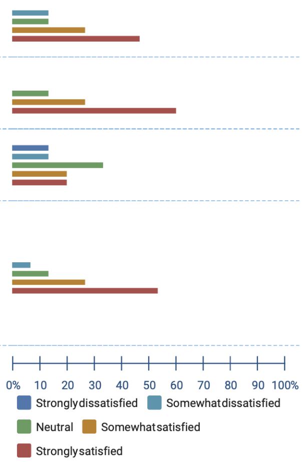
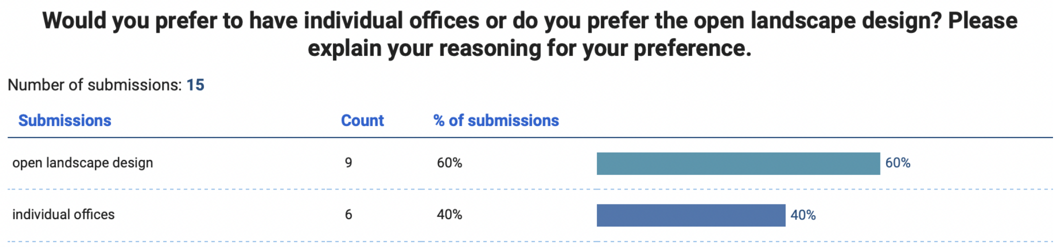


Figure 4.1.27: User satisfaction regarding functionality

According to the survey, 60% of the participants preferred the open landscape design while 40% preferred individual offices. Those who preferred individual offices cited reasons such as ease of concentration, less disturbance, and flexibility in work schedule. They also found it more suitable for tasks like reading, editing, and supervision of students. On the other hand, those who preferred open landscape design found it easier to collaborate and socialize with colleagues, and it created a sense of community and inclusiveness. They also found it more social and better for fostering innovation.

Regarding the ZEB laboratory building's design choice of open landscape design, opinions were mixed. While some participants found it perfect and modern, others found it less than optimal and distracting. However, most participants seemed to find the design choice acceptable, with some suggesting the inclusion of meeting rooms for private conversations and work meetings. Some also suggested that both options, individual offices and open landscape design, should be available to cater to the preferences of all users. Overall, it appears that the open landscape design has both its advantages and disadvantages, and a balance between the two options could be the ideal solution.


Would you prefer to have individual offices or do you prefer the open landscape design? Please explain your reasoning for your preference.

Number of submissions: 15

Submissions	Count	% of submissions	
open landscape design	9	60%	60%
individual offices	6	40%	40%

Figure 4.1.28: Open landscape design versus individual offices

Analysis and Discussions: The survey results provide insights into respondents' satisfaction with the functionality of the ZEB Laboratory. Overall, respondents were generally satisfied with the access to resources and technology, as well as the extent to which the meets their current work requirements. This indicates that the laboratory provides the necessary resources and infrastructure to support their work effectively.

However, the layout and design of the laboratory received moderate satisfaction ratings, with 73% of respondents reporting some level of satisfaction. It is worth noting that 13% of respondents expressed some level of dissatisfaction with the layout and design. This suggests that there may be room for improvement in optimizing the spatial arrangement and design elements to better cater to the needs and preferences of the laboratory occupants.

The level of privacy and quietness in the laboratory received the lowest satisfaction rating, with 26% of respondents reporting some level of dissatisfaction. This highlights the importance of providing spaces that offer sufficient privacy and minimize noise disturbances, as these factors can significantly impact concentration and productivity. Addressing this concern by incorporating designated quiet areas or acoustic treatments within the building could contribute to a more conducive work environment.

The survey also revealed varying preferences regarding the open landscape design versus individual offices. While 60% of participants preferred the open landscape design for its collaborative and social benefits, the remaining 40% expressed a preference for individual offices, citing concentration and privacy advantages. These differing preferences indicate the need to consider a flexible design approach that accommodates both options, allowing for a balance between collaboration and focused work.

It is noteworthy that some participants found the open landscape design distracting or less than optimal. To address this, suggestions were made to include meeting rooms for private conversations and work meetings, providing alternative spaces for more focused activities. This feedback highlights the importance of offering a variety of spaces within the laboratory that cater to different work styles and tasks.

In summary, while respondents expressed satisfaction with access to resources and technology, as well as the laboratory's ability to meet their work requirements, there is room for improvement in the layout and design, level of privacy and quietness. Considering the mixed preferences regarding the open landscape design versus individual offices, a flexible design approach that incorporates elements of both options could be beneficial. Incorporating private meeting rooms and designated quiet areas within the laboratory can address the need for privacy and focused work. By incorporating these suggestions and striving for a balanced and adaptable design, the ZEB Laboratory can create a functional and accommodating workspace for its occupants.

4.1.5.7 Safety and security

The majority of the respondents (86.6%) were either somewhat satisfied or strongly satisfied with the level of safety and security for occupants in the ZEB laboratory building. Only 6.7% were either somewhat dissatisfied or neutral about it. One respondent (6.7%) expressed being somewhat dissatisfied with the level of safety and security.

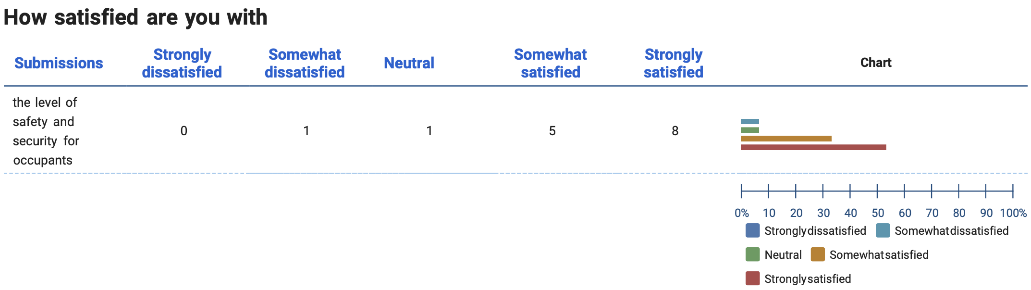


Figure 4.1.29: User satisfaction regarding safety and security

According to the results, 26.7% of respondents indicated that there are areas in the ZEB Laboratory where safety and security could be improved, while 73.3% indicated that they were satisfied with the current safety and security measures in place. The most common issues raised were related to the accessibility and design of the building. Some respondents suggested that the security measures in the building could be improved by having lower security, making it less exaggerated. Others pointed out that the universal design of the building could be improved, especially in the case of a fire emergency. One respondent also highlighted that the entrance door stays open for too long after being opened, which could be addressed by using a smarter sensor.

Another area for improvement mentioned was the functionality of the gate to the open landscape, as it does not effectively prevent anyone from jumping over it if they want to enter into the building. Some respondents also expressed concern that it is too easy to gain access to the building and move into the office spaces where people have laptops and other valuable items. Lastly, one respondent suggested that a doormat should be placed at the back door by the NINA building side, as it can be slightly slippery there, which could be a safety hazard. Overall, these suggestions could help to further enhance the safety and security of the ZEB Laboratory.

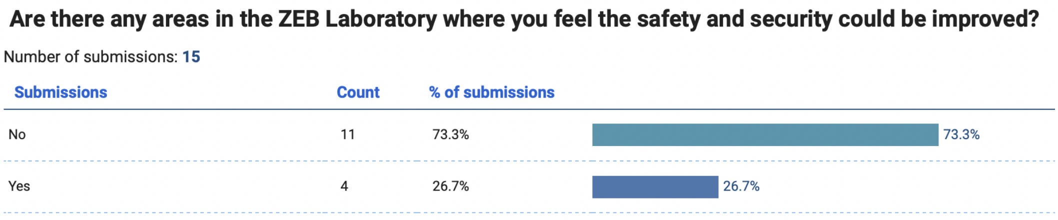


Figure 4.1.30: Areas for improving safety and security

Analysis and discussions: The survey results indicate that the majority of respondents (86.6%) were satisfied with the level of safety and security for occupants in the ZEB Laboratory building. This suggests that the current safety measures in place have generally been effective in providing a secure environment for the occupants. However, it is important to note that 6.7% of respondents expressed some level of dissatisfaction or neutrality regarding safety and security, indicating the need for further attention to address their concerns.

Among the respondents, 26.7% indicated that there are areas where safety and security could be improved. One common issue raised was the accessibility and design of the building. Some respondents suggested that the security measures could be improved by striking a balance between security and a less exaggerated approach. This feedback highlights the importance of implementing security measures that are effective while not causing inconvenience or hindrance to the occupants.

Additionally, respondents mentioned concerns regarding the universal design of the building, particularly in the context of fire emergencies. Improving the universal design aspects can contribute to enhancing the safety and accessibility of the building for all occupants, including those with disabilities or mobility limitations.

Specific suggestions were made to address certain issues. For instance, one respondent mentioned that the entrance door stays open for too long after being opened, which could be addressed by implementing smarter sensor technology. Another suggestion was to improve the functionality of the gate to the open landscape area, ensuring it effectively prevents unauthorized access. Respondents also expressed concerns about the ease of gaining access to office spaces where valuable items are kept, highlighting the need for stricter access control measures in these areas.

One respondent mentioned a safety hazard related to a slippery area near the back door of the NINA building side. Placing a doormat in that area could help mitigate this risk and improve safety.

Taking these suggestions into consideration and addressing the mentioned areas for improvement can contribute to enhancing the overall safety and security of the ZEB Laboratory. It is essential for the building management to carefully evaluate and implement measures that strike a balance between security, accessibility, and user convenience, ensuring a safe and secure environment for all occupants. Regular reviews and updates of safety protocols and infrastructure can help maintain and improve the safety standards of the laboratory over time.

4.1.5.8 Sustainability

The post-occupancy evaluation survey of the ZEB Laboratory at NTNU also included questions regarding the sustainibility features and images of the laboratory. The first question about sustainibility features was asking specifically about the tangible, practical aspects of the building that make it more environmentally friendly and resource-efficient. Examples of sustainability features could include the use of renewable energy sources, efficient heating and cooling systems, or recycling and waste management programs. By asking about satisfaction with these features, they had the opportunity to gauge how effective the features are at meeting the needs and expectations of building occupants.

The second question was asking specifically about the branding or perception of the building as being environmentally sustainable. Examples of sustainability images could include the use of marketing language that highlights the building's green credentials, or the use of sustainable materials in the building's design. By asking about satisfaction with the sustainability image, they had to gauge how effective the building's marketing efforts are at communicating its sustainability message to occupants and other stakeholders. The sustainability features was rated the highest, with 93% of respondents reporting that they were either extremely satisfied or somewhat satisfied with it. The sustainability image was rated second highest, with 86% of respondents reporting that they were either extremely satisfied or somewhat satisfied with it. None of the respondents were dissatisfied with these two aspects.

How satisfied are you with

Submissions	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied	Chart
the sustainability features	0	0	1	3	11	
the sustainability images	0	0	2	3	10	

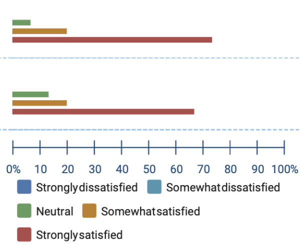


Figure 4.1.31: User satisfaction regarding sustainability features and images

In response to the question "In what ways do you feel that the ZEB laboratory building has inspired or influenced sustainable living practices, either within the building or in your personal life?", the survey yielded several interesting responses. Many respondents noted that the ZEB laboratory building served as a positive example of how sustainable construction practices and technologies can be implemented in a practical and effective way. For instance, the use of renewable technologies and carefully selected materials were highlighted as key inspirations for promoting sustainable living practices.

Additionally, the building's performance data being made available to the public was also noted as an inspiring aspect of the building. Some respondents noted that the building had led to personal changes in their behavior related to sustainable living practices. For instance, one respondent reported that they were inspired to travel less by plane, while another noted that they paid more attention to their energy use and solar panels.

Several respondents also noted that the building had raised their awareness of environmental choices on a daily basis, such as being more mindful of energy use and transportation. However, not all respondents felt that the ZEB laboratory building had influenced their behavior in a significant way. Some respondents noted that they were already very focused on sustainability, and while the building provided some enthusiasm, it did not change their behavior in a significant way. Additionally, some respondents noted that while the ZEB laboratory building was impressive, it was not always easy to translate its sustainability features to existing buildings.

According to the survey results, 33.3% of the respondents felt that working in a Zero emission building is much better than traditional office buildings, while 20% felt that it is slightly better. 46.7% of the respondents felt that it is about the same as traditional office buildings, and no one felt that it is slightly or much worse than traditional office buildings.

How do you feel about working in a ZERO emission building compared to other traditional office buildings you have worked in?

Number of submissions: **15**

Submissions	Count	% of submissions	
5 - Much better than traditional office buildings	5	33.3%	33.3%
4 - Slightly better than traditional office buildings	3	20%	20%
3 - About the same as traditional office buildings	7	46.7%	46.7%
2 - Slightly worse than traditional office buildings	0	0%	0%
1-Much worse than traditional office buildings	0	0%	0%

Figure 4.1.32: Zero emission building versus traditional office building

Based on the survey responses, the vast majority of participants (93.3%) would recommend a zero emission building to others looking for a sustainable workplace. The reasons given for this recommendation include the environmental and health benefits, the energy-saving and thermal comfort, the inspiration to live more sustainably, and the absence of hassle or problems with working in a zero emission building. One participant noted that the ZEB laboratory is still a "young" building and that with time, it is likely to perform even better in terms of indoor environmental quality. Another participant commented that the ZEB has helped them adapt their behavior outside of work to be more sustainable. The only negative feedback was regarding the outside appearance of the building, which was perceived as less attractive and unnatural due to the black panels.

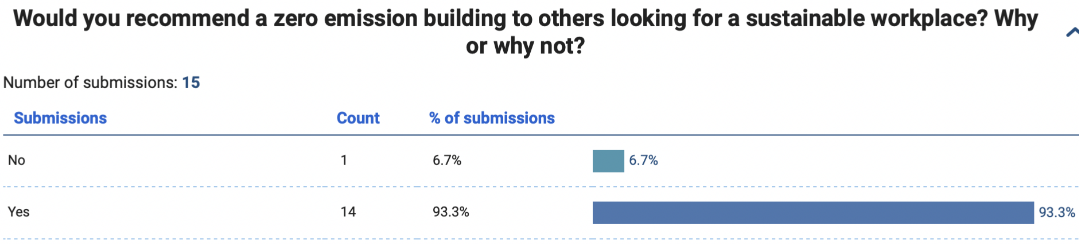


Figure 4.1.33: Recommending working in a zero emission building to others

Analysis and discussions: The post-occupancy evaluation survey of the ZEB Laboratory at NTNU included questions regarding the sustainability features and images of the laboratory. These questions aimed to assess the tangible aspects of the building that contribute to its environmental friendliness and resource efficiency, as well as the perception and branding of the building as environmentally sustainable.

In terms of satisfaction with sustainability features, the survey results indicate a high level of satisfaction, with 93% of respondents reporting that they were either extremely satisfied or somewhat satisfied. This suggests that the sustainable design elements and practices implemented in the building, such as the use of renewable energy sources and efficient heating systems have met the needs and expectations of the occupants. Similarly, the sustainability image of the building was well-received, with 86% of respondents expressing satisfaction. This indicates that the marketing efforts and communication regarding the building's sustainability message have been effective in conveying its green credentials.

The survey also explored the ways in which the ZEB Laboratory building has inspired or influenced sustainable living practices among the occupants. Many respondents acknowledged the building as a positive example of sustainable construction practices and technologies. The use of renewable technologies, carefully selected materials, and the availability of performance data were noted as key inspirations for promoting sustainable living practices. Some respondents mentioned personal changes in behavior, such as reducing air travel or being more conscious of energy use and solar panels, influenced by the building. The ZEB Laboratory building also raised awareness of environmental choices on a daily basis for several respondents.

However, it is worth noting that not all respondents felt a significant influence on their behavior, particularly if they were already highly focused on sustainability. Some respondents found it challenging to translate the sustainability features of the ZEB Laboratory building to existing buildings. These findings suggest that while the ZEB Laboratory serves as an inspiring example of sustainable practices, there may be opportunities to further educate and engage occupants in incorporating sustainable behaviors beyond the building's immediate environment.

Regarding the comparison between a zero-emission building and traditional office buildings, survey respondents had mixed opinions. While 33.3% felt that working in a zero-emission building was much better than traditional office buildings, 20% expressed a slightly better perception. On the other hand, 46.7% of respondents felt that the experience was about the same as traditional office buildings. No respondents felt that working in a zero-emission building was slightly or much worse than traditional office buildings. These results highlight the overall positive perception of working in a zero-emission building, although there is room for further improvement to enhance the differentiation from traditional office buildings.

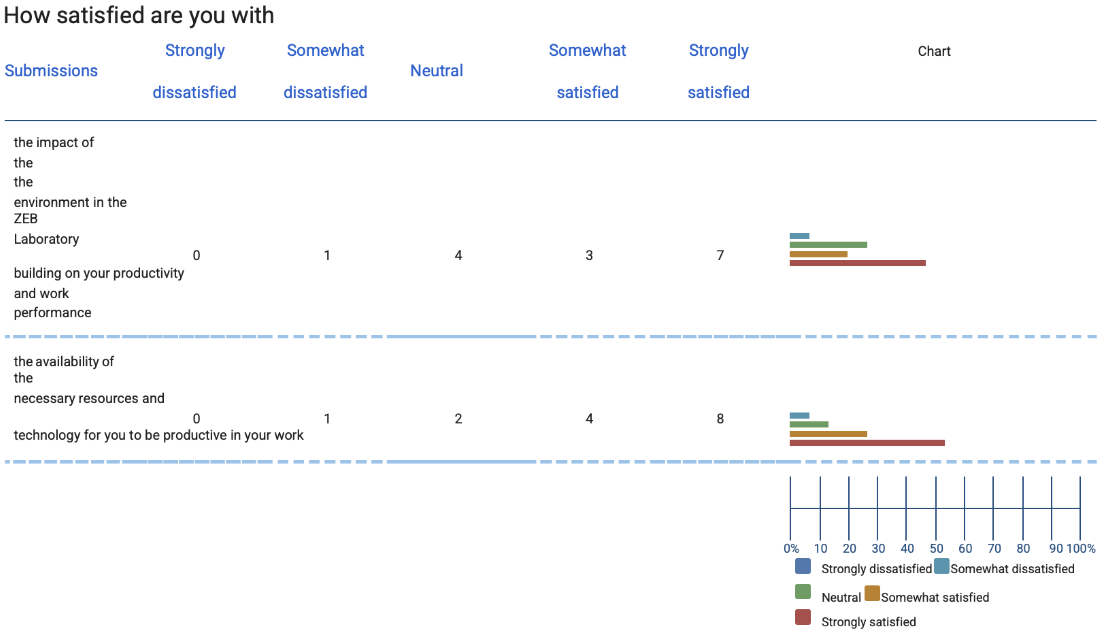
The survey results indicate that the majority of participants (93.3%) would recommend a zero-emission building like the ZEB Laboratory to others seeking a sustainable workplace. The reasons for this recommendation include the environmental and health benefits, energy savings, thermal comfort, and inspiration to live more sustainably. Participants appreciated the absence of issues or inconveniences associated with working in a zero-emission building. However, there was some feedback regarding the outside appearance of the building, with concerns about its attractiveness and the visual impact of the black panels.

In conclusion, the survey findings highlight the satisfaction of the respondents with the sustainability features and image of the ZEB Laboratory building. The tangible aspects, such as renewable energy use and efficient systems, were well-received, and the building's branding as environmentally sustainable was positively perceived. The building served as an inspiration for sustainable living practices for many occupants, although the level of influence on behavior varied. Overall, the ZEB Laboratory's status as a zero-emission building was seen favorably, and the majority of respondents would recommend it to others seeking a sustainable workplace. The feedback received provides valuable insights for further improving the building's sustainability features, communication efforts, and occupant engagement.

4.1.5.9 Productivity

The post-occupancy evaluation survey of the ZEB Laboratory at NTNU also included questions regarding the productivity in the laboratory. Respondents were asked to rate their satisfaction with two aspects, including the impact of the environment in the ZEB laboratory on their productivity and work performance and the availability of necessary resources and technology for them to be productive in their work.

The availability of necessary resources and technology for them to be productive in their work was rated the highest, with 86% of respondents reporting that they were either extremely satisfied or somewhat satisfied with it. The impact of the environment in the ZEB laboratory on their productivity and work performance was rated second highest, with 66% of respondents reporting that they were either extremely satisfied or somewhat satisfied with it. Only two of the respondents were somewhat dissatisfied with the both aspects.

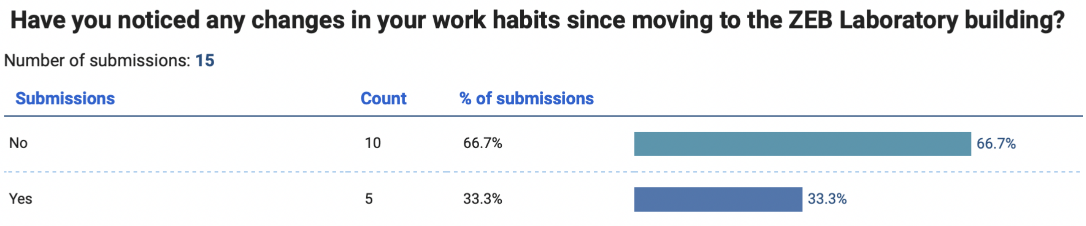


How satisfied are you with

Submissions	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied	Chart
the impact of the the environment in the ZEB Laboratory building on your productivity and work performance	0	1	4	3	7	
the availability of the necessary resources and technology for you to be productive in your work	0	1	2	4	8	

Figure 4.1.34: User satisfaction regarding the productivity

A majority of respondents (66.7%) have not noticed any changes in their work habits since moving to the ZEB Laboratory building. However, 33.3% of respondents have reported changes in their work habits. These changes include feeling inspired by the technologies and facilities used in the building, feeling more satisfied, being more aware of how they use their voice, keeping their desk tidy and without personal belongings for others to use easily, preferring to work in the evening due to the office landscape and meeting room location, experiencing a much better working environment, feeling proud and happy to work in such a building, and finding it easier to sell projects to customers when meetings are held in the ZEB laboratory.



Have you noticed any changes in your work habits since moving to the ZEB Laboratory building?

Number of submissions: **15**

Submissions	Count	% of submissions	
No	10	66.7%	66.7%
Yes	5	33.3%	33.3%

Figure 4.1.35: Change in working habits

The vast majority of respondents (86.7%) reflected positively about having their office in a living laboratory, with an average rating of 4.73 out of 5 and a median rating of 5. 13.3% of the respondents felt neutral about it.

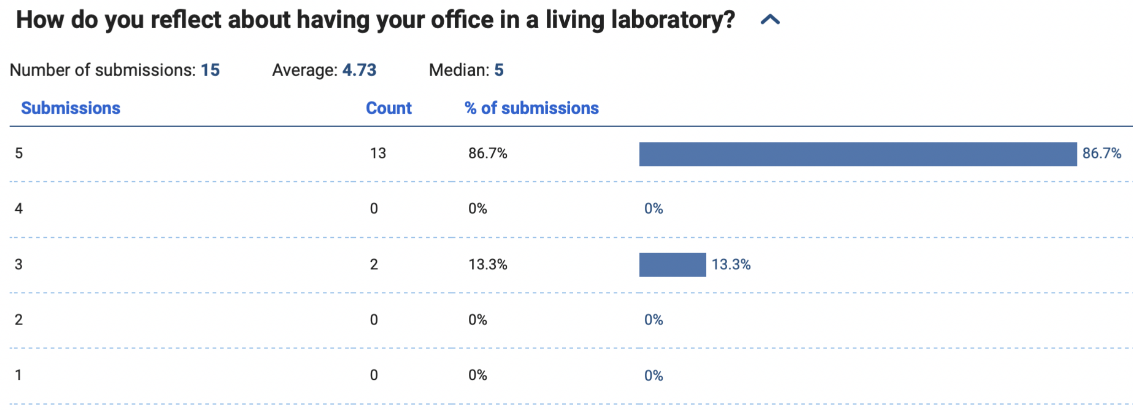


Figure 4.1.36: Reflection on having the office in a living laboratory

The survey results indicate that the average level of thinking about working in a living laboratory environment while working is moderate, with an average score of 3.07 and a median of 3. The majority of respondents (46.7%) rated their level of thinking about it as a 3, while 20% of respondents rated it as a 2, and 13.3% rated it as either a 4 or 5. On the other hand, 6.7% of respondents rated it as a 1, indicating that they do not think about it much while working. These results suggest that while working in a living laboratory environment is acknowledged, it is not a primary focus for most respondents.

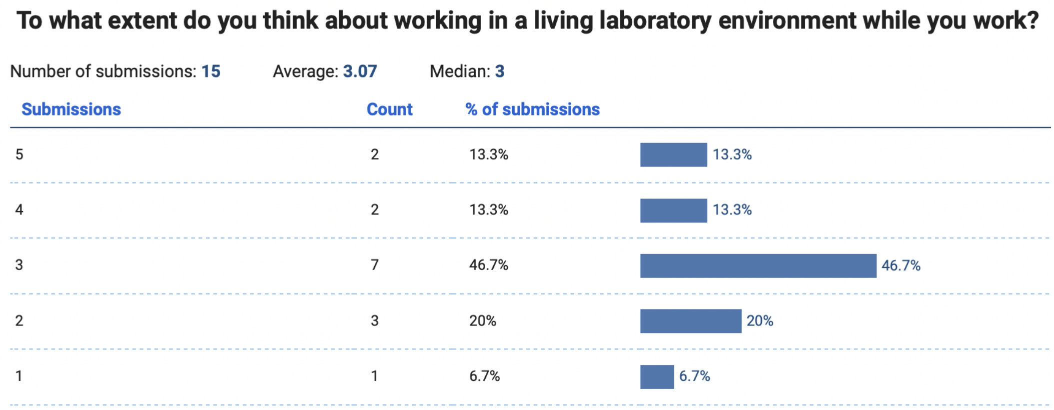
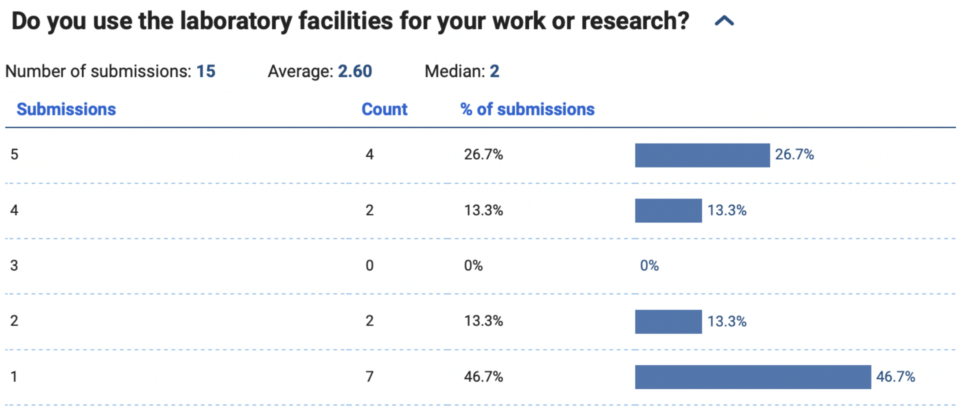


Figure 4.1.37: Working in a living laboratory

The survey results show that 60% of the respondents have not been disturbed by any activities or events taking place in the living laboratory environment, while 40% have experienced some form of disturbance. Examples of disturbances include people booking full day seminars/meetings in common spaces on the first floor, noise from visitors which can be distracting, and one instance where a seminar/-workshop was held in the canteen during normal lunch hours. However, these disturbances were generally considered to be minor and did not significantly impact the respondents' work. It's worth noting that only one respondent reported being affected by guided tours within the ZEB laboratory building, indicating that the building's design successfully separates the research spaces from the public areas.

Based on the responses of the participants, it appears that 40% of them have not used the laboratory facilities for their work or research, while 60% have used them to varying degrees. Among those who have used the facilities, some have mentioned that the living laboratory environment has provided them with new possibilities for their research or work. For example, some have mentioned the access to energy data and indoor climate data, while others mentioned meeting new people they can cooperate with and being in contact with academic and highly-educated people. The sensors all over a full-scale building during realistic operation have also been mentioned as a wonderful opportunity for research. On the other hand, some respondents have not yet found anything in particular that the living laboratory environment has offered them, but they still find it inspiring to work in such a place. Overall, the living laboratory environment seems to have the potential to provide new opportunities for research and work, but it may depend on the specific focus of the research and work being conducted.


Do you use the laboratory facilities for your work or research?

Number of submissions: 15 Average: 2.60 Median: 2

Submissions	Count	% of submissions	
5	4	26.7%	26.7%
4	2	13.3%	13.3%
3	0	0%	0%
2	2	13.3%	13.3%
1	7	46.7%	46.7%

Figure 4.1.38: Effects of laboratory on facilitating tasks

Analysis and discussions: The post-occupancy evaluation survey of the ZEB Laboratory at NTNU included questions related to productivity and the impact of the environment on work performance. The results provide valuable insights into respondents' satisfaction with the availability of necessary resources and technology for productivity, the impact of the laboratory environment on work performance, changes in work habits, reflections on working in a living laboratory, thoughts about the living laboratory environment while working, disturbances experienced, and utilization of laboratory facilities.

The availability of necessary resources and technology for work received high satisfaction ratings, with 86% of respondents expressing satisfaction. This indicates that the ZEB Laboratory provides the required tools and infrastructure to support productivity effectively. Similarly, the impact of the environment in the ZEB Laboratory on productivity and work performance was rated positively by 66% of respondents. This suggests that the design and functionality of the laboratory contribute to a conducive work environment that enhances work performance.

Regarding changes in work habits, a third of the respondents reported experiencing changes since moving to the ZEB Laboratory. These changes included feeling inspired by the technologies and facilities, improved satisfaction, better workspace organization, preference for working in the evening due to the office landscape and meeting room locations, and increased success in selling projects when meetings are held in the ZEB Laboratory. These responses highlight the positive influence the laboratory environment has had on work habits and overall job satisfaction.

Reflecting on having an office in a living laboratory, the vast majority of respondents (86.7%) expressed positive sentiments. This indicates a strong appreciation for being part of a living laboratory, where research and work take place simultaneously. The high rating suggests that occupants perceive the living laboratory concept as valuable and beneficial to their work.

When considering the level of thinking about working in a living laboratory environment, the survey results indicate a moderate level of consciousness among respondents. While it is acknowledged by most, it does not appear to be the primary focus of their thoughts during work. This suggests that while the concept is recognized, respondents primarily prioritize their specific tasks and responsibilities rather than the living laboratory aspect.

Disturbances in the living laboratory environment were reported by 40% of respondents. These disturbances included seminars or meetings in common spaces, noise from visitors, and occasional workshops during lunch hours. However, these disruptions were generally considered minor and did not significantly impact work performance. The low incidence of disturbances from guided tours indicates the successful separation of public areas from research spaces, maintaining a conducive work environment.

Regarding the utilization of laboratory facilities, 60% of respondents reported using them to varying degrees. The living laboratory environment provided new possibilities for research and work, including access to energy and indoor climate data, networking opportunities, and exposure to academic expertise. However, some respondents have not yet fully explored the potential of the living laboratory but still find it inspiring to work in such a place. This suggests that the living laboratory environment offers unique opportunities for research, collaboration, and innovation, although the extent of its utilization may depend on the specific focus of individual projects.

Overall, the survey results indicate that the ZEB Laboratory at NTNU provides a productive and inspiring workplace environment for its occupants. The availability of resources and technology, coupled with a positive impact on work performance, contribute to high levels of satisfaction. The living laboratory concept is generally well-received, with its potential for research and work recognized by respondents. However, some disturbances were reported, which may require further attention to minimize their impact. The utilization of laboratory facilities varied among respondents, indicating that the living laboratory environment offers diverse opportunities that align with specific research and work requirements. By considering the feedback and suggestions provided by the respondents, the management of the ZEB Laboratory can continue to enhance productivity and optimize the living laboratory experience. This may include maintaining the availability of necessary resources, addressing disturbances effectively, and promoting further utilization of laboratory facilities to maximize research and collaboration opportunities.

4.1.5.10 Learning and development

The post-occupancy evaluation survey of the ZEB Laboratory at NTNU also included questions regarding the learning and development opportunities in the laboratory. Respondents were asked to rate their satisfaction with two aspects, including the educational and training opportunities in the ZEB laboratory and the extent to which the ZEB laboratory has allowed them to advance their professional or personal goals. Respondents mostly felt neutral about these two aspects and 50% of respondents reporting that they were either extremely satisfied or somewhat satisfied with them.

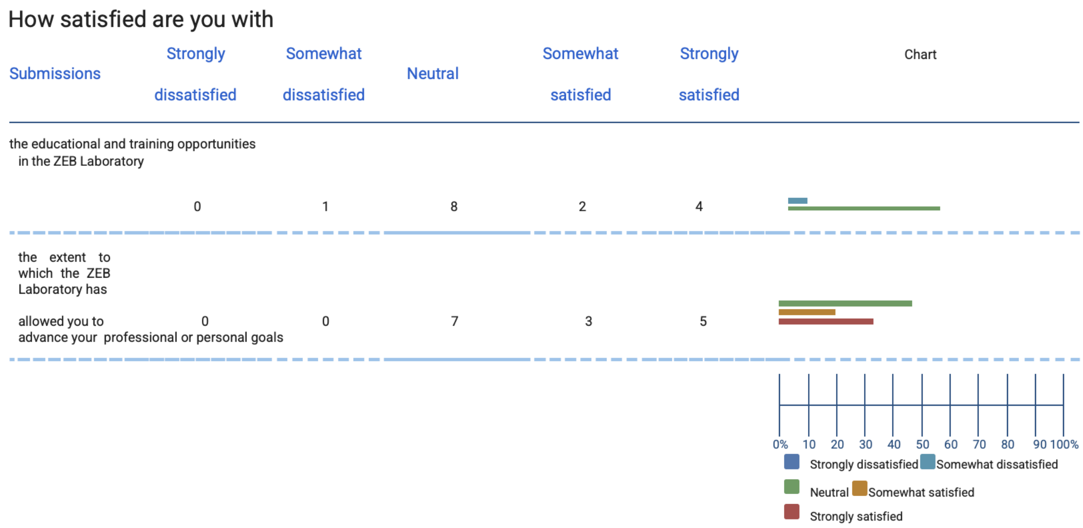


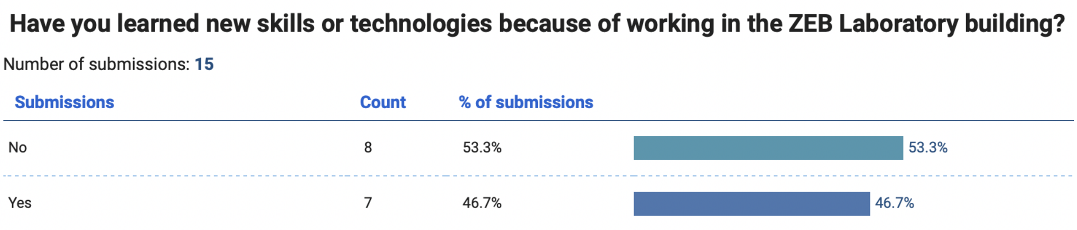
Figure 4.1.39: User satisfaction regarding learning and development

Out of the 15 respondents, 53.3% (8) reported that they did not learn new skills or technologies as a result of working in the ZEB Laboratory building, while 46.7% (7) reported that they did. The skills and technologies learned by those who responded positively varied, but included:

- Photovoltaics (PV)
- Energy technology
- Building-integrated photovoltaics (BIPV)

- Ventilation
- Indoor environment
- Stormwater management
- Phase change materials (PCM)
- Solar panel technology
- Life cycle assessment (LCA)
- Building automation

One respondent noted that they learned about PV technology through discussions with co-workers and viewing the lobby screen. Another respondent mentioned that they gained a comprehensive understanding of zero-emission building technologies. One person learned about building automation, while another mentioned the complexity of technical operations. One respondent also reported gaining experience as a tour guide.



Have you learned new skills or technologies because of working in the ZEB Laboratory building?

Number of submissions: 15

Submissions	Count	% of submissions	
No	8	53.3%	53.3%
Yes	7	46.7%	46.7%

Figure 4.1.40: Learning new skills or technologies

The majority of respondents (66.7%) reported that they have found the ZEB Laboratory building to be an inspiration for new ideas related to sustainability or other areas. The most commonly cited inspiration was the value of well-designed and functional spaces for human well being and productivity. Other ways in which the building has inspired respondents include new research possibilities, design of storm-water management systems, rain harvesting, performance requirements for BIPV, solar shading functionality, and questions about snow on PV, such as tilt angle, melting function, profitability, and price system.

Respondents also reported that the ZEB Laboratory has raised questions about the mismatch of PV production and has shown new opportunities for what is possible to measure and test in a realistic operational setting. Some respondents also mentioned that the lab has inspired them to think of new ways and strategies to control buildings. Finally, some respondents reported that the ZEB Laboratory has generated new research possibilities and projects in collaboration with other people they have not cooperated with before.

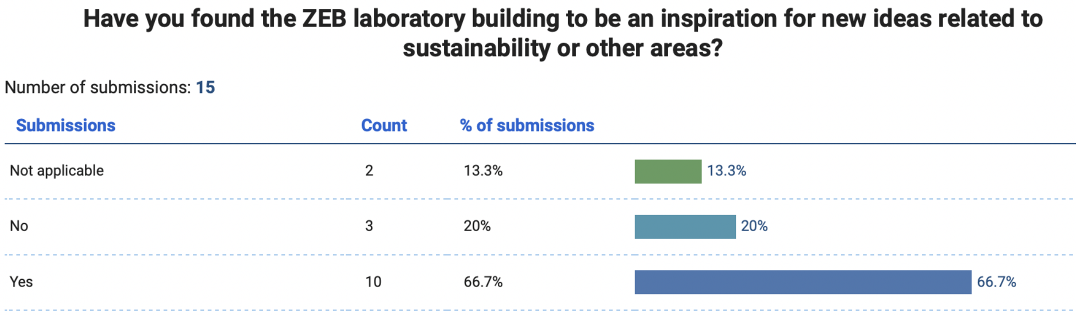


Figure 4.1.41: Inspiration for new ideas

Analaysis and Discussions: The findings from the post-occupancy evaluation survey of the ZEB Laboratory at NTNU regarding learning and development opportunities reveal a mixed response among the respondents. When asked about their satisfaction with educational and training opportunities in the laboratory, respondents mostly expressed a neutral stance. Only 50% of the participants reported being either extremely satisfied or somewhat satisfied with these aspects. This suggests that there is room for improvement in providing meaningful learning experiences within the ZEB Laboratory.

Among the respondents, 53.3% indicated that they did not learn new skills or technologies as a result of working in the ZEB Laboratory building. However, the remaining 46.7% reported that they did acquire new knowledge. The specific skills and technologies mentioned by those who responded positively varied, ranging from photovoltaics (PV) and energy technology to building-integrated photovoltaics (BIPV), ventilation, indoor environment, stormwater management, phase change materials (PCM), solar panel technology, life cycle assessment (LCA), and building automation. It is worth noting that some respondents learned through discussions with co-workers, viewing the lobby screen, or acting as tour guides, while others gained a comprehensive understanding of zero-emission building technologies or the complexity of technical operations.

Regarding inspiration, a majority of respondents (66.7%) reported that the ZEB Laboratory building had inspired them with new ideas related to sustainability or other areas. The most commonly cited source of inspiration was the value of well-designed and functional spaces for human well-being and productivity. The building also sparked ideas related to research possibilities, stormwater management systems, rain harvesting, performance requirements for BIPV, solar shading functionality, and questions about snow on PV panels. Additionally, the ZEB Laboratory raised questions about PV production, highlighted new opportunities for measuring and testing in a realistic operational setting, and prompted new strategies for building control. Some respondents mentioned that the laboratory had generated new research possibilities and collaborative projects with previously uncooperative individuals.

Based on these findings, it is evident that while learning and development opportunities in the ZEB Laboratory received mixed reviews, the building served as a source of inspiration for many respondents. However, there is a need to enhance the educational and training aspects to better meet the needs and expectations of the occupants. By expanding the range of skills and technologies offered, providing more structured learning opportunities, and fostering a collaborative environment, the ZEB Laboratory can further promote professional growth and personal development among its users.

4.1.5.11 Well-being

According to the survey results, occupants' satisfaction levels with the overall level of comfort in the building regarding temperature and noise levels were mixed. While 47% of respondents reported being strongly satisfied, 27% were somewhat satisfied, 20% were neutral, 7% were somewhat dissatisfied, and no one was strongly dissatisfied. Regarding air quality, the majority of respondents (60%) were satisfied, with 27% reporting being strongly satisfied, and 7% somewhat dissatisfied.

In terms of noise levels, 40% of respondents were strongly satisfied, 33% were somewhat satisfied, 20% were neutral, and 7% were somewhat dissatisfied. The building's facilities for rest and relaxation break rooms or quiet areas received mixed reviews, with 60% of respondents being satisfied, 20% neutral, 13% somewhat dissatisfied, and no one strongly dissatisfied. When it comes to the building's approach to reducing stress and promoting well-being in the workplace, 47% of respondents reported being strongly satisfied, 47% were somewhat satisfied, 13% were neutral, and no one reported being somewhat or strongly dissatisfied. Overall, occupants generally seemed to be satisfied with the building's approach to promoting well-being in the workplace.

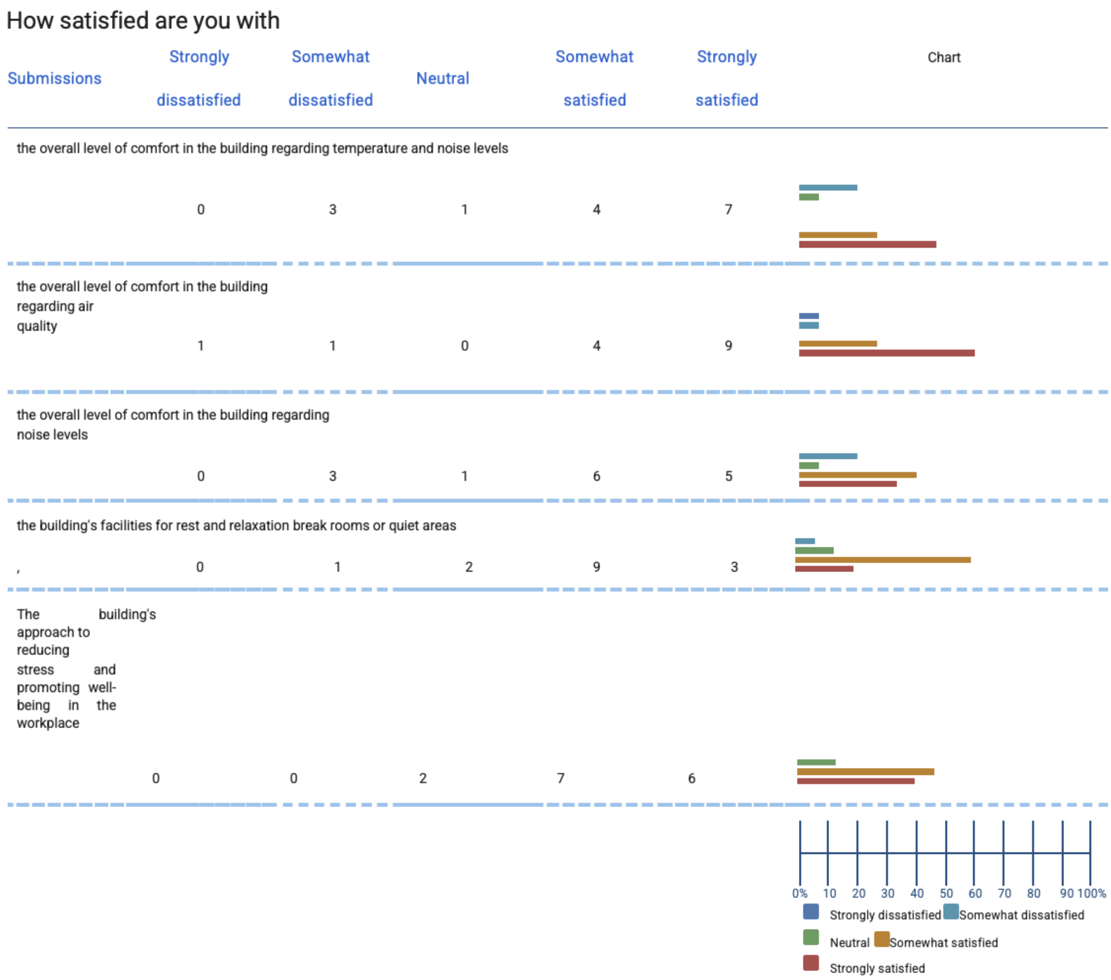


Figure 4.1.42: User satisfaction regarding well-being

*Analaysis and Discussions:*The survey results on occupants' satisfaction levels with the overall level of comfort in the building provide valuable insights into their experiences and perceptions. The mixed responses indicate that while there are areas of satisfaction, there are also areas where improvements or further attention may be needed.

In terms of temperature and noise levels, the satisfaction levels were diverse. While 47% of respondents expressed strong satisfaction with the comfort levels, indicating a positive experience, 27% were somewhat satisfied, suggesting that there is room for enhancement to meet the preferences of a larger portion of occupants. Additionally, 20% of respondents remained neutral, indicating a lack of strong opinion or a need for further evaluation. The presence of 7% who expressed dissatisfaction, although a relatively small percentage, highlights the importance of addressing specific concerns related to temperature and noise levels to ensure the well-being and productivity of all occupants.

Regarding air quality, the majority of respondents (60%) reported being satisfied. This indicates a positive overall perception, with 27% expressing strong satisfaction. However, it is worth noting that 7% were somewhat dissatisfied, suggesting the existence of issues that may need attention. Ensuring consistent and high-quality air quality throughout the building is crucial for the occupants' health and comfort, and addressing the concerns of those who expressed dissatisfaction is important to create a healthier indoor environment.

The feedback on the building's facilities for rest and relaxation, such as break rooms or quiet areas, was mixed. While 60% of respondents expressed satisfaction, indicating a positive experience, 20% remained neutral, and 13% expressed some level of dissatisfaction. This suggests that while a significant portion of occupants is content with the available facilities, there is room for improvement to better meet the needs and preferences of the occupants who expressed neutrality or dissatisfaction. Conducting further research or engaging with the occupants to understand their specific expectations and preferences could provide insights for enhancing these spaces.

When it comes to the building's approach to reducing stress and promoting well-being in the workplace, the survey results indicate a generally positive reception. Almost half of the respondents (47%) reported being strongly satisfied, and an additional 47% were somewhat satisfied. The absence of any respondents expressing dissatisfaction in this aspect is a positive outcome. It suggests that the building's initiatives and strategies for promoting well-being are appreciated by the occupants and have had a positive impact on their work experience.

Overall, the survey results indicate a generally positive perception of the building's approach to comfort, air quality, facilities for rest and relaxation, and promotion of well-being. However, there are areas, such as temperature and noise levels, where improvements or adjustments may be necessary to address the concerns of those who expressed dissatisfaction or neutrality. Additionally, enhancing the facilities for rest and relaxation based on the preferences and needs of the occupants can contribute to a more positive experience. Continual assessment, feedback collection, and targeted improvements will be essential for ensuring that the building's environment optimally supports the well-being and productivity of its occupants.

4.1.5.12 Community

Based on the survey responses, the level of community and interaction among occupants of the ZEB laboratory building was found to be generally positive. A majority of respondents (66.7%) reported being satisfied or strongly satisfied with the level of community and interaction, with only a small minority (10%) expressing dissatisfaction. In terms of the building's approach to promoting a sense of community and encouraging collaboration among occupants, the results were mixed. While 57.1% of respondents reported being satisfied or strongly satisfied, a significant portion (28.6%) expressed neutrality and 14.3% reported being dissatisfied or somewhat dissatisfied.

The level of interaction and cooperation between occupants of different departments or organizations within the building was also assessed. The results showed that while a majority of respondents (63.3%) reported being satisfied or strongly satisfied, a significant minority (26.7%) expressed dissatisfaction or somewhat dissatisfaction. Regarding the building's efforts to support and promote diversity, equity, and inclusiveness within the community of occupants, the majority of respondents (60%) reported being satisfied or strongly satisfied. However, there were still some who expressed dissatisfaction (10%) or neutrality (10%). Overall, the survey results suggest that the ZEB laboratory building is generally successful in promoting a sense of community and interaction among occupants. However, there is still room for improvement in terms of encouraging collaboration and promoting diversity, equity, and inclusiveness within the community of occupants.

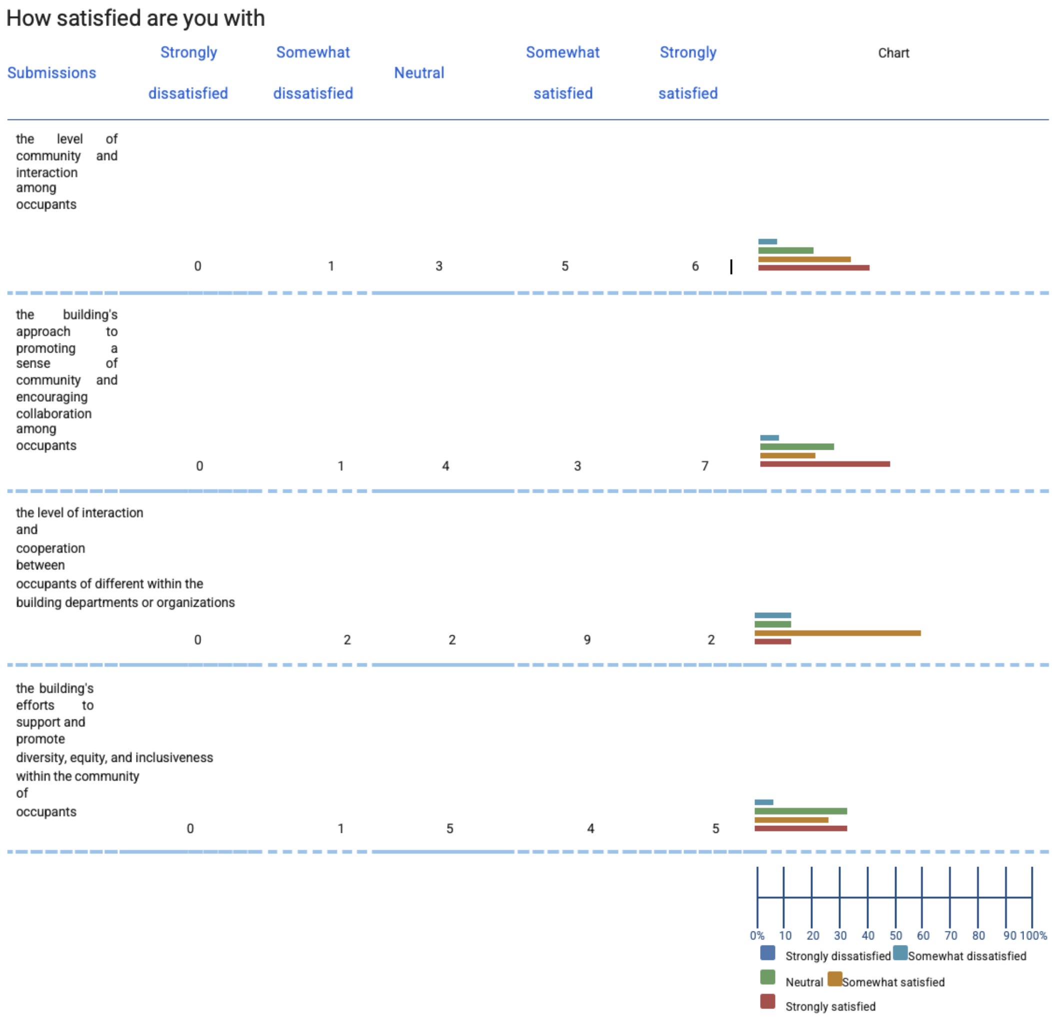


Figure 4.1.43: User satisfaction regarding community

The sense of community and interaction in the ZEB Laboratory building is attributed to several aspects, as stated by the survey responses. The mix of PhD candidates, NTNU and SINTEF employees was mentioned as a great aspect to promote interaction and collaboration. The common areas such as the staircase, the ground floor room, and the lunch room were highlighted as ideal meeting points for occupants. The open and flexible spaces, shared meeting rooms, and open offices that are separate but connected also contribute to the sense of community in the building. The fact that the building is jointly owned by NTNU and SINTEF makes it easier to cooperate on data and control. Additionally, events and activities, as well as the collaborative spaces, were mentioned as important aspects to foster interaction and collaboration among the occupants.

Analysis and Discussions: The analysis of the survey responses indicates that the level of community and interaction among occupants of the ZEB laboratory building is generally positive. A significant majority of respondents (66.7%) reported being satisfied or strongly satisfied with the level of community and interaction, which reflects a positive sense of belonging and engagement within the building. The small minority (10%) expressing dissatisfaction suggests that there may be some individuals who feel disconnected or less engaged in the community aspect.

When it comes to the building's approach to promoting a sense of community and encouraging collaboration, the results were more mixed. While 57.1% of respondents reported being satisfied or strongly satisfied, a notable portion (28.6%) expressed neutrality, and 14.3% reported being dissatisfied or somewhat dissatisfied. These findings indicate that while there is a positive perception of the building's efforts, there is still room for improvement in terms of fostering collaboration and strengthening the community atmosphere. This may involve exploring additional strategies or initiatives to encourage more interaction and collaboration among occupants.

The level of interaction and cooperation between occupants of different departments or organizations within the building was also assessed. The majority of respondents (63.3%) reported being satisfied or strongly satisfied with the level of interaction, indicating a positive cross-disciplinary and cross-organizational engagement. However, a significant minority (26.7%) expressed dissatisfaction or somewhat dissatisfaction, suggesting that there may be challenges or barriers to effective collaboration between different groups. Addressing these challenges and fostering a more inclusive and collaborative environment can lead to enhanced interactions and synergies among occupants.

In terms of supporting and promoting diversity, equity, and inclusiveness within the community of occupants, the majority of respondents (60%) expressed satisfaction or strong satisfaction. This indicates that the building's efforts in this regard have been recognized and appreciated. However, there were still some respondents who expressed dissatisfaction (10%) or neutrality (10%), suggesting the need for continued attention to ensure that all occupants feel included and valued within the community.

The sense of community and interaction in the ZEB laboratory building can be attributed to various factors as mentioned in the survey responses. The mix of PhD candidates, NTNU, and SINTEF employees was highlighted as a positive aspect that promotes interaction and collaboration, as it brings together individuals from different backgrounds and expertise. The availability of common areas such as the staircase, and lunch room as meeting points contributes to the sense of community and provides opportunities for informal interactions. The open and flexible spaces, shared meeting rooms, and connected but separate open offices also play a role in fostering collaboration and communication.

The joint ownership of the building by NTNU and SINTEF was mentioned as a facilitating factor for cooperation on data and control, indicating that organizational collaboration can be facilitated by shared ownership and shared goals. Events and activities organized within the building, along with the presence of collaborative spaces, were recognized as important aspects that foster interaction and collaboration among occupants. These findings highlight the importance of creating opportunities for socialization, knowledge sharing, and networking within the building to strengthen the sense of community and promote collaboration.

In conclusion, the survey results suggest that the ZEB laboratory building has generally succeeded in promoting a sense of community and interaction among occupants. However, there is still room for improvement in terms of encouraging collaboration, strengthening cross-disciplinary and cross-organizational interactions, and promoting diversity, equity, and inclusiveness. Addressing these areas can further enhance the sense of community, engagement, and collaboration within the building, ultimately contributing to a more vibrant and productive environment for all occupants.

4.1.5.13 User engagement

The survey results indicate that respondents had varying levels of satisfaction with different aspects of the design, construction, and maintenance phases of the ZEB laboratory building. When it comes to involvement and participation in the design phase, only 26.7% of respondents were satisfied or strongly satisfied, while 6.7% were dissatisfied or somewhat dissatisfied. However, a significant portion of respondents (33.3%) did not find this applicable, indicating that they were not employed at Sintef or NTNU during the phase mentioned in the questions. Similarly, when it comes to communication and feedback during the design and construction phases, only 33.4% of respondents found this applicable, and of those, only 33.4% expressed satisfaction or strong satisfaction.

On the other hand, a majority of respondents (53.3%) did not find this applicable. The level of opportunities for providing input and making suggestions during the design and construction phases yielded similar results. Only 33.4% of respondents found this applicable, and of those, only 33.4% expressed satisfaction or strong satisfaction. Additionally, 53.3% of respondents did not find this applicable However, when it comes to access to information about the design and construction phases of the building, a larger percentage of respondents expressed satisfaction. 60% of respondents found this applicable, with 20% being somewhat satisfied and 40% being satisfied or strongly satisfied.

Regarding the level of transparency and open communication from the building management team about the operation and maintenance of the building, there was a higher level of satisfaction among respondents. 53.3% of respondents found this applicable, with 53.3% expressing satisfaction or strong satisfaction. Finally, the opportunities for providing feedback and input into the operation and maintenance of the building received mixed results. 40% of respondents expressing satisfaction or strong satisfaction.

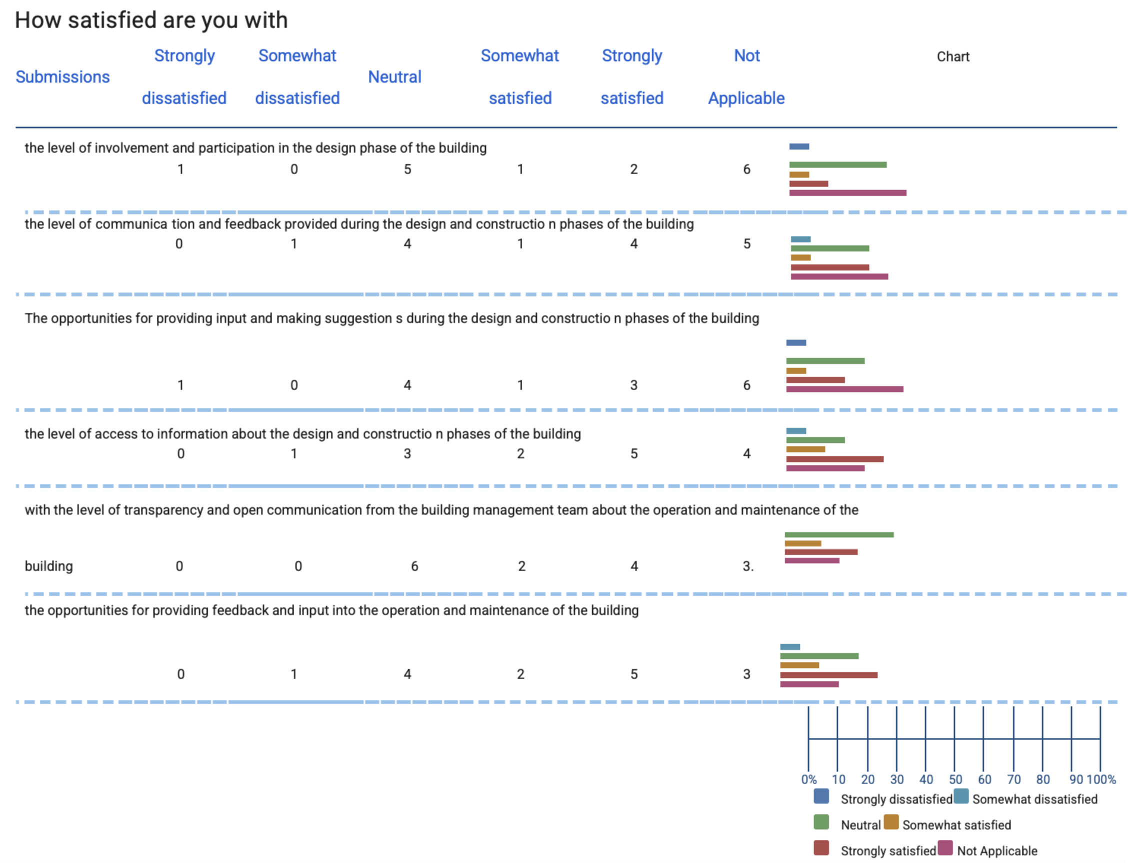


Figure 4.1.44: User satisfaction regarding users engagement

Based on the survey responses, the average rating for the extent to which involvement in the different phases of the ZEB laboratory building project and feedback after completion was valued and mattered was 3.47 out of 5, with a median of 3. This indicates that while some respondents felt their involvement was highly valued, others felt it was less so. When asked for suggestions on how to improve user engagement and participation during the design and construction phases of future buildings, some respondents suggested workshops and co-creation sessions, visualization tools, and better definition of expected user input during the design process. Others had no suggestions or were unsure. Overall, it may be beneficial for future building projects to clearly define the roles and expectations of users during the design and construction phases, and to actively seek out and incorporate user feedback and suggestions in a meaningful way. Additionally, incorporating visualization tools and collaborative workshops may help to increase user engagement and participation in the design process.

To what extent do you feel that your involvement in the different phases of the ZEB laboratory building project, and your feedback after completion of the project, was valued and mattered?

Number of submissions: **15** Average: **3.47** Median: **3**

Submissions	Count	% of submissions	
5	4	26.7%	26.7%
4	2	13.3%	13.3%
3	7	46.7%	46.7%
2	1	6.7%	6.7%
1	1	6.7%	6.7%

Figure 4.1.45: Importance of users' feedback

Analysis and Discussions: The analysis of the survey results reveals that respondents had varying levels of satisfaction with different aspects of the design, construction, and maintenance phases of the ZEB laboratory building. When it comes to involvement and participation in the design phase, a relatively low percentage of respondents (26.7%) expressed satisfaction or strong satisfaction. This suggests that there may have been limitations or challenges in providing opportunities for meaningful involvement during the design phase. Furthermore, a significant portion of respondents (33.3%) did not find this applicable, indicating that they were not employed at Sintef or NTNU during the mentioned phase. Communication and feedback during the design and construction phases also received relatively low satisfaction ratings. Only 33.4% of respondents found this applicable, and among those, only 33.4% expressed satisfaction or strong satisfaction. The majority of respondents (53.3%) did not find this applicable.

The level of opportunities for providing input and making suggestions during the design and construction phases yielded similar results, with a low percentage of respondents finding it applicable (33.4%) and expressing satisfaction (33.4%). A significant majority (53.3%) did not find this applicable. On the other hand, access to information about the design and construction phases of the building received a higher satisfaction rating, with 60% of respondents finding it applicable and expressing satisfaction or strong satisfaction. This suggests that providing transparent and accessible information about the design and construction processes can positively impact occupants' perception of the building project.

Regarding transparency and open communication from the building management team about the operation and maintenance of the building, there was a higher level of satisfaction among respondents (53.3% finding it applicable and expressing satisfaction or strong satisfaction). This indicates that occupants value clear and open communication regarding the ongoing operation and maintenance of the building. Opportunities for providing feedback and input into the operation and maintenance of the building received mixed results, with 40% of respondents expressing satisfaction or strong satisfaction.

This suggests that while some occupants feel their feedback is valued and acted upon, there is room for improvement in incorporating user input into the ongoing operation and maintenance processes. The average rating for the extent to which involvement in the different phases of the building project and feedback after completion was valued and mattered was 3.47 out of 5, with a median of 3. This indicates that there is a moderate level of perceived value placed on user involvement and feedback. However, there is room for improvement to ensure that occupants feel their contributions are genuinely valued and taken into account throughout the various phases of the building project.

Some respondents provided suggestions for improving user engagement and participation during the design and construction phases of future buildings. These suggestions included workshops and co-creation sessions, visualization tools to aid in understanding design concepts, and clearer definition of expected user input during the design process. These suggestions highlight the importance of creating structured opportunities for user engagement, utilizing innovative tools to enhance communication and understanding, and setting clear expectations for user involvement during the early stages of building projects.

In conclusion, the survey results emphasize the need for improved user engagement and participation during the design, construction, and maintenance phases of building projects. Clear communication channels, opportunities for meaningful involvement, and transparent information sharing can contribute to a higher level of occupant satisfaction and a sense of ownership. Incorporating user feedback and suggestions in a meaningful way can enhance the overall user experience and promote a greater sense of community within the building. Future building projects can benefit from clearly defining user roles and expectations, and incorporating user feedback throughout the design, construction, and maintenance phases.

4.1.5.14 Overall satisfaction

Based on the submissions, it seems that the majority of respondents 86% are satisfied with the ZEB laboratory building as a workplace. 13% of respondents expressed a somewhat dissatisfied opinion, while the remaining were neutral.

How satisfied are you with

Submissions	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied	Chart
overall with the ZEB laboratory building as a workplace	0	0	2	3	10	

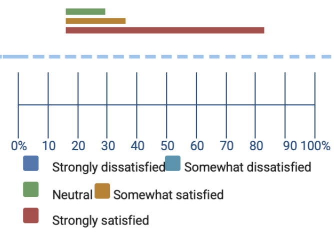


Figure 4.1.46: Overall user satisfaction

It appears that all respondents did not report any notable changes in their perceptions or experiences of the ZEB laboratory building during the two years of occupancy.

Have you experienced any changes in your perceptions or experiences of the ZEB laboratory building over the two years of occupancy? Please describe any changes you have noticed and whether you feel that these changes have been positive or negative.

Number of submissions: **15**

Submissions	Count	% of submissions	
No	15	100%	100%
Yes	0	0%	0%

Figure 4.1.47: changes over the years of occupancy

Based on the responses provided, here are some suggestions for enhancing the overall experience and satisfaction as an occupant of the ZEB Laboratory building:

- Provide a mix of individual and open office spaces to allow for privacy and focus when needed.
- Send reminders to individuals who have booked meeting rooms to ensure they are being used, freeing up the space for others to book.
- Install screens and dock-in-stations with webcams in smaller meeting rooms to make them more attractive for use.
- Improve solar shading to allow more natural light into the building and reduce the use of electric light.
- Offer lunch lectures with assessments of different aspects of how the building is performing, and what can be improved.
- Provide more relaxing common areas.
- Ensure that all researchers have a good understanding of the technical solutions of the ZEB laboratory and how to access the collected data.

- Encourage more chances for NTNU and SINTEF employees to meet and discuss ideas and projects in the building.
- Optimize the automatic exterior solar shading.
- Create an attractive outdoor space with shelter, sun, and greenery for occupants to sit and eat lunch.
- Provide a quiet room with a flat sofa for short breaks, with the option to dim or turn off the lights.

Analaysis and Discussions: The analysis of the survey responses reveals that the majority of respondents (86%) are satisfied with the ZEB laboratory building as a workplace. This high level of satisfaction indicates that the building has generally met the needs and expectations of its occupants. It is worth noting that a small percentage (13%) expressed a somewhat dissatisfied opinion, suggesting that there are areas for improvement to further enhance the occupant experience. In addition, the survey did not identify any significant changes in the respondents' perceptions or experiences of the ZEB laboratory building over the two years of occupancy. This suggests that the building has maintained a consistent level of satisfaction among its occupants, indicating a stable and well-performing environment.

The suggestions provided by the respondents offer valuable insights into areas that can be addressed to enhance the overall experience and satisfaction within the building. Some of the key recommendations include:

-Providing a mix of individual and open office spaces: This allows for flexibility, providing privacy and focus when needed, while also promoting collaboration and interaction among occupants.

-Improving meeting room utilization: Sending reminders to individuals who have booked meeting rooms can help ensure efficient use of the space and free up rooms for others to book.

-Enhancing quit box facilities: Installing screens, dock-in stations with webcams, and other amenities in boxes can make them more attractive and user-friendly, encouraging their use.

-Optimizing natural lighting: Improving solar shading systems to allow more natural light into the building can create a brighter and more comfortable workspace while reducing reliance on electric lighting.

-Promoting knowledge sharing: Offering lunch lectures that assess different aspects of the building's performance and provide insights on areas for improvement can foster a culture of continuous learning and engagement among occupants.

-Creating relaxing common areas: Increasing the availability of inviting and comfortable common areas provides occupants with spaces for relaxation, informal meetings, and social interactions, contributing to a positive work environment.

-Enhancing occupant understanding of technical solutions: Ensuring that all researchers have a good understanding of the technical solutions and access to collected data within the ZEB laboratory building can empower them to make the most of the building's features and contribute to its optimal performance.

-Facilitating collaboration between NTNU and SINTEF employees: Promoting opportunities for employees from different departments or organizations within the building to meet and discuss ideas and projects can foster collaboration, knowledge sharing, and interdisciplinary cooperation.

-Enhancing outdoor spaces: Creating an attractive outdoor space with shelter, sunlight, and greenery provides occupants with an inviting area to relax, eat lunch, and recharge during breaks.

-Providing quiet spaces: Designating a quiet room with a flat sofa and the option to dim or turn off lights allows occupants to take short breaks and find moments of tranquility within the building.

By addressing these recommendations, building management can actively respond to the suggestions provided by the occupants and further improve the overall satisfaction and experience of the ZEB laboratory building. Regular feedback collection, continuous improvement efforts, and a user-centric approach will contribute to creating a workplace that meets the evolving needs of its occupants.

4.1.5.15 Conclusion

The post occupancy evaluation of the ZEB laboratory provided valuable insights into user satisfaction and perceptions across various aspects of the facility. The findings indicate an overall positive level of satisfaction among users, with several aspects receiving favorable ratings. However, there are areas that require attention and improvement to further enhance the user experience. Additionally, the post occupancy evaluation of the ZEB laboratory has generated valuable user feedback, including suggestions and raised issues, which have been discussed in the previous analysis and discussion section. These user-driven insights provide actionable recommendations that can contribute to enhancing the overall user experience of the building.

The survey results reveal that users are highly satisfied with aspects such as sustainability, safety and security, amenities, temperature and air quality, and user well-being. These positive ratings highlight the successful implementation of environmentally conscious practices, safety measures, and the provision of comfortable and well-equipped facilities. On the other hand, aspects such as functionality, learning and development, user engagement, and community-building require focused attention. The lower ratings in these areas indicate the need to address specific shortcomings and implement targeted improvements. This may involve optimizing workspace design, providing resources and opportunities for skill development, fostering a sense of community and collaboration, and enhancing user engagement through interactive initiatives (figure 4.1.48).

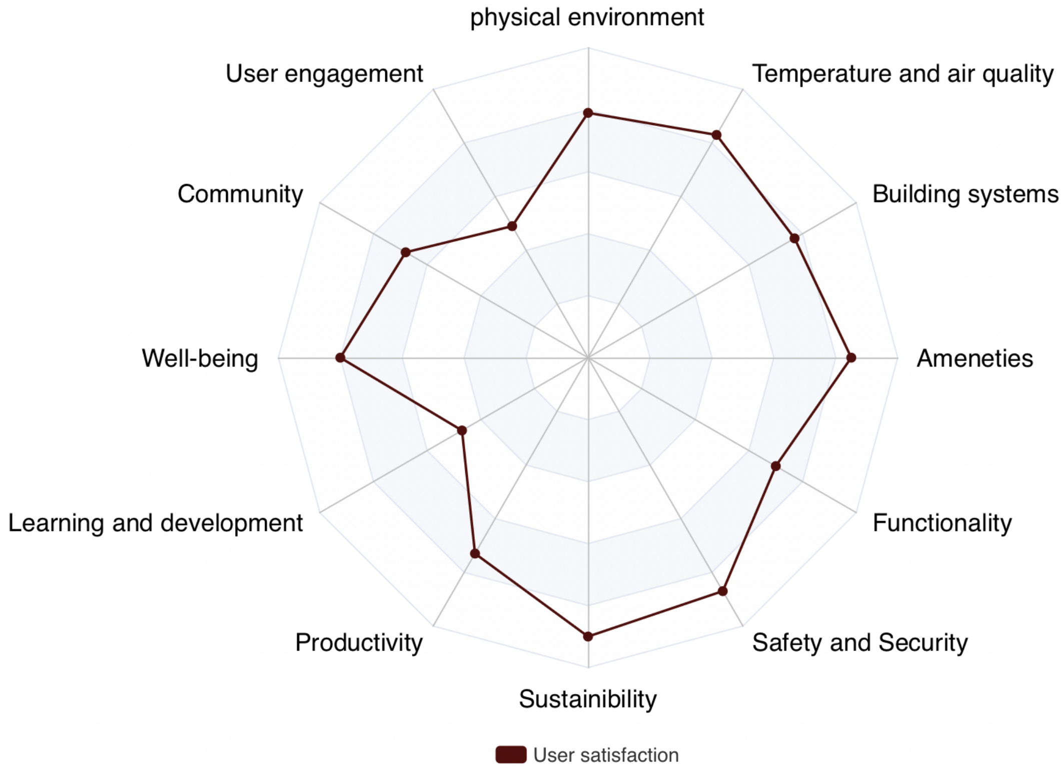


Figure 4.1.48: The Results of Post Occupancy Evaluation Survey

It is important to note that the results presented in the radar chart assume equal weight for the sub-factors within each aspect. While this approach provides a general overview, the relative importance of each sub-factor may vary among users. Considering a weighted evaluation approach in future assessments can offer a more nuanced understanding of user satisfaction and guide improvements that align with users' specific needs and preferences. Additionally, user engagement calculations are based on the number of individuals who found the engagement questions applicable to themselves. This acknowledges that engagement is subjective and not all users might have been part of NTNU or SINTEF during the project phases which the question was asking about.

In conclusion, the post occupancy evaluation of the ZEB laboratory demonstrates an overall positive user satisfaction across various aspects, indicating successful implementation in several areas. However, it also highlights the need for targeted improvements to enhance functionality, productivity, learning and development opportunities, user engagement, and community-building. By considering the varying importance of sub-factors and individual perspectives, future evaluations and improvement efforts can provide a more accurate representation of user satisfaction and guide interventions that optimize the user experience within the ZEB laboratory.

4.1.6 Findings from walkthrough

A walkthrough was conducted as part of the post occupancy evaluation process for the ZEB laboratory. The walkthrough method, as discussed in section 2.9.3 is a approach used in POEs to assess a building's performance and gather feedback from its occupants which involves physically visiting the building, observing its features, and conducting interviews with selected occupants. Its primary objective was to evaluate the laboratory's performance, user satisfaction, and overall functionality (Hansen, Blakstad, and Knudsen, 2010). By conducting this evaluation, we aimed to identify any strengths, weaknesses, or areas for improvement in the building's design and operation.

The ZEB laboratory, being the subject of this evaluation, is a multi-floor facility accommodating two organizations, namely the Norwegian University of Science and Technology (NTNU) and SINTEF. In order to capture a diverse range of perspectives and experiences, occupants were chosen from different floors and sides of the building, representing both organizations. To ensure a comprehensive evaluation, occupants were selected based on their affiliation to NTNU and SINTEF, as well as the physical locations of their offices within the building. Two individuals, Occupant 1NN and Occupant 2NS, were selected from NTNU. Occupant 1NN is situated in an office on the north side of the second floor, while Occupant 2NS works in an office on the south side of the second floor.

These occupants can provide insights into the specific requirements and perspectives of NTNU employees in their respective areas of the building. SINTEF, as a research organization, also has a presence within the ZEB laboratory. Occupant 3S, an employee of SINTEF, was chosen to represent their interests. Their office is located on the third floor, where the north and south sides of the building are not separated. This selection ensures the inclusion of perspectives from SINTEF employees and considers any unique aspects or requirements associated with their work environment.

For the purpose of this thesis, a coding method will be employed based on the occupants' affiliation to NTNU and SINTEF, as well as their place of office. The aim for utilizing this coding method is to maintain clarity and consistency throughout the report while ensuring the anonymity of the participants. It allows us to differentiate the perspectives and experiences of occupants based on their affiliation and physical location within the ZEB laboratory. In the following sections the responses provided by the selected occupants will be presented. The walkthrough plan including the stops and the questions asked is presented in appendix D.

4.1.6.1 Stop 1: Meeting Rooms

During the walkthrough, the occupants were met in one of the meeting rooms, and the interviewer introduced themselves and explained the purpose of the post occupancy evaluation (POE) method. The occupants were asked about their overall experience with the building and then specifically about their experience with the meeting rooms. The following topics were discussed: frequency of use, availability, size and numbers, comfort and functionality, acoustics, lighting, temperature and air quality, technology and AV equipment, difficulties in booking, and suggestions for improvement (figure 4.1.49).

Topic 1: Frequency of Use and Availability
Occupant 1NN reported using the meeting rooms approximately once per day, Occupant 2NS mentioned using them once per week, and Occupant 3S estimated using them three times per day. The availability of meeting rooms was generally satisfactory, although some participants emphasized the importance of planning ahead and booking in advance. Occupant 3S mentioned that booking a week in advance ensured a room could be obtained.

Topic 2: Size and Numbers
Participants acknowledged the availability of meeting rooms in various sizes, catering to different group requirements. Occupant 3S expressed satisfaction with the variety of sizes available, allowing for flexibility based on the number of participants.

Topic 3: Comfort and Functionality
Concerns were raised about a specific meeting room (Room 318) on the third floor, which lacks windows. Occupant 3S noted that after lunch, the room experiences poor air quality. No other major comfort or functionality issues were reported by the participants.

Topic 4: Acoustics and Lighting
Participants generally expressed satisfaction with the lighting and acoustics, considering them sufficient for their needs. Occupant 3S mentioned a minor issue when sitting with their back to the window during Teams meetings, resulting in a silhouette effect. However, this was not considered a significant concern.

Topic 5: Temperature and Air Quality
Overall, participants stated that the temperature in the meeting rooms is well-regulated.

Topic 6: Technology and AV Equipment No significant difficulties with technology or AV equipment in the meeting rooms were reported by the participants. However, Occupant 3S mentioned occasional connectivity issues when connecting their PC to the equipment, which they resolved independently.

Topic 7: Meeting Room Bookings
The participants expressed concerns about rooms being booked but not utilized, making it challenging for others to book them. Occupant 3S suggested implementing a check-in system to release unused rooms for others to use. This system would allow for better utilization of the meeting rooms and prevent unnecessary bookings.

Topic 8: Additional Features
No specific suggestions for additional features in the meeting rooms were provided by the participants.

Based on the feedback received from the participants, the meeting rooms at the ZEB laboratory generally met the occupants' requirements in terms of availability, size, comfort, lighting, temperature, and technology. However, specific concerns were raised regarding a meeting room without windows, which resulted in poor air quality after lunch. The participants also emphasized the need for better utilization of the rooms by addressing the issue of booked but unused rooms. Overall, the feedback provided valuable insights for improving the functionality and utilization of the meeting rooms, ensuring a more satisfactory experience for the occupants.

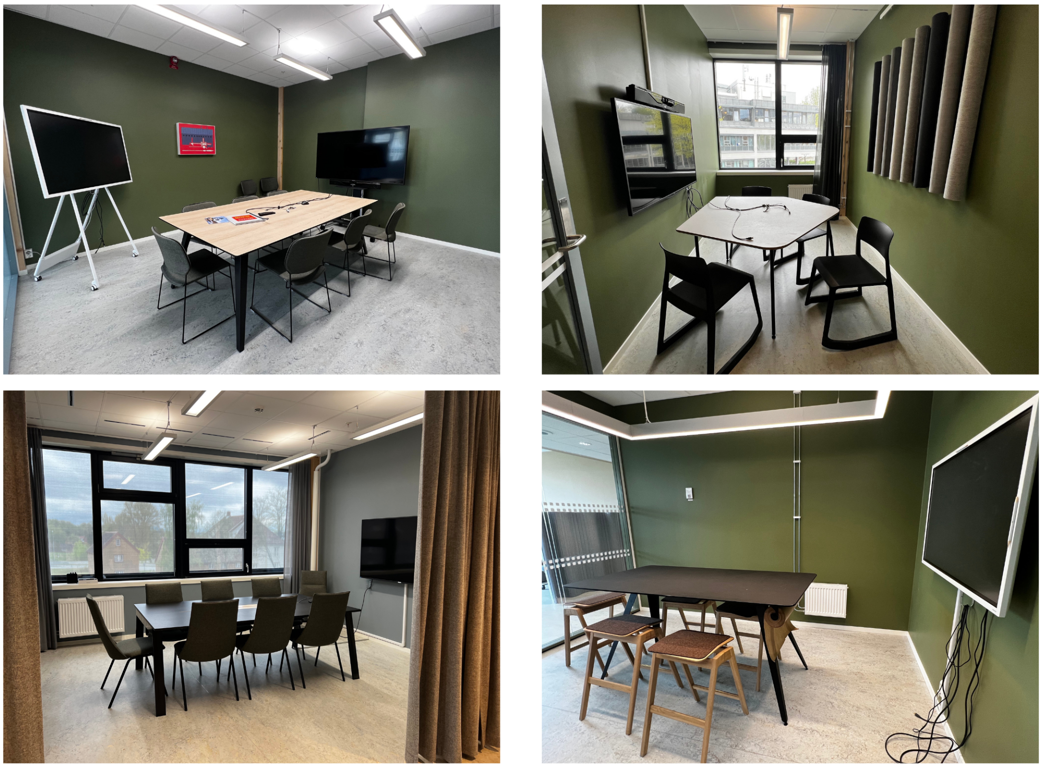


Figure 4.1.49: Meeting rooms, ZEB Laboratory, Photos taken by the author.

4.1.6.2 Stop 2: Living Lab Experience

In this part, the evaluation aimed to assess the occupants' perception of advantages, disadvantages, concerns, comfort with monitoring, and suggestions for improving the living lab experience.

Topic 1: Experience Working in a Living Lab Environment
The participants generally had a positive experience working in the living lab environment. Occupant 1NN mentioned that ongoing research was not currently taking place in the twin rooms, and the default settings were being used. The participants indicated that the lab's operation did not significantly disrupt their work.

Topic 2: Advantages and Disadvantages of Working in a Living Lab Environment
The participants discussed the advantages of the living lab environment. Occupant 1NN mentioned the immediate response to fix any broken equipment as it could affect data collection. This highlights the advantage of timely maintenance. However, no specific disadvantages were mentioned by the participants.

Topic 3: Concerns About Data Collection and Usage
The participants did not express any concerns about the data collected in the living lab. Occupant 3S stated that they did not have any concerns, while occupant 1NN mentioned that the data is likely anonymized and stored on a server, reducing privacy concerns.

Topic 4: Comfort with Monitoring and Privacy Concerns
The participants felt comfortable with the level of monitoring in the lab and did not express any privacy concerns. Occupant 1NN mentioned that the data is not monitored closely, and occupant 3S stated that the data is sufficiently anonymized.

Topic 5: Suggestions for Improving the Living Lab Experience
The participants did not provide any specific suggestions for improving the living lab experience. However, they expressed overall satisfaction with the comfort and functionality of the lab.

Topic 6: Impact on Work or Research
Occupant 1NN mentioned using data from the building, while occupant 2NS expressed awareness of the availability of data, although they had not used it for their research. The participants appreciated the learning opportunities provided by the technology presented in the building, especiually the screen which is located in the entrance and showing energy reports for the building.

Topic 7: Improvement or Expansion of the Living Lab
The participants did not suggest any areas for improvement or expansion of the living lab, indicating that they were satisfied with the existing setup and found it suitable for their research and work.

Based on the feedback received from the participants, the living lab environment at the ZEB laboratory was generally well-received. The occupants appreciated the immediate response to equipment maintenance, felt comfortable with the level of monitoring, and had no significant concerns about data collection or usage. They found the lab comfortable and conducive to their work, appreciating the availability of data and the learning opportunities provided by the technology in the building. The participants did not suggest any specific improvements or expansions, indicating their overall satisfaction with the living lab experience.

4.1.6.3 Stop 3: ZEB Laboratory App

During the walkthrough of the ZEB Laboratory, the occupants were asked about their experiences with the ZEB Laboratory app and its features. The following are their responses and discussions regarding the app (figure 4.1.9).

Topic 1: Experience with the App
Occupant 2NS mentioned that their experience with the ZEB Laboratory app has been mostly positive. They find it to be a useful tool for controlling various settings in the building. However, they noted that it can be frustrating when the app doesn't work properly, especially when they cannot override certain building functions like the solar shadings. Occupant 1NN also highlighted the inability to change the light in common areas through the app.

Topic 2: App Functionality and Features
Occupant 2NS stated that they frequently use the app to perform tasks such as opening windows, adjusting lights, and controlling various settings. They also mentioned that some features of the app, such as controlling solar shadings, are not fully functional and cannot be overridden when the app is not working. The discussion further touched on the stability of the indoor climate, with Occupant 3S noting that the north side of the building provides a more stable environment on the third floor.

Topic 3: Reporting Issues with the App
Occupant 1NN raised concerns about the lack of clarity regarding reporting issues with the app. They expressed uncertainty about who to contact when the app malfunctions and suggested the need for a dedicated "report issue" button within the app. Occupant 2NS agreed with this suggestion and mentioned that the current process for reporting issues is unclear, with limited information available about app developers or contacts.

Topic 4: Importance of the App
The occupants recognized the significance of the ZEB Laboratory app in their daily work and activities within the building. They mentioned that the app allows them to control various settings in their rooms, including window openings, lighting adjustments, and booking rooms. Without the app, it would be challenging to manually override solar shading or perform essential tasks related to room management.

Topic 5: Suggestions for App Improvement
Occupant 1NN suggested adding a feature that enables users to send requests to individuals who have booked meeting rooms. This feature would allow users to inquire about the availability of a room or request its usage if it appears to be unused. They also mentioned the need for more information on the "About the App" page, including clear contact details for reporting app issues.

In conclusion, the occupants had generally positive experiences with the ZEB Laboratory app, finding it valuable for controlling various building settings. However, they expressed concerns about app malfunctions and the lack of clarity in reporting issues. The importance of the app in their daily work was emphasized, and suggestions were made for app improvements, including a dedicated "report issue" button and more detailed contact information within the app.

4.1.6.4 Stop 4: Solar Shadings and Movement Sensors

In this section a comprehensive discussions was held with the occupants regarding two topics: Solar Shadings and Movement Sensors. The objective was to gather detailed feedback, experiences, and suggestions related to these features in the building.

Topic 1:Issues with Solar Shadings
During the discussions on solar shadings, Occupant 1NN expressed concerns about the aggressive behavior of these shadings. They reported that the blinds often lowered even with minimal sunlight entering the room, leading to frequent manual overrides. Occupant 2NS shared a similar experience, stating that even a slight ray of sun on the window triggered the blinds to lower, causing inconvenience. Additionally, it was observed that the blinds on the east side operated even when the sun was in the west, suggesting that the sensors treated the entire room as one unit. Occupant 3S confirmed this behavior and mentioned that the solar shadings in the lunchroom and common area were particularly problematic.

Topic 2: Daylight Levels and Adjustments
The occupants expressed varying opinions regarding the level of daylight entering the building. Occupant 1NN and Occupant 2NS reported that certain areas, particularly the north side and some parts of the south side, had satisfactory daylight levels. However, they highlighted the need for adjustments with curtains or blinds to achieve the desired lighting conditions. Occupant 1NN specifically mentioned that solar shadings on the north side were not generally needed, except for a brief period when sunlight reflects on a specific wall. Occupant 3S agreed with this observation, emphasizing that the reflection from neighboring buildings provided ample natural light for most of the day.

Topic 3: Suggestions for Improvement
Based on the discussions, the occupants shared valuable suggestions for improving the solar shading system. Given the fact that sensors are adjusted to sense and react every 15 mins, they were in the opinion that the current system of automatic solar shadings needs manually overriding many times in certain situations and also frequent change of their positions in a meeting could be distracting. They proposed reducing the sensitivity of the solar shadings to prevent frequent and unnecessary lowering, which could improve user comfort and minimize the need for manual overrides. Additionally, they recommended enhancing manual control options to allow users to specify desired settings for a certain period, overriding automatic adjustments. Occupant 3S further suggested incorporating an app feature that enables users to program the blinds' positions until a specified time,

providing greater customization and convenience.

Topic 4: Experience with Movement Sensors
All occupants confirmed their positive experience with movement sensors for lighting in their workspaces. Occupant 1NN reported that the sensors generally worked well, promptly turning on lights upon detecting movement. However, they noted that if someone remained very still at their desk, the lights might temporarily turn off. Occupant 2NS echoed this sentiment and added that the presence of sufficient daylight in their workspace mitigated any inconvenience caused by temporary light turn-offs.

The discussions provided valuable insights into the issues, experiences, and suggestions related to solar shadings and movement sensors in the building. The occupants expressed concerns about the aggressive behavior of the solar shadings, frequent manual overrides, and the need for adjustments in specific areas. Regarding movement sensors, they acknowledged their effectiveness but highlighted the occasional temporary light turn-offs. The suggestions for improvement included reducing sensitivity, enhancing manual control options, and introducing app features for greater customization. These findings can serve as valuable feedback for future enhancements to the building's solar shading and movement sensor systems, aiming to enhance user experience, improve energy efficiency, and strike a balance between natural and artificial lighting in the workspace.

Figure 4.1.50: Solar shadings, ZEB Laboratory, Photos taken by the author.

4.1.6.5 Stop 5: Offices

This section focuses on the discussions held with the occupants regarding open offices in different sides of the building. The purpose was to gather insights into the occupants' experiences, concerns, and suggestions related to layout, occupants' combination, noise levels, privacy, lighting, temperature, air quality, and additional features in the open offices (figure 4.1.51).

Topic 1: Layout and Occupants' Combination During the discussions, occupants expressed overall satisfaction with the layout of the open offices. They appreciated the collaborative environment and the opportunity to interact with colleagues. Occupant 1NN described the open landscape as nice and enjoyed having people around. Occupant 2NS agreed, mentioning that working in an open landscape was preferable. Occupant 3S highlighted the advantage of having mixed occupants, including PhD students, visiting scholars, and postdocs, as it fostered a social and diverse environment.

Topic 2: Noise Levels and Distractions
Regarding noise levels and distractions, occupants shared mixed experiences. Occupant 1NN noted that in their office on the north side, they occasionally noticed noise from the traffic passing by the desks. However, at present, it was not a significant issue due to lower occupancy. Occupant 3S added that the nearby bathrooms and meeting rooms also contributed to increased walking traffic, which could potentially become a problem with higher occupancy. Speaker 3S acknowledged the importance of individuals being mindful of their noise levels while walking through the open landscape.

Topic 3: Privacy in Open Landscape
Occupant 1NN mentioned that their activities are visible to others, while Speaker 3Sz highlighted the lack of soundproofing in the landscape. However, occupants shared strategies to address confidentiality concerns, such as using meeting rooms for confidential conversations or finding alternative spaces within or outside the building. Occupant 1NN mentioned using the cleaners' office when necessary.

Topic 4: Lighting, Temperature, and Air Quality
Occupants generally expressed satisfaction with the lighting in the open offices, considering it sufficient for their work. Occupant 3S highlighted the advantage of having windows that could be opened for improved ventilation, especially during warmer days. Occupant 1NN mentioned testing algorithms for window opening and noted that the windows were slightly open at the time of the discussion. Occupant 2NS mentioned the fact that the offices in the south side of the building might get warm in the summer and cold in the winter. No significant concerns were raised regarding temperature or air quality.

Topic 5: Additional Features
Occupants did not have specific requests for additional features in the open offices. Occupant 3S mentioned bringing in shelves to store books, which were initially lacking but resolved by repurposing furniture from another area on campus. Over-

all, occupants indicated that they did not feel anything was missing in the open offices.

The discussions with the occupants provided valuable insights into their experiences and perspectives regarding open offices. Occupants generally appreciated the collaborative environment and the opportunity for interaction. Noise levels, privacy, lighting, temperature, and air quality were discussed, with occupants sharing their strategies to address concerns. The absence of specific requests for additional features suggests that the open offices meet the occupants' current needs. These findings can inform future decisions and improvements related to open office spaces, aiming to maintain a conducive and comfortable work environment for the building's occupants.

Figure 4.1.51: Offices, ZEB Laboratory, Photos taken by the author.

4.1.6.6 Stop 6: Shared Waiting Areas (informal sitting space by the staircases)

This section focuses on the discussions held with the occupants regarding shared waiting areas located by the staircase. The purpose was to gather insights into the occupants' experiences, concerns, and suggestions related to the usage, comfort, functionality, acoustics, lighting, and potential additional features of these areas.

Topic 1: Usage and Purpose
Occupants described using the shared waiting areas for various purposes. Occupant 2NS mentioned using them as a substitute for meeting rooms when they were not available. Occupant 1NN and occupant 3S highlighted using the areas for small gatherings, meetings with supervisors, and even celebrating occasions.

These spaces provided flexibility for informal meetings and social interactions.

Topic 2: Comfort and Functionality
Overall, occupants did not report any significant issues regarding the comfort or functionality of the shared waiting areas. Occupant 1NN mentioned never being disturbed by others using the space, indicating a peaceful environment. Occupant 2NS appreciated the availability of blinds, which could be adjusted to control brightness and glare in these areas. No concerns about seating or functionality were raised during the discussions.

Topic 3: Acoustics
There were no explicit comments regarding acoustics in the shared waiting areas. Occupants did not perceive any noticeable acoustic issues or disturbances in these spaces, as no concerns or suggestions were shared.

Topic 4: Additional Features
Occupants did not express any specific desires for additional features in the shared waiting areas. Occupant 2NS and occupant 3S indicated satisfaction with the existing amenities. Occupant 1NN mentioned that the fourth floor shared waiting area stood out due to better views and the presence of a kitchen. However, it was considered unnecessary to have a kitchen on every floor, suggesting that the current facilities adequately serve the occupants' needs.

Based on the discussions, the shared waiting areas by the staircase were found to be useful and versatile spaces for informal meetings, gatherings, and social interactions. Occupants did not report any significant concerns related to comfort, functionality, or acoustics in these areas. The availability of solar shadings for controlling lighting conditions was appreciated. Additionally, while the presence of a kitchen in the fourth floor shared waiting area was acknowledged as a valuable feature, occupants did not express a need for additional amenities in these spaces. These findings suggest that the current design and functionality of the shared waiting areas meet the occupants' requirements and contribute to a satisfactory user experience.

Figure 4.1.52: One of the shared Waiting Areas, Photo taken by the author.

4.1.6.7 Stop 7: Staircase

This section focuses on the discussions held with occupants regarding their experience, concerns, and suggestions related to the usage, lighting, noise, and potential improvements of the staircase (figure 4.1.53). The purpose was to gather insights into the occupants' perspectives and identify any areas of concern or opportunities for enhancement.

topic 1: Usage
The staircase was generally well-received by the occupants. Occupant 2NS described it as a "very nice" and distinctive feature of the building. Occupant 4S also referred to it as a "nice wooden staircase." Occupants expressed a preference for using the staircase over the elevator. Occupant 1NN mentioned occasional use of the elevator when carrying heavy items or moving between floors with a lot of belongings.

Topic 2: Corners and Flow
One concern raised by occupant 1NN was the presence of sharp corners in the staircase. This design feature could potentially lead to collisions between people moving in opposite directions if they both approach the corners simultaneously. However, this was not considered a significant issue, and it did not deter occupants from using the staircase.

Topic 3: Lighting
No explicit concerns were raised regarding the lighting in the staircase. The lighting was not mentioned as being too bright or too dim, suggesting that it met occupants' expectations. No specific areas with poor lighting were identified during the discussions.

Topic 4: Noise and Echoes
While occupant 1NN acknowledged that noises from other people using the staircase can be heard, this was not considered a significant problem. Occupant 2NS agreed, stating that the noise was not an issue.

Topic 5: Suggestions for Improvement
There were suggestions for potential improvements to the staircase. Occupant 3S mentioned the potential for adding artwork to enhance the aesthetics. However, it was noted that the current design, particularly the wooden surface, was already visually appealing. However, it was recognized that such modifications might not be necessary considering the staircase's current functionality.

Based on the discussions, the staircase was generally well-regarded by the occupants, who preferred using it over the elevator. The presence of sharp corners was mentioned as a minor concern, but it did not significantly impact the overall experience. Lighting, noise, and echoes were not major issues. The suggestions for improvement included the addition of artwork and potential safety enhancements such as climbing grips on the outside of the railing. However, these suggestions were not deemed critical as the current design and functionality of the staircase were already satisfactory.

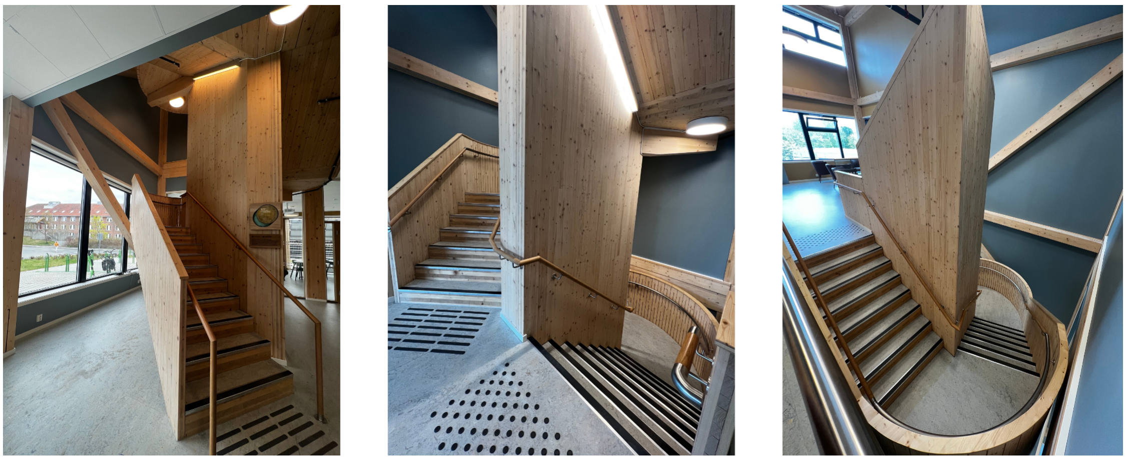


Figure 4.1.53: Staircase, Photo taken by the author.

4.1.6.8 Stop 8: Quit Boxes

This section summarizes the discussions held with occupants regarding their experience, concerns, and suggestions related to the usage, comfort, functionality, lighting, temperature, noise levels, and potential improvements of the quit boxes (figure 4.1.54). The aim was to gather insights into the occupants' perspectives and identify any areas of concern or opportunities for enhancement.

Topic 1: Usage
Occupants 2NS and 3S frequently used the quit boxes for various purposes such as teams meetings, phone calls, and short meetings. However, occupent 1NN mentioned never using them.

Topic 2: Comfort and Functionality
Occupants expressed several suggestions for improving the comfort and functionality of the quit boxes. Occupant 2NS mentioned the need for a slightly bigger desk and the ability to connect a computer to a larger screen. Occupant 1NN suggested better chairs, but acknowledged the limited space inside the quit boxes.

Topic 2: Lighting
One concern raised by occupant 3S during the discussions was the insufficient lighting inside the phone boxes (quit boxes), particularly on the 4th floor. When the lights outside the boxes turn off, it becomes quite dark inside. This could pose a problem during winter when the lack of light makes the space completely dark.

Topic 4: Ventilation and Air Quality
No specific concerns were mentioned regarding ventilation or air quality in the quit boxes. Occupants appeared to be satisfied with the existing conditions.

Topic 5: Noise Levels
Occupants noted that the quit boxes were not entirely soundproof. Conversations from neighboring boxes could be heard, especially if someone spoke loudly. Occupant 3S mentioned that this lack of soundproofing raised concerns about maintaining confidentiality during sensitive discussions.

Topic 6: Nearby Distractions
Occupants did not report significant distractions from the close-by area. However, occupent 3S mentioned that conversations from inside the quit boxes could be heard outside, which might disturb others in the vicinity.

Topic 7: Suggestions for Improvement
Aside from the aforementioned suggestions for larger desks and the ability to connect computers to larger screens, no additional features or improvements were mentioned during the discussions.

The quit boxes were frequently used by occupants for various purposes, including meetings and phone calls. Suggestions for improvement included larger desks, the ability to connect computers to larger screens, and better chairs. Concerns were raised regarding insufficient lighting inside the phone boxes, as well as the limited soundproofing, which could impact privacy and confidentiality. Overall, occupants were generally satisfied with the ventilation, air quality, and lack of distractions from nearby areas. These insights can help guide future enhancements to the quit boxes to better meet the occupants' needs and improve their overall experience.

Figure 4.1.54: Quit boxes, Photos taken by the author.

4.1.6.9 Stop 9: Lunch Room

This section provides an overview of the discussions held with occupants regarding their experience, concerns, and suggestions related to the lunch room. The aim was to gather insights into the frequency of use, usage patterns, noise disturbances, lighting, temperature, air quality, design, and functionality of the lunch room (figure 4.1.55). Additionally, suggestions for improvements were also sought.

Topic 1: Frequency and Usage
Occupants reported using the lunch room daily for lunch and sometimes for tea breaks in the afternoon. The room was reserved for lunchtime only and not available for meetings or seminars during that period.

Topic 2: Noise and Inconvenience
During lunchtime, no issues or inconveniences were reported when others used the lunch room and the room is sometimes being used for having meetings in other time of the day. However, occupant 3S mentioned that important meetings or discussions involving classified information should not take place in the lunch room.

Topic 3: Design and Functionality
Occupants generally rated the design and functionality of the lunch room positively. The presence of small sitting groups and comfortable lounge chairs was appreciated. However, some suggestions were made regarding the arrangement of the sink, paper dispenser, and waste bins, as well as their proximity to each other for more convenience during handwashing and cleaning up after meals by occupent 1NN. They were in the opinion that there is a need to add an extra handwashing sink close to the paper dispenser as well as adding a waste bin close to the entrance.

Topic 4: Lighting
The presence of solar panels and solar shading in the lunch room was discussed. All participants felt that the solar shading and curtains were too aggressive, causing excessive darkness when closed. However, when the solar shadings were up, there was ample natural light, creating a bright atmosphere.

Topic 5: Temperature and Air Quality
Overall, the temperature and air quality in the lunch room were deemed satisfactory. However, occupant 3S mentioned that during very cold weather, the large number of windows could result in slightly lower temperatures. Occupant 1NN suggested adding an extra degree of control in the voting system for adjusting the temperature.

Topic 6: Suggestions for Improvement
In addition to the suggestions regarding the sink arrangement and waste disposal, suggestions for improvement in solar shadings were raised during the discussions.

In conclusion, the lunch room was generally considered well-designed and functional. However, suggestions were made to improve the arrangement of the sink, paper dispenser, and waste bins for increased convenience during hand-washing and cleaning up. Concerns were raised about the aggressiveness of the solar shading when closed, but the availability of natural light when the shadings were up was appreciated. The temperature and air quality were generally satisfactory, with minor adjustments suggested for better control. These insights can help guide future improvements to the lunch room and enhance the overall experience for occupants.

Figure 4.1.55: Lunch room, Photos taken by the author.

4.2 Case study 2: Energy Academy Europe

The Energy Academy Europe (EAE) is a state-of-the-art building that focuses on energy and the transition towards sustainable energy production. The building aims to achieve a cleaner and more efficient production of energy while integrating renewable energy sources into existing energy infrastructures(figure 4.2.1). This building is also unique because it combines fundamental, applied, and practice-oriented research with education. It brings together expertise in different fields, involving students and teachers from vocational, higher, and university education. One of the key features of the EAE is the circulation of knowledge between educational and research partners, including the Hanze University of Applied Sciences and the University of Groningen, and businesses (Wijk, 2012).

This approach ensures that research, education, and innovation projects are practice-oriented, and the content is determined in collaboration with market parties. The Hanze University of Applied Sciences and the University of Groningen aimed to develop the Zernike Campus into a 'Knowledge Arena' by strengthening the connection between education and research, inviting collaborative partners to the campus, making research processes and results more visible, promoting knowledge sharing, and strategically locating student facilities. The EAE building is an essential pillar of both the University of Groningen and the Hanze University of Applied Sciences, and the building's design reflects its role in connecting different routes on the campus. The building is a 'Place to Be' for the Energy Community and a meeting point for everyone interested in sustainable energy. It is an energy icon and a flagship of Groningen, catering to a diverse range of target groups (Wijk, 2012).

Figure 4.2.1: Energy Academy Europe, Groningen, Photo taken by the author.

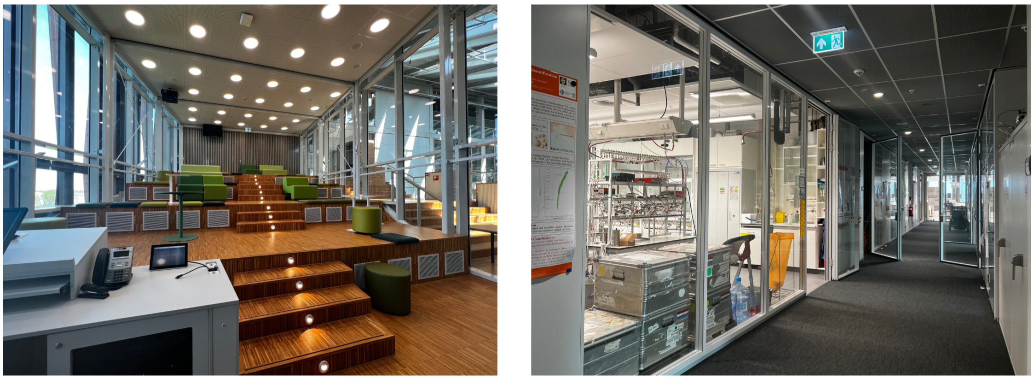


Figure 4.2.2: Laboratories and classrooms, EAE, Photo taken by the author.

The building is designed to promote collaboration and multidisciplinary cooperation, which are crucial for innovation. It provides an environment in which change can occur relatively easily, which is important for the continuous process of energy chain sustainability. The building tells the energy story while also serving as an example of ambitions in sustainability. The primary layout of the building consists of an 'Energy Plaza' surrounded by laboratories, educational spaces, and a well-designed workspace for energy professionals. The EAE laboratories are connected to the newly built facility for mathematics and natural sciences, allowing for collaboration, shared facilities, and flexibility to adapt to growth or contraction (Wijk, 2012). Overall, the Energy Academy Europe is a significant step towards a sustainable energy future, and the building serves as a symbol of this vision. With its unique combination of research, education, and innovation, the EAE brings together expertise and knowledge to create a better future for all.

4.2.1 Context

New international markets, societal developments, and the policies of the Dutch government are stimulating changes in the energy supply sector, with the goal of providing a reliable, affordable, and sustainable energy supply for everyone. The Netherlands is one of the top 10 gas producers in the world and, as a prominent gas country, has a unique proposition based on its own energy history, anchored by gas. It has experience with the societal developments that come with a new energy supply and has built up infrastructure, trade and knowledge positions of global importance since the 1950s in a unique collaboration with leading international companies (Wijk, 2012).

Groningen's position as an 'energy roundabout' is internationally renowned. The Dutch government considers knowledge development and innovation important and has included energy in its economic top sector policy. Dutch businesses, knowledge institutions, and the government are taking up the challenge to realize new developments in the energy supply and have established the Energy Academy Europe (EAE) for this purpose. The university of Groningen and Hanze University of Applied Sciences brought their relevant research and education activities together and invite market parties and other knowledge institutions from both the Netherlands and abroad to participate and develop useful connections and joint ventures. The EAE works on the technical, economic, societal, and legal aspects necessary to make the energy supply more sustainable (Wijk, 2012).

4.2.2 Location

The Zernike Campus is home to the University of Groningen (Rug) and the Hanzehogeschool (HG), with most of both organizations' housing located on this site. The various buildings on the campus largely correspond to the separate domains for Rug faculties and HG Schools. The plans for EAE fit into the development of the Zernike Campus as a whole, with the general objective of strengthening the connection between education and research with the (network) society, identifying and developing nodes where knowledge sharing, collaboration, and meeting with external parties occur, and inviting collaboration partners to establish connections on the Zernike Campus. Additionally, strengthening the Zernike Campus as a "knowledge arena" for the Rug and HG knowledge communities requires different spatial environments that encourage more knowledge sharing and make research themes and results more visible (4.2.3) (Wijk, 2012).

Promoting cross-border knowledge sharing was achieved by situating knowledge centers in recognizable and inviting locations, combined with educational spaces and providing student facilities for general use, such as cafeterias and study landscapes. In the context of the case study on the EAE building and the branding of the Hanzehogeschool and Rijksuniversiteit Groningen (RuG), the EAE connects education, research, and entrepreneurship. For the natural and chemical laboratories, this means a functional connection with the laboratories as well. However, the EAE should not have been seen as just another RuG building, and the architecture of the new building should emphasize its autonomous status and distinctive character. As the Hanzehogeschool will have more intensive use of the space than the RuG, it is important that their role and presence are clearly recognizable. Connecting the EAE to the campus through a chain of "hotspots," as well as to the plans for the Mathematics and Natural Sciences laboratories, and positioning it as a highlight at the entrance of the campus can further promote cross-border knowledge sharing (Wijk, 2012).

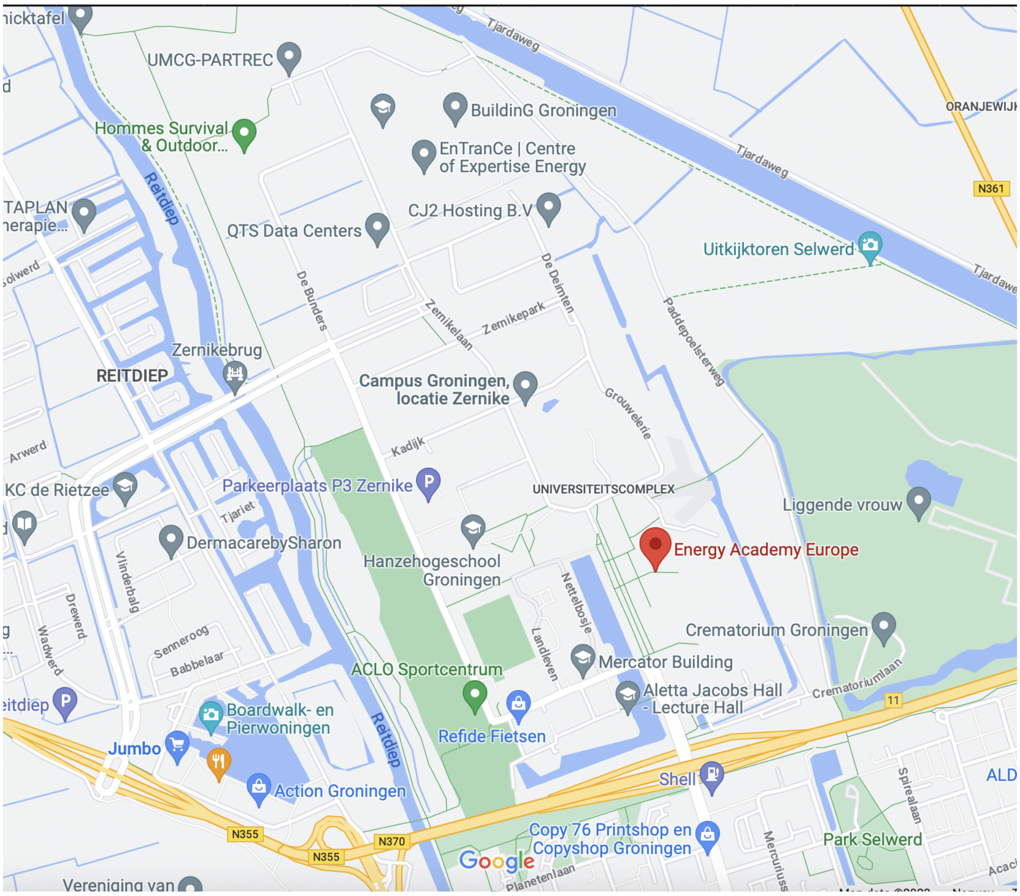


Figure 4.2.3: Location of Energy Academy Europe (Google maps)

4.2.3 Project Objectives

According to the project brief document, the Energy Academy Europe (EAE) building project has eight main objectives that guide the design and construction of the building. These objectives are as follows (Wijk, 2012):

- To create an inviting and attractive building that serves as a "Place to Be" for everyone, including students, employees, and businesses. The building should be a hub for inspiration and energy, offering a variety of activities such as workspaces, study areas, exhibitions, and meeting places. The goal is to make the building a melting pot where people from different disciplines can come together for learning and collaboration. Furthermore, the building should be a hub for discussion, information, and inspiration about sustainability and energy-related issues.

- To make the EAE building a "Paradepaardje" of Groningen, drawing attention from beyond the region's borders. The building should showcase zero-emission solutions through a district-based approach to energy consumption and stand-alone solutions that others can adopt. The building's design should be unique and visionary, featuring an energy icon that contributes to the building's identity. The icon could be anything from wind turbines to natural hills that merge the building with nature.

- To use the Kagan educational approach of "Matching, Stretching and Celebrating" in the design and operation of the EAE building. The environment should match the needs and characteristics of the three primary user groups: education, research, and entrepreneurship. The building should stretch the boundaries of knowledge and encourage knowledge sharing and critical mass. Finally, the building should celebrate the sense of belonging to a strong and innovative energy community, which brings together the university, higher education, business, and government.

- To create a sense of belonging and home for everyone in the energy community, including representatives from the entire energy value chain, from high-tech energy companies to small-scale energy producers and end-users. The building should provide an attractive working environment for start-ups and incubators, with workshops and laboratories to support their work. The design should accommodate the diverse needs of different user groups and foster a sense of ownership among them.

- To make the EAE building an energy-neutral or energy-positive building that generates more energy than it consumes, by using innovative energy-saving solutions and renewable energy sources. The building should serve as a living lab for testing and demonstrating new energy technologies and solutions.

- To ensure that the building's design and operation promote health, well-being, and productivity among its users. The building should be a healthy indoor environment with good air quality, natural light, and comfortable temperatures. It should also provide facilities for physical activity, relaxation, and social interaction.

- To promote interdisciplinary and transdisciplinary collaboration in research, education, and entrepreneurship, by providing spaces and facilities for knowledge sharing, networking, and co-creation. The building should foster a culture of innovation and experimentation, where people can try out new ideas and approaches.

- To make the EAE building a showcase for sustainable and circular building design and construction, using environmentally friendly materials, minimizing waste, and reducing the building's carbon footprint. The building's life cycle should be considered from design to decommissioning, and the building should be designed to adapt to future changes in technology, user needs, and societal expectations.

In summary, the eight objectives of the EAE building project aim to create an inspiring and inviting building that serves as a hub for energy and sustainability, a showcase for zero-emission solutions, and a home for the energy community. The building should promote interdisciplinary collaboration, healthy indoor environments, and sustainable building practices, contributing to a more sustainable future.

4.2.4 Technical characteristics

The Energy Academy Europe building is specifically designed to promote collaboration and creativity among its occupants while also harnessing natural elements. It was designed to serve multiple purposes, including as a research center for sustainable energy and an educational facility. The guiding principle of the building is to create a natural climate that utilizes natural air flows and solar energy, using the earth for heating and cooling, and rainwater harvesting (*Energy Academy Europe*, 2017).

The building's unique design serves as a testament to the potential of architecture to make the most of these natural elements as a primary source of energy. The building is designed to minimize heat loss and energy consumption, with a compact shape and a large atrium built between two parts of the building to allow light to enter everywhere (*Energy Academy Europe*, 2017).

The building can be roughly divided into two sections. The north side of the building will host the research areas, which include laboratories and related workspaces, while the south side will be occupied by the workspaces, teaching areas, and a winter garden (Figure 4.2.4). The large 'energy square' located between the two sections serves as the lively heart of the building, bringing together all aspects of the building's diverse functions. Natural materials are used throughout the floors, connecting all parts of the building. The wide and attractive stair ramps will encourage users and visitors to take the stairs instead of the elevator, promoting exercise and sociability while conserving energy. The building will feature a large winter garden that can serve as an open extension of the rest of the building, but can also be closed off if required. This winter garden will be a public space that can be used as both a pause and workplace (figure 4.2.5) (*Energy Academy Europe*, 2017).

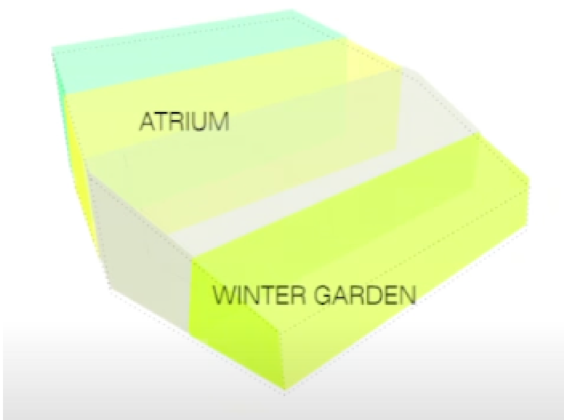


Figure 4.2.4: Zoning in Energy Academy Europe (*Energy Academy Europe*, 2017)

Figure 4.2.5: Winter garden, EAE, Photo taken by the author.

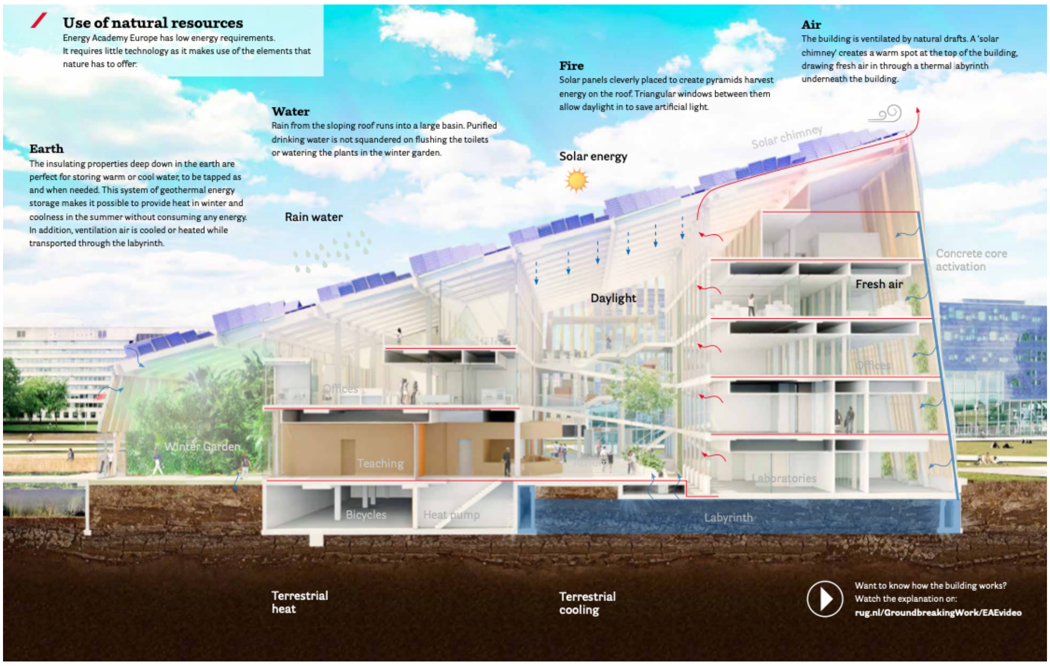


Figure 4.2.6: Use of natural resources (*Energy Academy Europe*, 2017)

The building is designed to produce more energy than it consumes, with zero emissions. The building's sloping roof is equipped with solar panels that are strategically placed to optimize the collection of solar energy. Not only do these solar panels provide a substantial amount of energy, but their placement also allows for maximum natural lighting within the building. The design includes 2000 solar panels placed in a special triangular configuration, which covers almost the entire roof and captures 37% more solar energy while leaving gaps for sunlight to enter, reducing the need for artificial light (Figures 4.2.7). The building also includes energy-efficient LED lighting that switches on automatically. The outer layer of solar panels gives the building a distinct and recognizable appearance, which highlights the innovative energy management taking place inside (*Energy Academy Europe*, 2017).

In designing this building, a conscious decision had been made to take a low-tech approach to energy consumption. The goal is to make the most of the natural resources that are readily available, such as earth, water, air, and sunlight. By doing so, a building was created that is highly sustainable and energy efficient. To achieve this, a 200-metre-long air vent under the building have been incorporated, using the idea of ancient Persian wind towers (also known as bagdirs) which uses the earth to cool and heat the air and water. Also rainwater is used to flush the toilets, and the ventilation system is powered by a 'solar chimney' (*Energy Academy Europe*, 2017).

Figure 4.2.7: Solar panels, EAE, Photo taken by the author.

The building design makes optimal use of sunlight for lighting and energy production. Fresh air flows through the entire building through a natural flow of outside air, which enters through a winter garden and flows through a 200-meter-long labyrinth that sits below ground, steadily reaching the current ground temperature, moving at a rate of less than a meter per second. This natural ventilation saves about 20% in ventilation energy. The fresh air passes from the labyrinth to the offices, the atrium, and then via the solar chimney to the outside to ensure a pleasant climate (Figure 4.2.9 & 4.2.10 4.2.8). CO2 levels in every space are constantly monitored, and the mechanical ventilation functions as backup, supplying more fresh air into the space if CO2 levels become too high (*Energy Academy Europe*, 2017).

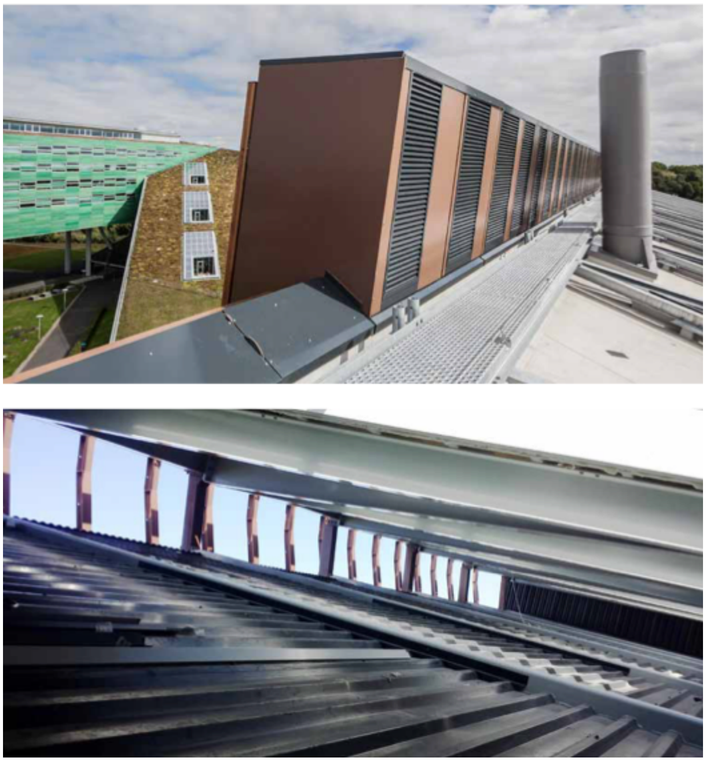


Figure 4.2.8: Solar chimney powers natural ventilation (*Energy Academy Europe*, 2017)

Figure 4.2.9: The walls of the labyrinth heat or cool the ventilation air, Photo taken by the author.

Figure 4.2.10: The outlet of the air flowing through labyrinth to the building, Photos taken by the author.

The building's heating and cooling comes mainly from the ground, with two water reservoirs located near the building at a depth of 100 meters, one for heating and one for cooling. The water is heated by a heat pump that efficiently converts electricity into heat and distributed through the building for underfloor heating, which provides 60% of the heating in all rooms, and to heat the air flow through climate ceilings. Cool water from the nearby pond is also used for cooling in summer (Figure 4.2.11 & 4.2.12).

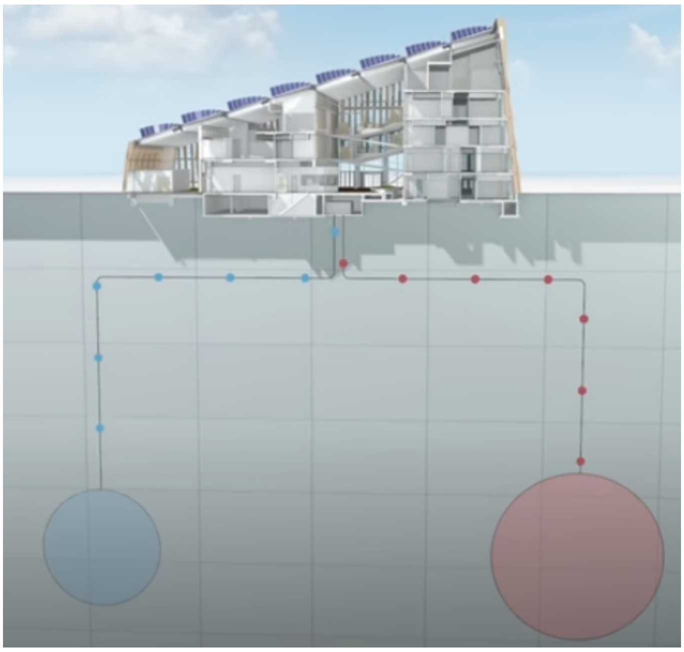


Figure 4.2.11: Underground heating and cooling system (*Energy Academy Europe*, 2017)

Figure 4.2.12: Under-floor heating and cooling system (*Energy Academy Europe*, 2017)

In cases where the natural sources of energy become insufficient, backup installations for heating, ventilation, and lighting are used. By using renewable energy in innovative ways, the operating expenses of the building has been significantly reduced over the long term. The building's sustainability and energy consumption standards are so high that it has been given a BREEAM-rating of 'Outstanding'. The set of energy saving solutions which had been coorporated in this project is listed below and shown in the Figure 4.2.13 (of Groningen, 2021):

1. Very good insulation of the exterior shell, keeping heat and cold outside and blocking sunlight when necessary.

2. Natural ventilation through opening windows, a labyrinth that heats or cools outside air, and through a winter garden.

3. Fresh air, CO2 detection controls the ventilation system, natural circulation through large air ducts, corridors, and atrium.

4. Optimal lighting, occupancy and daylight sensors control lighting levels. 5.Daylight shelves behind the facade for optimal distribution.

5. Fins on the facade: allow daylight, shield solar heat.

6. Concrete core activation for constant temperature, adjusting through ventilation air is possible.

7. Use of thermal energy storage, utilizing the existing earth temperature.

8. Minimal use of the elevator through split-levels with ramps.

9. Rainwater collection for toilet flushing and other uses.

10. PV-balcony for research and education.

11. Central energy performance display."

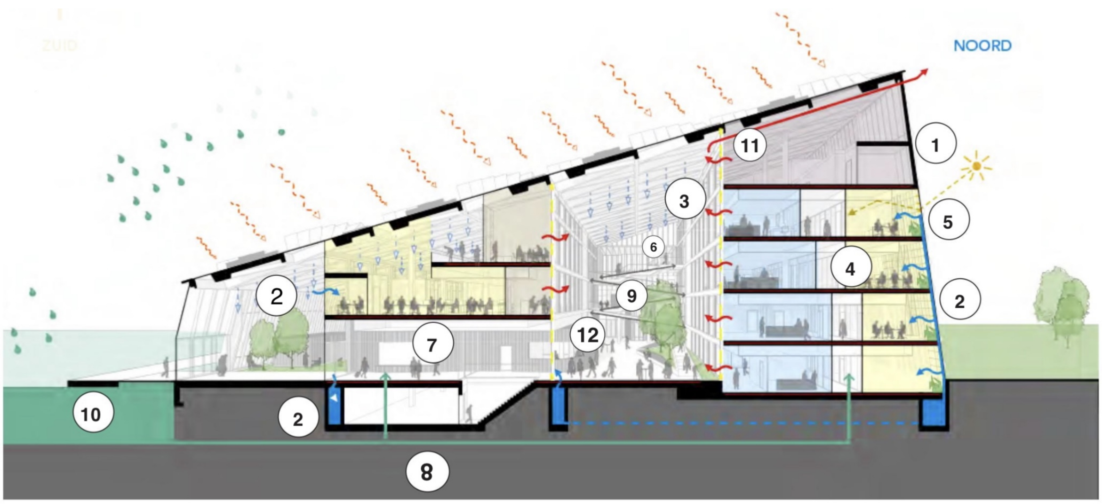


Figure 4.2.13: Energy saving solutions in Energy Academy Europe (of Groningen, 2021)

Figure 4.2.14: Split-levels with ramps, EAE, Photo taken by the author.

The earthquakes in Groningen are caused by drilling for gas. The effect of these earthquakes is different from that of tectonic earthquakes, which occur as a result of natural fault lines in the Earth's crust, as in Japan for example. 'Groningen-quakes' are usually short and sharp, with a vertical acceleration (compression wave) followed by a horizontal acceleration (shift wave). They can cause more damage than natural earthquakes of a similar strength. The Scale of Richter does not apply to these earthquakes as it is the effect of the Peak Ground Acceleration that counts. Energy Academy Europe is one of the first buildings in Groningen to be designed to withstand earthquakes. If an earthquake occurs, six seismic walls absorb the energy generated by the earthquake. The building will sway flexibly around these solid, seismic cores. Other special features that make the building earthquake-proof are: extra hard, laminated glass, walkways in the atrium to connect sections of the building and a roof that moves if the building shakes (*Energy Academy Europe*, 2017).

Figure 4.2.15: Six seismic walls are in place to absorb possible earthquakes(*Energy Academy Europe*, 2017).

The building's construction and layout have created a natural environment where knowledge, research, and innovation can flourish. It has achieved the most sustainable educational building in the Netherlands through intelligent and smart design while increasing comfort levels for all occupants. The project team, including the contractor, placed particular emphasis on ensuring the building had good airtightness, resulting in a building that performed even better than the requirement for passive construction (*Energy Academy Europe*, 2017).

The main challenge of this project was to create a building that was as energy-efficient as possible, with low energy usage. The project manager worked with the client to translate their ambition for sustainability and energy efficiency into a BREEAM outstanding design, as well as specific solutions such as energy-saving ventilation. The design team also addressed acoustics, building physics, fire safety, and facade technology, and ensured these elements were monitored during the construction phase (*Energy Academy Europe*, 2017).

The building has become an iconic structure and a symbol of sustainability, serving as a model for sustainable construction practices. The project team aimed to achieve a BREEAM outstanding 5-star rating, and the building has been recognized with various awards for its sustainable design and construction, including the BREEAM Award for the best office building in Europe in 2017 (*Energy Academy Europe*, 2017). Overall, the Energy Academy Europe building is an innovative and sustainable educational building that exemplifies the principles of sustainable energy and construction.

4.2.5 Interview findings: unveiling perspectives of project key players

This section aims to provide an introduction to the interviews conducted for the case study of the Energy Academy Europe (EABE) in Groningen. The focus of these interviews is to gain insights and perspectives from key individuals involved in the project, including representatives from the campus development team at the University of Groningen (the client), as well as advisors who played a crucial role in the design phase. The interviews were conducted with the intention of understanding the early phase activities in building projects and their subsequent impact on the value generated during the occupancy phase and the use value for building users.

The interviews conducted for the EABE case study serve an essential purpose in obtaining a comprehensive understanding of the early phase activities and their significance in the overall project. By engaging with individuals who possess firsthand knowledge and expertise gained through their active participation in the project, valuable insights can be gathered regarding the design, planning, and decision-making processes that shape the project's outcomes during the occupancy phase. Interviewing stakeholders from different perspectives, including the client, and the advisors, offers a multi-dimensional understanding of the project. Each participant brings a unique viewpoint and experiences, providing valuable insights into the project's development, decision-making processes, challenges faced, and opportunities seized.

This diverse range of perspectives allows for a holistic assessment of the project. Moreover, these interviews contribute to the broader body of knowledge in the field of sustainable building and construction. The EABE project, renowned for its ambitious goals and innovative design, presents an opportunity to identify best practices, lessons learned, and potential areas for improvement in future sustainable building projects, particularly in the context of campus development.

In total, two sets of interviews were conducted for the EABE case study, each involving two participants. The interviews included representatives from the Groningen campus development team (the client) , referred to as Informant 6G and Informant 7G, respectively. Additionally, advisors who played a significant role in the design phase were interviewed as Informant 4A and Informant 5A. Anonymity has been ensured for the participants. This approach allows for the free exchange of information while respecting the privacy and confidentiality concerns of the individuals involved.

The interviews followed a semi-structured approach, combining pre-planned questions with the flexibility to ask follow-up questions based on the participants' responses. An interview guide was prepared in advance, consisting of predetermined questions relevant to the research objectives. These questions aimed to elicit insights on various topics, such as project goals and objectives, performance and operation, user involvement, early phase activities, challenges encountered, value achieved and delivered, and lessons learned. The semi-structured format allowed for dynamic and interactive conversations, facilitating a deeper exploration of the participants' perspectives and experiences. In the Appendix B, the findings from these interviews is presented, highlighting the insights and perspectives shared by the participants.

CHAPTER

FIVE

DISCUSSION

In this section, the aim is to apply the theories learned by thoroughly analyzing and interpreting the research findings. The purpose of this section is to provide a comprehensive analysis and interpretation of the research findings in relation to the research objectives and questions outlined in this study. The research objectives set the direction for this investigation, defining research questions, guiding the analysis and interpretation of the data collected.

The first research question focuses on identifying the key activities in early phases of building projects that contribute to the successful realization of building projects, specifically in terms of value for users during the occupancy phase. The second research question centers around the post-occupancy evaluation of the ZEB Laboratory and examines user satisfaction regarding the building's performance and overall use value. Lastly, the third research question seeks to uncover lessons that can be learned from the case studies of ZEB Laboratory and Energy Academy Europe.

These research questions were derived from the main objectives of this study which were to identify key factors contributing to successful project realization in terms of use value, to conduct a comprehensive post-occupancy evaluation of the ZEB Laboratory, and to draw lessons and recommendations for improving early phase activities and enhancing outcomes in the occupancy phase of building projects. Ultimately, this research aims to contribute to the existing knowledge and understanding of the connection between early phase activities and building project outcomes, bridging the gap between project ambition and actual building performance.

5.1 Analysis of Interview Findings: Key Patterns and Themes for Early Phase Activities Contributing to Use Value

In this section, I will discuss the findings of the interviews conducted with key informants regarding the key factors in the early phase activities that contribute to the successful realization of building projects, specifically in terms of user satisfaction and building performance in the occupancy phase, which ultimately leads to use value. These interviews provided valuable insights into the practices and strategies employed by industry professionals to achieve favorable outcomes regarding value for users in building projects.

The interview results were carefully analyzed, allowing me to identify patterns and themes that emerged from the informants' experiences and perspectives. By systematically reviewing and synthesizing the interview data using a manual content analysis technique known as open coding, I gained a comprehensive understanding of the key factors that contribute to the success of building projects in the early phases. The identified patterns and themes will be the focus of the discussion in the following sections. Through a detailed exploration of these patterns, I aim to shed light on the activities and strategies that play a crucial role in creating use value during the early phases of building projects. These patterns represent recurring ideas, practices, and considerations that were highlighted by the informants as key contributors to user value and building performance in case studies.

All the informants emphasized that the activities conducted in the early phases have a significant impact on the ultimate use value of the building. By implementing effective strategies and approaches during the initial stages, project teams can lay a solid foundation for a successful outcome in terms of user satisfaction and building performance. By examining these key patterns and themes, I seek to provide insights and practical implications for professionals involved in building projects. The knowledge derived from these findings can inform decision-making processes and guide the early phase activities to maximize use value, ultimately leading to the creation of valuable built environments. It is important to note that the discussion presented here is based on the perspectives and experiences of the informants involved in the interviews. Their insights, expertise, and diverse backgrounds enrich our understanding of the factors that contribute to successful building projects.

5.1.1 Defining Clear Goals and Objectives

The importance of having clear ambitions, goals and expectations in the early phase of building projects cannot be overstated, as it sets the foundation for the project's overall direction. In the case of the ZEB Laboratory project, Informant 1N, representative of the client, emphasized the significance of the "Ambition Note" in shaping the project's vision and ensuring its successful realization in terms of use value. The Ambition Note served as a preliminary document that provided a broad overview of the project's aspirations and served as a reference point throughout the project's lifecycle. While it did not contain specific details, it outlined several key ambitions that were crucial for the project's success. Moreover, the Ambition Note recognized the ZEB Laboratory's dual purpose as both a research facility and an office building. This acknowledgement reflected an understanding that the building needed to meet the needs of both researchers and regular occupants. By emphasizing the desire for an aesthetically pleasing design and moving away from the conventional perception of unattractive office buildings, the Ambition Note demonstrated a commitment to creating an engaging and inviting environment that would contribute to user satisfaction.

Importantly, the Ambition Note also played a significant role in defining the evaluation criteria for the ZEB Laboratory's performance and operation. By including sustainability and energy efficiency as key criteria, the Ambition Note set clear expectations for the building's environmental performance. The zeb-com standard, mentioned by Informant 1N, provided a benchmark against which the building's sustainability and energy efficiency could be measured. This commitment to meeting specific criteria ensured that the project stayed on track and aligned with its initial ambitions. In addition to environmental considerations, the Ambition Note also highlighted the importance of the ZEB Laboratory's research capabilities and opportunities. Informant 1N emphasized that one of the key expectations was for the building to provide a suitable environment for conducting various types of research. By facilitating the exploration of new technologies, testing energy-efficient solutions, and studying sustainable building practices, the laboratory aimed to contribute to the knowledge base in the field. This research potential not only added value to the project but also underscored its broader societal impact.

Similarly, representatives of the client in Energy Academy Europe project mentioned that defining clear goals and objectives plays a pivotal role in the successful realization of building projects. Informant 6G highlighted the significance of determining the desired level of sustainability in the early phases and its direct impact on the engineering process. One aspect emphasized by Informant 6G was the importance of setting a clear goal for the engineering team to create a building with minimal energy consumption. This objective serves as a guiding principle for the engineers, influencing their calculations and proposals to align with the goal of energy efficiency. To illustrate the importance of defining clear goals and objectives, Informant 6G provided an example related to materials selection. When aiming for an outstanding level of sustainability, more considerations and requirements must be addressed during the building phase compared to lower levels. This demonstrates how the desired level of sustainability directly influences decision-making processes and the subsequent engineering efforts which will directly affect user experience.

Another example, presented by Informant 7G, focused on the utilization of daylight to reduce energy consumption from LED lights. However, a challenge arises when incorporating solar panels, as they work most efficiently when placed flat on the roof, obstructing the access of natural daylight. Balancing these conflicting requirements becomes crucial. Informant 7G explained that the current design of the solar panels was optimized to provide more evenly spread energy throughout the day, with increased production in the morning and evening. By adjusting the orientation and angle of the solar panels, the project team achieved a solution that maximized energy production while minimizing the obstruction of natural daylight. Informant 6G further highlighted that mounting the panels flat on the roof would result in peak energy production at noon, which is less desirable. These examples demonstrate the importance of defining clear goals and objectives early in the project. By establishing a goal of minimal energy consumption and sustainability, the engineering team can focus their efforts on developing solutions that align with this objective. The choice of materials and the design of energy-efficient systems are driven by these goals, ensuring that the building performs optimally in terms of energy efficiency and user comfort.

In the same vein, advisors in the Energy Academy Europe project believed that in the early phase of building projects, the process of defining clear goals and objectives emerges as a fundamental factor that significantly contributes to the use value. Informant 4A emphasized the importance of setting clear goals and direction from the outset, as it provides an opportunity to have the most influence and establish the right course for the building's construction and design. By defining clear goals and objectives early on, the design team ensures that the building is aligned with the needs and expectations of the users. This proactive approach sets the foundation for a successful project, as it allows for a thorough understanding of the project's purpose and desired outcomes. Defining clear goals and objectives provides a framework for decision-making throughout the project, guiding design choices, resource allocation, and construction processes.

This findings align with the importance highlighted in a two research done by Hisham Said and Mauger which was disscussed in section 2.7. Hisham Said emphasized the significance of the eco-charrette process during the predesign phase in setting sustainability goals and objectives for the entire project, involving major stakeholders to make informed decisions for achieving targeted certification levels (Said et al., 2014). Mauger highlighted the challenges faced by the Construction Industry, particularly in terms of quality, cost, and delay problems that affect customer satisfaction, with the briefing process identified as a crucial phase where customer requirements are defined (Mauger et al., 2010).

In conclusion, the findings emphasize the importance of defining clear goals and objectives in the early phases of a project to achieve use value in the occupancy phase. Clear ambitions, expectations, and sustainability goals establish the project's foundation, guide decision-making, and align with user needs and industry trends. The case studies of the ZEB Laboratory and the Energy Academy Europe project highlight the benefits of such clarity, including improved environmental performance, user satisfaction, and research potential. These findings contribute to future projects at NTNU campus and the construction industry as a whole by promoting the importance of defining clear goals and objectives early on which provides a framework for successful project realization and enhances the overall use value of the built environment.

5.1.2 Users involvement

The research findings have revealed that active user engagement during the initial stages of projects plays a pivotal role in guaranteeing an enhanced user experience once the building is occupied. According to the representative of the client in ZEB laboratory project, to achieve successful realization of user satisfaction, the involvement of students and researchers played a crucial role. They emphasized the importance of engaging students and researchers in the early phase of the project, with a specific focus on the fact that the building was a living lab, designed to facilitate research while incorporating innovative solutions. They emphasized the significance of learning and gathering lessons during the development and construction of the building. This approach implied that the project aimed to offer valuable insights not only to the client but also to the students involved and the wider construction industry. The intention was to identify and document the challenges, successes, and best practices encountered throughout the project's life cycle. This knowledge could then be shared to benefit future projects and contribute to the overall advancement of sustainable building practices.

In addition, they mentioned that one of the primary avenues for engaging building users and stakeholders, especially researchers, was through research projects conducted within the laboratory. These research projects often generated ideas and suggestions for improvements that could be implemented to enhance the building's operation. This indicates that researchers, who had direct involvement with the laboratory and its facilities, were given a platform to provide valuable feedback and contribute to the ongoing development of the building. In the context of involving users in the design phase, the primary users in this case were the researchers who would be utilizing the facility. While not all researchers were directly involved in the collaboration process, their input and feedback were sought through regular communication channels. A specific group of researchers was identified and consulted when needed, providing valuable information and insights for the design process.

Furthermore, the involvement of students in the early phase brought about innovative ideas that were incorporated into the building's design. For instance, in the case of color selection, students participated in a competition where they proposed color templates for various elements of the building. The feedback received from the students helped create a visually appealing and user-friendly environment, promoting relaxation and ease of navigation within the building. Moreover, the involvement of researchers and future occupants throughout the project was crucial. Prior to signing the contract, several meetings were held to gather their input and requirements. This collaboration continued during the construction process, with regular check-ins to ensure that the project remained aligned with their needs. The researchers shared their solutions and suggestions, which helped refine the design and incorporate innovative systems.

An exemplary outcome of such collaboration was the implementation of a novel heating storage system. This system involved storing heat collected from the indoor climate and heat pumps in a special tank with a phase-changing material (PCM) having a melting point of 38 degrees Celsius. This innovative approach allowed for the collection and storage of excess heat during the day, which could be utilized to heat the building in the morning, thereby reducing the need for additional energy from external sources. The PCM system enabled the dimensioning of the heating system based on average energy demands rather than peak energy demands, resulting in optimized energy usage.

They also explained involvement of users and stakeholders, including students and researchers, in the early phase of building projects presents its own set of challenges. One significant challenge identified was the uncertainties surrounding the specific individuals who would occupy the building. While the occupancy by NTNU and SINTEF was known, the exact individuals were not identified at that stage. However, selected researchers, including the informant themselves, were given the opportunity to provide input and feedback on the design. Informant 1N acknowledged that effective communication and collaboration among the various groups involved were essential but posed difficulties.

To address this, the collaborative process included regular evaluations and feedback sessions, was conducted. External evaluators were also brought in to provide insights and suggestions for improvement. These measures helped identify issues early on and allowed for necessary changes to be implemented before problems escalated. Managing the involvement of researchers who were focused on their individual work proved to be another challenge. Integrating their activities within the collaboration group while also engaging students and other external contributors without disrupting the design process required careful management. With approximately 2,200 students involved in the project, their valuable input had to be balanced and coordinated to ensure it did not disrupt the overall workflow.

To address this challenge, a leadership structure was established, comprising representatives from the contractor and SINTEF. Regular meetings were held to discuss the relevance and significance of different initiatives and determine whether larger presentations or further actions were necessary. The contributions of the students were reviewed and controlled by the core group, ensuring that only relevant and appropriate ideas were integrated into the project. This approach helped manage the influx of input and ideas without disturbing the core group's work. By implementing these strategies, the challenges associated with involving users and stakeholders were effectively mitigated. The established communication channels, evaluation processes, and leadership structure facilitated a collaborative environment where the input from students, researchers, and other external contributors could be integrated thoughtfully into the project. These measures ensured that the involvement of users and stakeholders was managed in a way that enhanced the design process and contributed to the successful realization of the building project.

Similarly, the informant from architecture team in ZEB laboratory, believed that user involvement is a significant factor in the early phase activities of building projects, contributing to successful project realization. They highlighted the efforts made to involve end users, particularly students, in the project, as well as the active participation of clients as end users. Although their direct interactions with students or other end users were limited, Informant 2A mentioned that students had assignments related to the project and were informed about the ongoing work. They observed the collaborative process and conducted research on the project's development.

While their direct involvement may have been limited, their exposure to the project and engagement in related activities provided valuable insights and perspectives. However, Informant 2A emphasized that the clients themselves were considered end users, and their involvement from the beginning of the project was crucial. The clients brought valuable knowledge and insights to the project, ensuring that their needs and expectations were considered throughout the design and development process. Their active participation in workshops and collaborative discussions allowed for continuous development and evaluation of the design, ensuring that it aligned with their requirements and contributed to user satisfaction.

In the same vein, Informant 3C, representative of contractor in ZEB laboratory project, emphasized the importance of user involvement and how it was ensured through the project manager from NTNU (client). Client team played a vital role in teaching the project team about the required expertise and knowledge, thereby facilitating effective communication and collaboration with the users. The involvement of researchers from NTNU in the decision-making processes during both the front end and execution phases of the project was instrumental in implementing their expertise into the project. Their insights and contributions helped address complex challenges, ensuring that the project integrated the latest knowledge and best practices.

Moreover, the involvement of scientists and students was recognized as a significant factor in achieving the use value of the project. Their participation went beyond research objectives and brought fresh perspectives and ideas to the table. Scientists and researchers from academic institutions, such as NTNU, played a pivotal role in providing expertise and knowledge, particularly in terms of sustainability and specialized areas. Their insights and contributions added value to the project, ensuring that it aligned with the latest research findings and best practices. Additionally, the participation of students in the project had multiple benefits. Students not only gained valuable hands-on experience and exposure to real-world projects but also brought enthusiasm and innovative thinking to the table. Their involvement in measuring temperature and moisture levels during the construction phase, as well as conducting laboratory tests, provided valuable data for decision-making. This collaboration between professionals and students fostered a dynamic learning environment while contributing to the project's success.

However, informant 3C acknowledged that engaging users in the early phases presented challenges, particularly in establishing the right boundaries between users and the project team. It was crucial to involve users at the right time and to the right extent, ensuring their expertise and perspectives were heard and utilized, while still allowing the project team to develop the project creatively in a free space. Open communication and dialogue played a significant role in addressing these challenges and establishing effective engagement strategies. They mentioned that the project management team from NTNU and SINTEF, being the actual users of the building, possessed valuable insights into their own needs and requirements. This insider knowledge was critical in ensuring that the project met the expectations and requirements of the end-users. The proximity and understanding of the user group by the project manager played a vital role in the project's success.

Additionally, the involvement of students in the project was emphasized by informant 3C. Students engaged in various tasks, such as measuring temperature and moisture levels during the construction phase, and contributed valuable data for decision-making. The collaboration with students extended to laboratory tests for designing components effectively. This involvement not only provided students with a unique learning experience but also offered valuable support to the project. While the involvement of students and frequent visits to the construction site consumed time and effort, informant 3C viewed it as mostly positive, generating interest in the project and instilling a sense of pride among the participants.

Along the same lines, Informant 6G, client representative of Energy Academy Europe project, emphasized the importance of understanding how users will interact with the building and highlighted the distinction between user-focused aspects and technical considerations. According to Informant 6G, there are two distinct engineering processes: one that focuses on understanding how users will interact with the building and another that involves technical aspects, such as energy solutions. While users' feedback on functionality and user experience is valuable, their input regarding technical installations may be limited. Users may not possess detailed knowledge of complex energy systems like solar chimneys or technical engineering solutions. However, their perspectives and insights on their overall experience within the building are still highly valuable. Involving users in the early phases of a building project allows the project team to gain insights into user needs, preferences, and expectations. Understanding how users will interact with the building and the spaces within it can significantly influence the design and decision-making processes.

Correspondingly, Informant 4A and Informant 5A, representatives from advisors in Energy Academy Europe project, provided valuable insights into the importance of user involvement and the methods employed to facilitate meaningful participation. Informant 4A emphasized the long-standing practice of user involvement in their firm, particularly in the context of school and cultural buildings, which is deeply embedded in the Dutch culture. User involvement is seen as a vital aspect to counterbalance the influence of architects and constructors, ensuring better building outcomes. Despite sometimes needing to convince clients of its importance, a relatively small budget is allocated to user involvement compared to the overall project budget, with a significant impact on use value and successful building utilization. .

They mentioned that to facilitate user involvement, a project organization or development group was formed, comprising individuals focused on understanding stakeholders' needs rather than solely concentrating on design aspects. However, organizing meetings posed challenges due to the involvement of different organizations and limited time availability. Informant 4A emphasized the importance of validation meetings to ensure stakeholders' input was validated and made sense. These meetings involved seeking feedback from external parties or individuals who could provide an objective perspective on stakeholders' requirements, ensuring the feasibility and reasonableness of proposed solutions. Informant 5A highlighted the significance of visualization and validation meetings within the project. During validation meetings, drawings showcasing the organizational layout of the building were presented, enabling stakeholders to consider their positions within the building and assess whether their needs were adequately addressed. This visual representation enhanced clarity for end users and facilitated a better understanding of how the building would accommodate their requirements.

They also explained about challenges arose in dealing with the diverse ambitions and perspectives of different stakeholders, such as top professors and researchers with varying priorities. The design team took a proactive approach to address these challenges by engaging in conversations with stakeholders individually to understand their specific needs and concerns in Energy Academy Europe project. Building relationships and demonstrating genuine interest in their perspectives fostered cooperation and collaboration. Open communication and dialogue were facilitated during validation meetings, where everyone had an equal opportunity to express their thoughts and concerns. This inclusive setting allowed for constructive discussions and critical feedback, enabling the design team to navigate conflicts and find common ground. Informant 5A further elaborated on the engagement with end users during the design process. Workshops were conducted with different parts of the organization to gather input on office space requirements and design preferences. This approach ensured that end users had a chance to contribute later in the process, enabling their needs and preferences to be incorporated into the design.

These findings are in line with previous studies conducted in the field, further validating the importance of user involvement in the early phases of projects for optimizing the overall user experience presented in section 2.7. As discussed before, according to a study conducted by Michele Caroline Bueno and her colleagues, User involvement is highly valued in building design as it aligns users' needs with the design process, preventing changes, frustration, and additional costs, and it can take various forms and occurs at different levels, ranging from exclusive decision-making by architects to user decision-making without architect intervention, with different stages of participation in between. (figure 2.9.1) .

According to the framework developed by Tae Wan Kim and colleagues, which was discussed in section 2.7, the degree of user involvement (ranging from production for users to production by users) and the time span of involvement (programming, design, construction, and occupancy phases) matters(Kim, Cha, and Kim, 2016). According to the framework provided in figure 2.9.2, we can analyze and map the degree of user involvement in the Zeb Laboratory and Energy Academy Europe projects. By examining the extent of user engagement and the time span of their involvement, we can gain insights into the methods employed and the impact of user input on the projects' outcomes.

In the Zeb Laboratory project, users (researchers, client and students) were directly involved in the decision-making process. They provided input during the design phase, influencing aspects such as the heating system and color theme. Additionally, a post-occupancy evaluation was conducted in the current study, which involved gathering real usage data after the building was occupied for two years. This indicates a comprehensive user involvement approach, encompassing both "Production with real users" and "Production for users" categories. Considering the time span of user involvement, the user participation in the design phase aligns with the "Programming - Developing design requirements" phase. The post-occupancy evaluation represents the "Occupancy - Gathering real usage data" phase, where insights are gathered to understand the users' experiences and inform future design and construction practices.

Zeb laboratory project:

- Degree of Involvement: Combination of "Production with real users" and "Production for users."
- Time Span of User Involvement: Programming - Developing design requirements (direct user involvement during the design phase). Occupancy - Gathering real usage data (post-occupancy evaluation).

Similarly, in the Energy Academy Building project, there were meetings called "pressure cookers" involving users, researchers, and an advisor firm to identify users' needs and involve them in the process based on their specialized expertise. This indicates a direct involvement of users in the decision-making process. The user involvement in this case study can be classified as "Production with real users" and production for users." based on the theory. Regarding the time span of user involvement, the user involvement methods were employed throughout the project phases. The "pressure cookers" meetings and the collaboration with the advisor firm likely occurred during multiple phases, such as programming, design, and construction. This comprehensive involvement of users throughout the project aligns with the theory's goal of integrating user input across the project lifecycle.

Energy Academy Europe:

- Degree of Involvement: Combination of "Production with real users" and "Production for users."
- Time Span of User Involvement: throughout the project phases: programming, design, and construction.

In conclusion, the findings from the research highlight the crucial role of user involvement in the early stages of building projects for ensuring an enhanced user experience. The case study of the ZEB laboratory project emphasizes the significance of engaging users as active participants in the design and development process. Their input and feedback were sought, resulting in valuable insights, innovative ideas, and improved solutions. The involvement of users, including students, researchers, and clients, proved essential in refining the design, addressing challenges, and aligning the building with their needs and expectations. Challenges related to user involvement were effectively managed through regular communication, evaluation processes, and a leadership structure.

The successful implementation of a novel heating storage system exemplifies the positive outcomes of user collaboration. User involvement was also recognized in the Energy Academy Europe project, where it contributed to better building outcomes and user satisfaction. The involvement of users in understanding their interaction with the building and considering their perspectives significantly influenced the design process. Challenges such as diverse stakeholder ambitions were addressed through open communication, validation meetings, and workshops. These findings reinforce the importance of user involvement in optimizing user experiences and align with previous studies in the field. User involvement can take different forms and levels, from observation and interviews to co-design, ultimately leading to improved usability and functionality of buildings. The research findings support the notion that user involvement is a valuable approach for creating successful and user-centered building projects.

5.1.3 Effective Communication Methods

Effective communication between building management and other stakeholders, especially users is crucial for ensuring user satisfaction and optimal building performance during the occupancy phase. The representative of the client in ZEB laboratory project, Informant 1N, mentioned the importance of the direct reporting system as a means of maintaining effective communication channels and facilitating timely feedback and engagement. Informant 1N emphasizes the value of the direct reporting system in establishing a communication mechanism between building management and users. This system allows users to report any concerns or issues directly to the management, enabling a direct line of communication. By providing users with a straightforward means of reporting, it promotes transparency, responsiveness, and accountability in addressing user feedback.

While the number of reports received through the direct reporting system in ZEB laboratory may not have been extensive, the mere existence of feedback from users indicates its usefulness in encouraging users to actively participate in the communication process. Even a small number of reports can provide valuable insights into areas that require improvement or attention. It demonstrates that users perceive the direct reporting system as a reliable and accessible means of communication, leading to their willingness to engage and provide feedback.

Similarly, Informant 6G, client representative of Energy Academy Europe project, emphasized the importance of communication in managing conflicts that may arise due to differing perspectives and desires among stakeholders. By ensuring that all stakeholders are well-informed and involved, conflicts can be addressed and resolved in a constructive manner. One key aspect of effective communication highlighted by Informant 6G is the provision of regular updates and newsletters to stakeholders. These communication channels serve as valuable tools for keeping stakeholders informed about the project's progress, decisions, and any changes that may occur. By maintaining open lines of communication and sharing pertinent information, misunderstandings can be minimized, and stakeholders can feel more engaged and involved in the project. They provided an example of conflicting preferences regarding large windows in the building. While some individuals may prefer more privacy and window coverage, the building's concept prioritizes transparency and large windows. In such cases, effective communication becomes vital in clearly conveying the reasons behind design choices and ensuring that stakeholders understand and align with the overarching goals of the project. By openly communicating the design concept and its implications, the project team can manage conflicting preferences and foster understanding among stakeholders.

Furthermore, Informant 6G emphasized that effective communication involves considering the building's concept and overall goals, such as energy efficiency, when making decisions. In instances where a user's request conflicts with the building's concept or energy consumption goals, the project team takes the opportunity to explain the reasons why the request cannot be accommodated. By providing clear explanations and considering the broader objectives of the project, stakeholders can gain a deeper understanding of the decision-making process and the rationale behind design choices.

The case studies of the ZEB laboratory project and the Energy Academy Europe project highlight the critical role of effective communication in ensuring user satisfaction and optimal building performance. The direct reporting system implemented in the ZEB laboratory project demonstrates the value of providing users with a straightforward means of reporting concerns or issues directly to building management. This system promotes transparency, responsiveness, and accountability in addressing user feedback, leading to active user participation and a reliable communication channel. Incorporating a direct reporting system reflects a commitment to user-centered practices and allows building management to gather valuable insights for improvement.

Similarly, the Energy Academy Europe project emphasizes the importance of regular updates and newsletters to stakeholders, enabling open lines of communication and minimizing misunderstandings. Effective communication helps manage conflicts and align stakeholders with the project's goals, even when differing perspectives or preferences arise. By considering the building's concept and overall objectives when making decisions, the project team can provide clear explanations and foster understanding among stakeholders. Overall, these case studies underscore the significance of effective communication in achieving user satisfaction, resolving conflicts, and aligning stakeholders with the project's vision.

5.1.4 Collaborative Project Delivery Model

Collaboration between stakeholders plays a crucial role in the early phase activities of building projects, significantly influencing building performance and user experience. The representative of client in ZEB laboratory project, Informant 1N, mentioned the importance of establishing a collaborative project approach involving key participants, such as the contractor, architect, consultant, researchers, and building operator, and the positive impact it has on the project's outcomes. By bringing together key participants from different disciplines and roles, effective communication, information exchange, and decision-making are facilitated throughout the project's life-cycle. This collaborative approach ensures that the project goals, requirements, and objectives are clearly defined and understood by all stakeholders from the outset. By involving relevant parties from the beginning, a holistic and integrated design and construction process are achieved. This ensures that the building's systems and features are tailored to meet the specific needs and expectations of the occupants. Moreover, the inclusion of researchers and building operators in the early phase enables the integration of their input and expertise into the design and operational aspects of the building. This collaborative inclusion likely leads to a better understanding of user requirements, improved functionality, and enhanced building performance.

Informant 1N highlights that the design phase specifically needs a collaborative effort among various stakeholders. The presence of the client, contractor, architect, plumbers, electricians, and other relevant parties in the same room promotes direct communication and coordination. This collaborative approach ensures that each team member's expertise and input are considered during the design phase, fostering a comprehensive and well-rounded design process. Effective collaboration between stakeholders can be facilitated through several strategies. Regular meetings, workshops, and collaborative sessions provide a platform for stakeholders to exchange ideas, share knowledge, and align their perspectives. Clear communication channels, both formal and informal, are established to ensure timely information flow and foster a collaborative atmosphere. Additionally, the use of collaborative technologies and tools, such as Building Information Modeling (BIM), enables real-time collaboration, visualization, and coordination among stakeholders. Collaboration allows for a comprehensive understanding of the project's requirements, encourages innovative solutions, and promotes collective ownership and responsibility. It also helps identify potential conflicts or discrepancies early on, enabling proactive resolution and minimizing costly revisions or rework during later stages.

Representative of architecture group in ZEB laboratory also explained that collaboration between stakeholders is a critical factor in the early phase of building projects to ensure the successful realization of the project by users. Informant 2A emphasized the importance of effective communication and inclusive decision-making processes among stakeholders. To ensure effective communication, Informant 2A highlighted the preference for in-person meetings and workshops over electronic means of communication. The team engaged in regular weekly meetings and workshops where they discussed various aspects of the project in ZEB laboratory project. This approach fostered direct interaction, encouraged meaningful discussions, and facilitated a deeper understanding of stakeholder perspectives.

In terms of decision-making, Informant 2A emphasized the collaborative nature of the project, with all stakeholders actively involved in every phase of the work. Rather than working in isolation, the team received continuous input from other stakeholders, which influenced their designs and proposals. This inclusive approach required flexibility and open-mindedness as the team had to adapt and make changes based on the feedback received. The iterative process of refinement and improvement allowed for alignment of project elements, including economic viability and sustainability considerations, to achieve desired outcomes. The involvement of clients, from the beginning of the project was deemed essential by Informant 2A. They brought the project brief and important knowledge related to sustainability aspects. Their participation ensured that sustainability was incorporated into the design, and informative lectures further educated the project team on relevant research fields. Extensive discussions and input from SINTEF and users were highlighted as valuable in exploring different approaches and challenging established workspace regulations. This collaborative process led to the design of innovative ways of working within the building, enhancing user satisfaction and building performance.

Collaborating closely with the contractor from the beginning of the project was considered necessary and a valuable learning experience by Informant 2A. The expertise of all parties was integrated early on, adjusting the building design accordingly and fostering a more integrated and collaborative workflow. The traditional approach of involving contractors after the design process is complete is becoming less common, as architects recognize the benefits of early engagement with stakeholders. From the perspective of Informant 2A as a designer, having the contractor present in the early phase of the project is valuable, provided they allow architects to do their job and provide timely input. Clear input on the budget and cost evaluation is crucial to design with a better understanding of financial constraints and avoid costly redesigns later. Projects that involve collaborations between architects and contractors from the early stages tend to have more successful outcomes, according to Informant 2A. This collaborative approach enables regular follow-ups, cost evaluation, and pricing of the design, minimizing surprises or major changes later in the project.

In the same vein, representative of contractor in ZEB laboratory project, Informant 3C, emphasized the effective collaboration among project stakeholders as a key factor in the successful realization of building projects, specifically in terms of user satisfaction. Informant 3C emphasized the importance of regular team meetings as a crucial aspect of achieving use value for all stakeholders involved in the project. These meetings provided a platform for the entire team to come together on a weekly basis and collaborate towards the project goals. Furthermore, thematic group sessions were conducted, allowing different designers and advisors to focus on specific aspects of the project in parallel. This collaborative approach facilitated innovation and made it easier to address the project's challenges effectively.

Informant 3C also highlighted the significance of having a contract and project structure that enables everyone involved to work towards the same sustainability goals. This alignment and shared purpose create a conducive environment for achieving those goals and overcoming obstacles along the way. By ensuring that all stakeholders are working towards a common direction and goal, the project team can harness the collective desire to succeed, which is more important than relying solely on individual geniuses or experts. In future projects, informant 3C intends to apply this understanding of the importance of focus and shared goals. They recognize that maintaining a consistent focus on sustainability or any other key objective requires ongoing effort and dedication from the project team. By emphasizing this focus and working together towards a common purpose, significant achievements can be made in sustainability and other project goals. Informant 3C also highlights the collaborative and trust-based contract model as a means to reduce risks for both the client and the contractor. However, they acknowledge that some individuals may not fully realize this and perceive early involvement of contractors as risky. Issues of trust may also come into play, as concerns about sharing control and decision-making with contractors early in the project may arise.

These findings align with prior research in the field, discussed in section 2.7, providing further validation for the significance of collaborative project delivery methods in optimizing the overall user experience. The consistent evidence from previous studies reinforces the importance of adopting collaborative approaches to achieve successful project outcomes and enhance user satisfaction. For instance, as presented in section 2.7, Atle Engebø and his colleagues believed that construction industry can promote sustainable construction by adopting collaborative project delivery methods that involve diverse project teams working together. Integration, facilitated by early involvement of contractors and continuous collaboration, improves teamwork and enhances overall project performance (Engebø et al., 2020). Furthermore, in another research on collaborative construction projects, Moradi et al. identified core success factors including equality, mutual trust, selecting competent people, commitment to a win-win philosophy, reasonable contracts, collaboration and cooperation, open communication, and incentive systems. These factors contribute to project organization, contractual relationships, and the operational system, highlighting their significance in achieving success in collaborative construction projects (figure 2.9.4) (Moradi and Kähkönen, 2022).

In conclusion, collaborative project delivery model is advantageous for achieving optimal building performance and user satisfaction. By involving key participants such as the contractor, architect, consultant, researchers, and building operator, effective communication, information exchange, and decision-making are facilitated throughout the project's life-cycle. This collaborative approach ensures that project goals, requirements, and objectives are clearly defined and understood by all stakeholders from the outset, leading to a holistic and integrated design and construction process. The inclusion of researchers and building operators in the early phase enables the integration of their expertise into the design and operational aspects of the building, resulting in a better understanding of user requirements, improved functionality, and enhanced building performance.

Effective collaboration is facilitated through strategies such as regular meetings, workshops, and collaborative sessions, as well as clear communication channels and the use of collaborative technologies and tools. Overall, collaborative project delivery method contributes to successful project outcomes and the achievement of sustainable and user-centered buildings.

5.1.5 Building Trust

In this study, informants discussed the role of trust in managing the needs and desires of different stakeholders involved in the project, such as contractors, designers, clients, students, and researchers, and its impact on effective collaboration and decision-making. According to representative of client in ZEB laboratory project, Informant 1N, excellent project management and the establishment of trust among all parties involved were key to managing the diverse needs and desires of stakeholders. Trust played a crucial role in fostering effective collaboration throughout the project's life-cycle. In ZEB laboratory project, trust between the contractor and the client formed the foundation for open communication and mutual understanding. A high level of trust allowed both parties to engage in transparent discussions, share their perspectives, and address concerns openly. This open dialogue enabled a better understanding of each other's expectations and facilitated the alignment of project goals and objectives. As a result, decision-making processes were streamlined, and potential conflicts or misunderstandings were proactively addressed.

Furthermore, trust between the project leader and the users was instrumental in creating an environment conducive to collaboration in Zeb laboratory project. The establishment of trust enabled the free flow of ideas, feedback, and constructive discussions. Researchers felt comfortable expressing their opinions, providing valuable insights, and engaging in problem-solving activities. This collaborative atmosphere not only promoted innovation but also fostered a sense of ownership and shared responsibility among all stakeholders. By building trust, stakeholders were more willing to collaborate, share knowledge, and contribute their expertise to the project. Trust encouraged stakeholders to be proactive in identifying potential challenges or risks and seeking mutually beneficial solutions. It created a safe space for open communication, where concerns could be raised and addressed promptly. This facilitated effective decision-making and problem-solving, ultimately leading to improved project outcomes.

In the same vein, representative of contractor in ZEB laboratory prtoject, Informant 3C, emphasized the importance of trust in the project and acknowledged that it could be both crucial and challenging to establish and maintain. According to informant 3C, building trust requires open communication, honesty, and a genuine willingness to work in the best interests of the project. It is not something that can be taken for granted but requires continuous effort and a proactive approach. They emphasized that clever tactics or playing games were not suitable for a project with collaborative nature, as trust was a key factor in fostering successful collaboration. Moreover, informant 3C highlighted the need for a different mindset compared to traditional contracts. Rather than solely focusing on personal gain, it was essential to consider the best interests of all stakeholders involved. This collaborative approach requires individuals who are willing to prioritize the success of the entire project and work in a mutually beneficial manner.

Informant 3C explained that building trust as a contractor involves several key aspects. One important factor is adopting an open book approach, where contractors transparently share their costs and financial information with the client. This transparency helps establish trust and demonstrates a commitment to working collaboratively. Additionally, building trust goes beyond the numbers and involves personal interactions. Contractors should invest time and effort in getting to know the client and building relationships on a human level. Effective communication plays a vital role in building trust, ensuring that information is clearly conveyed and understood by all parties. Finding the right balance in communication is crucial, providing the necessary information without overwhelming the client. Another aspect of building trust, according to informant 3C, is the willingness to give and take. This requires flexibility and accommodation in finding mutually beneficial solutions throughout the project. It may involve making compromises in certain areas while expecting reciprocation in others. This collaborative mindset fosters trust and creates a positive working relationship.

These findings align with prior research in the field, providing further validation for the significance of building trust in collaborative construction projects in order to achieve project goals and use value, which was presented in section 2.7. For example, Wood et al.'s research emphasizes the crucial role of trust in successful implementation of relationship-based procurement strategies in the construction industry. The study highlights that increased cooperation requires increased trust, and as parties demonstrate competence, honesty, open communication, and mutually beneficial outcomes, trust deepens, leading to closer and more open relationships (Wood, McDermott, et al., 2001). Furthermore, Laan et al.'s study highlights the prevalent conflict and lack of trust between clients and contractors in construction projects. They argued that trust in construction projects is influenced by uncertainty, risk, and the performance and quality of the relationship between partnering organizations. The behaviors of representatives from each organization are crucial in building trust, and successful trust-building efforts can lead to improved project outcomes and collaboration (Laan et al., 2011).

In conclusion, the role of trust in managing the diverse needs and desires of stakeholders involved in construction projects cannot be overstated. The findings of this study highlight the critical importance of trust in fostering effective collaboration and decision-making. Trust between contractors, clients, designers, and users forms the foundation for open communication, mutual understanding, and transparent discussions. It enables stakeholders to share their perspectives, address concerns openly, and align project goals and objectives.

Trust creates a collaborative environment where stakeholders feel comfortable expressing their opinions, providing valuable insights, and engaging in problem-solving activities. By building trust, stakeholders are more willing to collaborate, share knowledge, and contribute their expertise, ultimately leading to improved project outcomes. Building trust requires open communication, transparency, personal interactions, and a collaborative mindset that prioritizes the success of the entire project. Previous research further supports the significance of trust in collaborative construction projects, emphasizing its role as a binding force in cooperative relationships. Efforts to establish trust can contribute to improved project performance, cooperative and trusting relationships, and better collaboration between clients and contractors. In an industry characterized by conflict and lack of trust, the development of trust becomes crucial for successful project execution and final use value for the end users.

5.1.6 Utilization of Low Technological Methods

In the early phase activities of building projects, the utilization of low-tech technologies alongside high-tech solutions in the design of the building can contribute to the successful realization of the project in terms of user satisfaction and building performance. Representative of architects in ZEB laboratory project, Informant 2A, highlighted the unique approach of combining both high-tech and low-tech technologies, aiming to achieve optimal sustainability outcomes by integrating advanced and traditional techniques.

By incorporating low-tech technologies, the project team acknowledged the value of traditional and time-tested methods in promoting sustainability and user satisfaction. These low-tech solutions often rely on simpler, more environmentally friendly approaches that can be cost-effective and have a reduced impact on the environment. In fact, low-tech technologies often offer greater accessibility and ease of use for building occupants. These solutions can be intuitive, user-friendly, and require minimal maintenance. By incorporating low-tech features, such as natural ventilation, daylighting, or passive heating and cooling strategies, the building can provide a comfortable and healthy indoor environment for users. This, in turn, contributes to user satisfaction and well-being. Additionally, the utilization of low-tech technologies can enhance the overall resilience of the building. By incorporating passive design principles and strategies, the building can rely less on energy-intensive systems and reduce its dependence on external resources. This can lead to long-term cost savings, increased energy efficiency, and improved building performance in the occupancy phase.

Simillarly, representative of the contractor in ZEB laboratory project, Informant 3C, highlighted the valuable lessons learned from the sustainable features and goals achieved through the implementation of low-tech solutions in the project. Informant 3C emphasized that many of the solutions for sustainability are not complex or groundbreaking but rather based on basic principles and common-sense thinking. The utilization of low-tech technologies involves employing simple and traditional techniques to achieve sustainable outcomes. These approaches often rely on leveraging existing knowledge and practices that have been proven effective over time. By embracing low-tech solutions, the project team can harness the power of simplicity and practicality in addressing sustainability goals.

Informant 3C's experience also demonstrates that the successful implementation of low-tech technologies requires a dedicated commitment to sustainability from the early phases of the project. It involves considering sustainability aspects and integrating them into the project's design and planning stages. By prioritizing sustainability as a fundamental principle, the team can make informed decisions that lead to positive outcomes in terms of user satisfaction and building performance. The key takeaway from informant 3C's perspective is that the effective utilization of low-tech technologies is not solely about the specific technologies themselves but about the mindset and commitment to sustainability.

It involves recognizing that sustainability is not solely about complex or revolutionary solutions but about embracing and implementing simple, practical, and environmentally friendly strategies throughout the project lifecycle. By adopting low-tech approaches, the project team can achieve sustainability goals while maintaining a strong focus on user satisfaction and building performance. These solutions often prove to be cost-effective, easily maintainable, and accessible, ensuring that they can be implemented and utilized effectively in the long term.

In the same vein, representatives of client in Energy Academy Europe project, Informants 6G and 7G, highlighted several innovative and unique low-tech approaches that were implemented, showcasing the importance of simplicity, natural elements, and the principle of "less is more" in the design philosophy. One noteworthy low-tech method mentioned by Informant 6G was the incorporation of a labyrinth in the ventilation system. This feature played a significant role in achieving efficient ventilation within the building. The labyrinth facilitated the natural flow of air, contributing to improved indoor air quality and thermal comfort for the occupants. By leveraging this low-tech approach, the project team demonstrated their commitment to sustainable and energy-efficient solutions.

Additionally, the integration of LED lighting, windows, and solar panels was highlighted as a unique method employed in the project. This combination allowed for the optimization of natural light, reducing the reliance on artificial lighting and minimizing energy consumption. The integration of solar panels further enhanced the building's energy performance by generating clean and renewable energy. By utilizing these low-tech methods, the project team was able to achieve a balance between energy efficiency, user comfort, and sustainability goals.

Informant 7G furhter emphasized the significance of the large atrium in the building, which served both as a functional space and a crucial component of the ventilation concept. The atrium facilitated the natural flow of warm air from the ground level to the rooftop, contributing to efficient ventilation throughout the building. Furthermore, the atrium created an inviting and pleasant environment for people entering the building, enhancing the overall user experience. The focus on simplicity and the utilization of natural elements in the design philosophy from the project's inception played a vital role in the success of these low-tech methods. By embracing the principle of "less is more," the project team demonstrated their commitment to sustainable and user-centric design solutions. These low-tech methods not only contributed to improved building performance but also created a sense of pride and uniqueness in solving complex challenges.

Along with the same lines, representatives of advisors in Energy Academy Europe project, Informant 4A and Informant 5A provided valuable insights into the Energy Academy building, where innovative low-tech solutions were employed to achieve sustainability goals. Informant 4A highlighted the development of innovative solutions for the Energy Academy building, some of which were previously unexplored. An example of this is the air cooling system inspired by ancient Persian architecture (badgirs). By incorporating an underground tunnel, the air was cooled before being circulated through the building. This combination of high-tech and low-tech solutions created a hybrid system that effectively contributed to the building's sustainability.

Informant 5A further emphasized the significance of low-tech solutions in achieving a high level of sustainability in the Energy Academy building. The sustainability of the building was measured using the BREEAM method, which required the installations to perform well even under less-than-ideal climate conditions. By incorporating low-tech solutions such as solar chimneys and labyrinths, the building successfully achieved its sustainability objectives. The certification process for sustainability also included the evaluation of the entire installation system. The effectiveness of basic techniques, including underground ventilation and low-tech energy solutions, was highlighted by both informants.

These low-tech solutions, when combined with proper insulation and building physics, contribute to the robustness of buildings, requiring less maintenance and offering longer lifespans compared to installation-intensive approaches. This approach not only promotes sustainability but also enhances the overall performance and resilience of the building. Based on these findings, they were in the opinion that it is recommended to adopt a similar approach in future building projects. Starting with a focus on building physics, early consideration should be given to low-tech methods that can address key challenges and contribute to the sustainability and performance of the building. By prioritizing low-tech solutions and integrating them with high-tech systems, a balanced and effective approach can be achieved.

These findings align with prior research in the field, providing further validation for the advantages of using Low-technological methods, presented in section 2.7. For example, Emekci's research emphasizes the concept of "appropriate technology" in sustainable architecture. While high-tech solutions have led to significant advancements in building technologies, they often neglect a holistic approach and prioritize technological solutions. On the other hand, low-tech approaches propose conservative resource use and prioritize a human-centered perspective (Emekci, 2021).

In conclusion, the utilization of low-tech methods alongside high-tech solutions in building projects offers numerous benefits in terms of user satisfaction, building performance, and sustainability. By incorporating low-tech technologies, such as natural ventilation, daylighting, and passive heating and cooling strategies, buildings can provide a comfortable and healthy indoor environment for occupants, leading to increased user satisfaction and well-being. Moreover, low-tech solutions promote accessibility, ease of use, and minimal maintenance, contributing to long-term cost savings and improved building resilience. The successful implementation of low-tech technologies requires a dedicated commitment to sustainability from the early stages of the project, prioritizing sustainability as a fundamental principle and making informed decisions throughout the project lifecycle.

By embracing simplicity, practicality, and environmentally friendly strategies, low-tech approaches can effectively address sustainability goals while maintaining a strong focus on user satisfaction and building performance. The integration of low-tech solutions, along with high-tech systems, creates a balanced and effective approach that enhances building robustness, longevity, and energy efficiency. Overall, the combination of high and low-tech methods represents an "appropriate technology" approach, striking a balance between technological advancements and vernacular architectural techniques to achieve truly sustainable buildings. By harnessing the power of both approaches, buildings can optimize resource utilization, minimize environmental impacts, and create harmonious spaces that prioritize human-centered design principles.

5.1.7 Visualization

In the early phase activities of building projects, the utilization of visualization techniques can significantly contribute to the use value in occupancy phase. Representative of advisors in Energy Academy Europe project, Informant 2A, highlighted the unique and innovative approach of relying heavily on a 3D model from the very beginning of the project, departing from their usual sketch-based approach. The use of 3D modeling technology provided a tangible and visual representation of the design, allowing the project team to evaluate and assess each step of the design process more effectively.

By creating a detailed 3D model, the team can visualize the spatial relationships, proportions, and overall aesthetics of the building in a more realistic and immersive manner. One of the key benefits of 3D modeling is the ability to obtain immediate feedback and evaluation from the project team especially end users. With a 3D model, stakeholders, including architects, engineers, clients, and other relevant parties, can easily review and analyze the design from various perspectives. This enables better communication, collaboration, and decision-making during the early phase of the project.

Furthermore, visualization facilitates a deeper understanding of the design and its implications for user satisfaction and building performance. The realistic visualization provided by the model allows the team to assess factors such as spatial functionality, circulation patterns, natural lighting, and material selections. This level of detail enables early identification of potential design issues, allowing for necessary adjustments and improvements before the construction phase. Moreover, 3D modeling technology enhances the efficiency and accuracy of the design process. It enables the exploration of different design alternatives and scenarios, facilitating the identification of optimal solutions.

By simulating the building's performance and behavior, such as thermal analysis or daylighting studies, the team can optimize energy efficiency and occupant comfort. The use of 3D modeling also extends beyond the design phase and contributes to user satisfaction in the occupancy phase. The detailed visual representation of the building allows users to better understand and envision the final product before its construction. This helps set realistic expectations and promotes effective communication between the project team and end-users.

In the same vein, representative of contractors in ZEB laboratory, Informant 3C, highlighted the importance of visualization tools in the project, specifically mentioning the use of BIM and VR technologies. These tools provided a means to effectively communicate and visualize the project to stakeholders, enabling them to actively participate in the decision-making process. By creating realistic and immersive virtual representations of the building, these technologies allowed stakeholders to better understand the design concepts, spatial arrangements, and material choices. This visual clarity facilitated meaningful discussions and feedback, leading to informed decisions that align with the project's objectives and the expectations of the end-users.

Simillarly, representative of advisors in Energy Academy Europe project, Informant 4A, highlighted the crucial role played by designers in translating the project's initial ambitions into the final design of the Energy Academy by visualizing potential layouts and showing the placement of end users within the building. 3D modeling and visualization techniques offer a powerful means of communication and representation in the early stages of a project. By creating three-dimensional digital models of the building design, designers can provide a realistic and immersive representation of the proposed spaces, layout, and spatial relationships.

This visual representation allows stakeholders, including end users, to better understand and engage with the design concept. Through 3D modeling and visualization, designers can demonstrate how the building's spaces will be utilized and how end users will be situated within them. This level of detail and realism helps stakeholders envision themselves in the building, providing a sense of scale, proportion, and spatial experience. By visualizing the potential layouts, designers bridge the gap between abstract ideas and tangible representations, facilitating a more meaningful and informed dialogue with stakeholders.

In terms of user satisfaction, 3D modeling and visualization enable designers to incorporate user feedback and preferences into the design process. By presenting visual representations to end users and stakeholders, designers can solicit their input, gather feedback, and accommodate their specific needs and aspirations. This user-centered approach ensures that the building design aligns with the expectations and requirements of the intended users, ultimately enhancing user satisfaction and experience.

These findings align with prior research in the field presented in section 2.7, providing further validation for the significance of utilizing visualization methods in the early phases of building projects in order to provide users with an immerse environment representing the end result. For instance, In their research, de Klerk and colleagues highlight the value of sketching in architectural design and the potential of augmented and virtual reality (AR/VR) technologies to revolutionize the design process. They were of the opinion that VR systems provide an immersive and efficient alternative to physical models and detailed 3D renderings, enabling architects to test spatial hypotheses, gain insights into design challenges, and explore alternative design solutions (de Klerk et al., 2019). Furthermore, Shakil Ahmed discussed the advancements in virtual reality (VR) technologies and their impact on construction projects. They highlight how VR enables the creation of realistic virtual models of projects before their physical realization, providing a comprehensive and parametric information resource for all departments involved in the construction team (Ahmed, 2018).

In conclusion, the utilization techniques in building projects offer numerous benefits throughout the project lifecycle. By relying on 3D models from the early stages, project teams can effectively evaluate and assess the design, enabling better decision-making and collaboration. The immersive and realistic visual representation provided by 3D models allows stakeholders to review and analyze the design from various perspectives, promoting effective communication and enhancing user satisfaction. Furthermore, 3D modeling facilitates a deeper understanding of the design's implications for user satisfaction and building performance, enabling early identification of potential issues and optimization of energy efficiency. The use of visualization tools, such as VR technologies, further enhances communication and decision-making among stakeholders. Overall, these findings validate the significance of incorporating visualization methods in building projects, improving project outcomes and user experiences. With the continued advancements in technology, such as augmented and virtual reality, the potential for enhancing the architectural design process and construction management continues to grow.

5.1.8 Involving Experts in Building Physics

Through interviews and analysis, it has become evident that the inclusion of experts in building physics during the initial stages of construction projects plays an indispensable role in maximizing value for users. Representative of the client in Energy Academy Europe project, Informant 6G, emphasized the importance of considering the functional layout of the building, particularly in relation to energy usage and efficiency. One aspect highlighted by Informant 6G is the placement of laboratories on the north side of the building. This strategic decision aims to reduce the need for excessive cooling due to sun exposure. By involving experts in building physics during the early phases, the project team can benefit from their knowledge and insights regarding energy optimization strategies.

Experts can provide valuable input on how different functions and spaces within the building can be organized and positioned to maximize energy efficiency by using natural conditions. The example of locating laboratories on the north side of the building demonstrates the thoughtful approach to functional layout and its impact on energy usage. By placing spaces with higher cooling requirements away from direct sun exposure, the project team can minimize the energy demand for cooling, thus contributing to improved energy performance and sustainability. This decision showcases the importance of considering building physics expertise in the early phases to make informed choices that optimize energy consumption.

Involving experts in building physics early on also allows for the integration of sustainable design principles into the project. These experts can provide valuable insights into energy-efficient building envelope design, insulation techniques, natural ventilation strategies, and other factors that contribute to the overall energy performance and occupant comfort. Their expertise helps identify potential challenges and opportunities related to energy usage, enabling the project team to make informed decisions that align with sustainability goals and enhance user satisfaction.

In the same vein, the insights provided by representative of advisors in Energy Academy Europe project, Informant 5A, shed light on the significance of building physics in achieving sustainability goals and reducing energy consumption. Informant 5A emphasized the importance of taking a holistic approach to sustainability that goes beyond just energy considerations. By prioritizing building physics, they were able to minimize the need for additional energy-consuming components.

This highlights the critical role played by building physics in shaping the overall sustainability and energy efficiency of a building. Informant 4A further emphasized the importance of building physics and the need for its due consideration right from the beginning of a project. They pointed out that architects often overlook building physics, assuming they can handle it themselves. However, building physics plays a vital role in defining and shaping the overall experience of the building, influencing factors such as temperature regulation, air quality, daylighting, and overall user comfort.

The tip shared by Informant 5A regarding the prioritization of building physics over selecting an architect is significant. Building physics, as a specialty, greatly influences the user experience within the building. Approximately 80% of the user experience is influenced by how well the building functions in relation to its climate conditions. By ensuring a well-regulated and comfortable internal environment, potential complaints from users can be eliminated, allowing them to focus on their work and enhancing user satisfaction.

The layout and connectivity within the building were also mentioned as important considerations. However, Informant 5A emphasized that building physics should take precedence over architectural considerations. While people may initially have thoughts or opinions about the architectural design, their primary concern once inside the building becomes the indoor environmental quality. A well-functioning building with optimal building physics eliminates discomfort and complaints related to the indoor environment, ultimately enhancing user satisfaction. Informant 4A provided an example of a school building in the Netherlands that faced issues due to improper consideration of building physics. The architectural design, resembling pyramids, led to problems such as excessive heat from direct sun exposure and rainwater leakage. This example highlights the significance of integrating building physics early in the design process to ensure efficiency and functionality.

These findings not only confirm and reinforce previous research in the field, discussed in section 2.7, but also provide robust evidence to underscore the immense importance of integrating the expertise of building physics experts right from the early stages of building projects. For instance, as discussed comprehensively in theory section, the editorial board of the 7th International Building Physics Conference (IBPC2018) highlighted the significance of Building Physics research in understanding the impact of buildings on people's health, well-being, carbon emissions, energy efficiency, and environmental quality. Designing and constructing buildings that meet multiple performance goals while considering energy conservation, occupant needs, and indoor environmental quality pose challenges (J. Zhang et al., 2019).

In conclusion, the findings of this study emphasize the critical role of building physics experts in achieving value for users in construction projects. By involving these experts during the initial stages, valuable insights and knowledge can be utilized to optimize energy usage, enhance sustainability, and improve occupant comfort. The examples highlighted in the Energy Academy Europe project demonstrate the positive impact of considering building physics expertise in making informed decisions that maximize energy efficiency.

Moreover, the integration of sustainable design principles and the prioritization of building physics over architectural considerations further contribute to achieving sustainability goals and user satisfaction. The study underscores the importance of addressing building physics early in the design process to ensure efficiency, functionality, and a well-regulated indoor environment. The significance of building physics research in addressing the complex challenges of building performance, occupant well-being, and environmental quality is also recognized. As the field continues to evolve, integrating technological advancements with social, economic, cultural, and policy developments remains crucial for creating sustainable and high-performing built environments.

5.1.9 Flexibility in Design

Flexibility in design emerges as a crucial factor in the early phase activities that contribute to user satisfaction. Representatives of advisors in Energy Academy Europe project, Informant 4A, highlighted the importance of flexibility in accommodating the diverse needs and preferences of end users, ensuring their satisfaction and productivity within the Energy Academy building. For example, during the later stages of the EAE project, the design team actively involved a group of end users in determining their preferred working spaces within the open floor fields. This participatory approach allowed end users to explore the space, envision their working environment, and provide input on furniture design and layout.

They proposed the use of specific furniture and designated spaces with plants to create more secluded and peaceful zones within the open floor plan. The design of the Energy Academy was prepared to accommodate different layout possibilities, including both various rooms and an open floor plan. This flexibility was intentionally incorporated into the design phase to ensure that the building could adapt to different needs. By considering potential layout changes and incorporating them early in the design process, the team aimed to create a building that could evolve and respond to user requirements.

Informant 4A also emphasized the significance of micro-level considerations in ensuring user satisfaction and productivity. Factors such as acoustics, chair and table quality, and the arrangement of surroundings directly impact the daily work experience of users. By paying attention to these details and incorporating them into the design, the team aimed to create a supportive and comfortable working environment. Informant 5A highlighted the practical and functional aspects that end users often prioritize, such as proximity to the coffee machine, further emphasizing the importance of considering user preferences.

In addition to user satisfaction, flexibility in design also plays a role in encouraging efficient and sustainable building usage. The design of the Energy Academy aimed to make it intuitive for users to adopt sustainable practices. For example, the layout of the building encouraged the use of stairs instead of elevators, and connections were designed to facilitate interactions between different parts of the building. Energy-saving features, such as automatic adjustments to the ventilation system when windows were opened, were also incorporated. The combination of sustainable elements with conventional ones created an efficient and effective overall solution, comparable to a hybrid car, as described by Informant 4A.

Informant 5A highlighted the importance of adopting a flexible approach in the design of the Energy Academy building to accommodate the changing needs of different parties over time. The energy transition involves a transition of various stakeholders working together, and a design process focused solely on one type of user could lead to a building tailored specifically to their needs. By considering flexibility in the design, the Energy Academy building was designed to accommodate the transformation of users over time and support their evolving requirements.

These findings corroborate earlier research emphasizing the significance of flexible building design in delivering value to users which were discussed in section 2.7. For instance, according to Khwla A.M.H. Alaraji and colleagues, the inclusion of more options and choices in the physical environment can improve users' sense of control and overall well-being, emphasizing the importance of flexibility in building design (Alaraji and Jusan, 2015).

In conclusion, flexibility in design emerges as a crucial factor in ensuring user satisfaction and productivity within the Energy Academy building. The project showcased the importance of involving end users in determining their preferred working spaces and incorporating their input on furniture design and layout. This participatory approach allowed for a personalized and comfortable working environment. Micro-level considerations, such as acoustics and surroundings arrangement, were also emphasized to create a supportive atmosphere.

Additionally, flexibility in design promotes efficient and sustainable building usage by encouraging sustainable practices and accommodating the changing needs of different parties over time. The findings align with previous research highlighting the significance of flexibility in enhancing users' sense of control and overall well-being. Studies have explored various principles and applications of flexibility, emphasizing the importance of considering users' perspectives in customizing their living spaces. Overall, incorporating flexibility in design maximizes user satisfaction and contributes to the long-term adaptability of buildings.

5.1.10 Team building

Team building in the early phases of building projects is widely recognized as a crucial component in guaranteeing not only value for the end users but also optimal performance of the project outcomes. Representative of contractor in ZEB laboratory project, Informant 3C, stressed the importance of team building and creating a safe and creative environment within the project team. Activities were designed to foster collaboration, strengthen relationships, and ensure that everyone in the team shared a common understanding and commitment to the main project goals. By engaging in team-building exercises and fostering a supportive culture, the project team could leverage their diverse expertise and perspectives, leading to enhanced creativity and innovation.

Continuous evaluation was another crucial aspect emphasized by informant 3C during the workshops. Regular progress evaluations provided the team with valuable insights into what was working well and what required improvement. This self-assessment and reflection allowed the team to identify areas of strength and areas that needed attention, enabling them to make necessary adjustments and optimize their performance. By maintaining a constant focus on evaluation, the project team could continuously refine their approach, resulting in a more efficient and successful project execution.

In the same vein, representative of advisors in Energy Academy Europe project, highlighted several aspects of team building that were instrumental in the Energy Academy project. One key aspect was the procurement of top engineers with creative thinking. Informant 4A emphasizes the importance of attracting and securing the expertise of these engineers, even though they may come at a higher cost. By procuring top engineers, the project team ensures a high level of competence and innovative problem-solving abilities, which are essential for achieving successful outcomes. Creating a strong and collaborative team is another important factor. The team building activities, such as the two-day excursion to visit other buildings in Amsterdam, provided inspiration and fostered a sense of camaraderie among team members. This environment of teamwork and openness facilitated fruitful discussions and the exchange of ideas between different specialties, ultimately enhancing the overall quality of the building design.

Informant 4A mentions that investing in team building activities helps build unity among team members and increases their understanding of individual dynamics within the team. By being aware of these dynamics, the project team can select members who are more likely to be team players and contribute to a harmonious working relationship. This proactive approach helps prevent conflicts and promotes better collaboration among stakeholders. Connecting with team members on a personal level is also highlighted as an important part of the team building process. Informant 5A emphasizes the benefits of team building activities conducted at the beginning of the design phase.

Excursions and social interactions, such as the visit to a solar panel exhibition in France, allowed team members to establish strong bonds and build relationships. These connections greatly facilitated problem-solving and enhanced the design process, leading to innovative solutions and better technical outcomes. Establishing connections and building relationships among stakeholders early in the building process is emphasized as a valuable practice. Celebrations and social interactions at the beginning of the project create an opportunity for stakeholders to get to know each other, establish rapport, and foster a collaborative work environment. This approach enhances teamwork and productivity throughout the project, contributing to its success.

The findings of this study are consistent with prior research conducted in the construction industry presented in section 2.7, which has consistently highlighted the significant importance of team building strategies in construction projects. For example, the study by David M. Spatz highlighted the significant role of teamwork in the construction industry for successful project completion. They argued that effective teamwork leads to increased efficiency, adherence to schedules, meeting deadlines, improved employee morale, and customer satisfaction (Spatz, 2000).

In conclusion, team building in the construction industry is widely recognized as crucial for ensuring successful project outcomes. This study aligns with previous research, emphasizing the importance of creating a safe and creative environment within project teams, fostering collaboration, and establishing a common understanding and commitment to project goals. Continuous evaluation and self-assessment help identify areas of strength and improvement, leading to enhanced performance. Additionally, procuring top engineers with creative thinking ensures competence and innovative problem-solving abilities.

Team-building activities, such as excursions and social interactions, foster camaraderie, encourage fruitful discussions, and enhance the overall quality of the project. Establishing early stakeholder connections and a collaborative work environment facilitates teamwork and productivity throughout the project. By implementing effective team building strategies, construction companies can leverage diverse expertise, stimulate creativity and innovation, and achieve successful project execution.

5.2 Value Blueprint for ZEB Laboratory

Chapter 2.6 delved into the value blueprint, a remarkable tool developed by Marina Bos de Vos, which plays a pivotal role in visualizing the value flow within a project (Vos, n.d.). This process entails engaging various project stakeholders through targeted questions and mapping their responses onto the blueprint. In this study, the emphasis lies on the use value, resulting in the mapping of all blueprint steps except for step 8, which pertain to revenue models. It is assumed that all the stakeholders achieved their financial expectations from this project.

To comprehend the value flow within the ZEB laboratory project, in-depth interviews were conducted with the primary stakeholders. The value blueprint (figure 2.8.1) vividly demonstrates the convergence of stakeholders' value exchanges in the "value for others" section of the value octagonal, a concept commonly referred to as value co-creation in project management literature, discussed in section 2.5. Value co-creation denotes a collaborative, simultaneous, and peer-based process that generates innovative value, comprising both tangible and intangible elements. Equally significant is the other side of the octagonal, which represents the values that stakeholders themselves capture from the project, known as value capture or value appropriation, presented in section 2.5.1. Value capture pertains to the mechanism by which organizations retain a portion of the value they generate. The remaining sides of the octagonal encompass professional expertise, risks, partners, activities, collaboration agreements, and revenue models. By methodically asking value-related questions specific to the ZEB laboratory project from the architect and the contractor, a comprehensive understanding of critical relationships, tensions, and opportunities related to value flow is attained. Figures 5.2.1 and 5.2.2 offer invaluable insights into the value blueprints for the architect and contractor involved in the ZEB laboratory project.

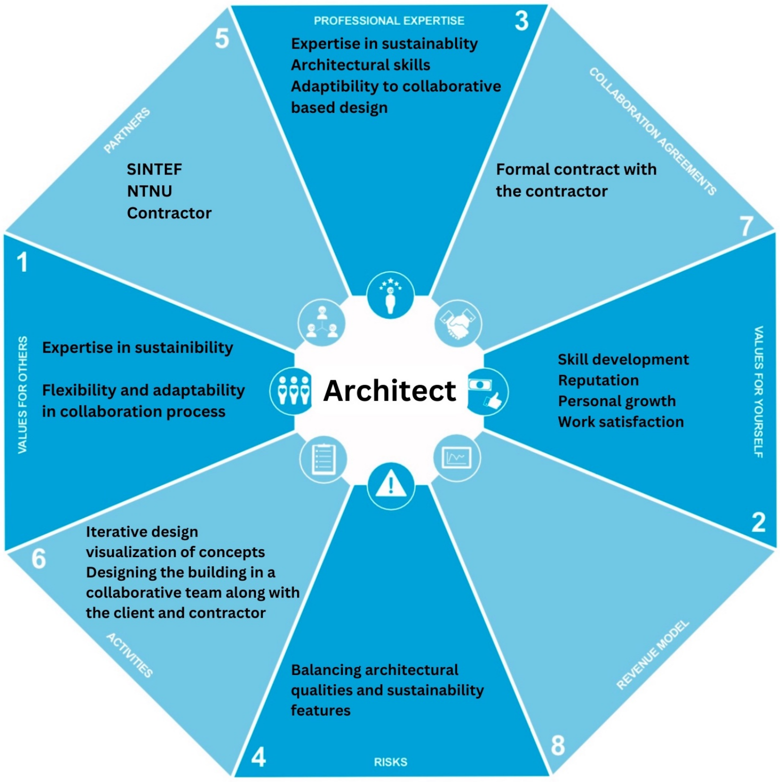


Figure 5.2.1: Value blueprint for the Architect in ZEB laboratory project

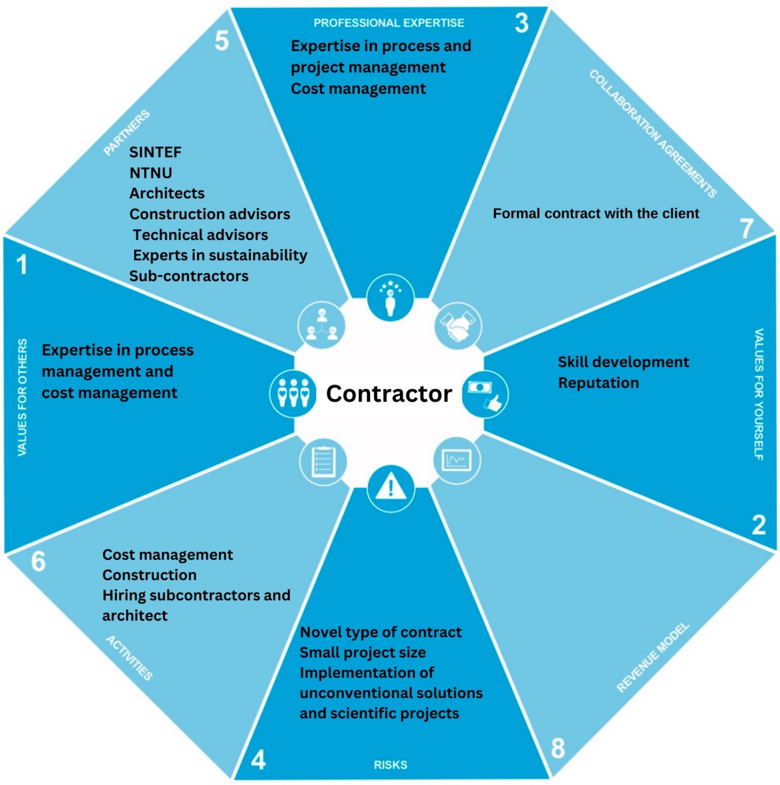


Figure 5.2.2: Value blueprint for the Contractor in ZEB laboratory project

Concerning value for others, both parties articulate the values they contribute to the other stakeholders. The architect brings forth their expertise in sustainability, flexibility, and adaptability in the collaborative design process. According to Marina's value framework, discussed in section 2.2, these values fall under the category of use value in utility and environmental value. These factors exert a direct influence on project outcomes, encompassing value for the client and users. The architect's proficiency and skills establish a foundation that assists the client in achieving the project's sustainability goals while facilitating a seamless design process. Furthermore, these factors engender user satisfaction by designing a sustainable building that aligns with users' needs. In contrast, the contractor contributes their expertise in process and cost management, encompassing use value in utility and economical value for the client. These competencies prove indispensable in realizing a successful project outcome by expediting processes prior to the occupancy phase and mitigating the risk of cost overruns.

Regarding value for themselves, the architect and contractor share similar experiences. Engaging in the ZEB laboratory project, renowned as the epitome of sustainable building projects, provided them with opportunities to cultivate their skills in sustainability and innovative collaborative project delivery methods. They both acknowledge that their involvement in this project has enhanced their reputation and bolstered their prospects of securing similar projects in the future. While financial gain, not explicitly mentioned in the blueprint, forms part of the value for themselves, the architect also derives personal growth through the collaborative process, leading to job satisfaction. According to Marina's framework, presented in section 2.2, these values encompass human values in achievement and enjoyment, as well as economic value in terms of monetary gains and reputation.

The architect's professional expertise required to achieve values for others and for themselves revolves around their proficiency in sustainability, backed by a dedicated department, and their adaptability to the collaborative design process. Notably, the design process for this project deviates significantly from conventional practices, presenting both challenges and invaluable learning experiences. In contrast, the contractor's expertise in process and project management, along with cost management, plays a crucial role in achieving values for others and for themselves. The contractor's adeptness in these areas was instrumental in securing the project through a competitive procurement process. Their responsibilities encompassed managing costs and facilitating the execution process.

When considering the risks associated with the project, the architect expressed concerns regarding the delicate balance between architectural qualities and sustainability features. Given that architectural qualities ranked lower in priority, it posed challenges in the design process. On the other hand, the contractor identified the novelty of the collaborative project delivery model with early contractor involvement as a risk factor. Additionally, the project's relatively small size while it was demanding in terms of resource allocation was another risk factor. Furthermore, the incorporation of unconventional solutions and scientific elements introduced uncertainties regarding their functionality. However, the contractor mentioned the client's approach in defining clear boundaries of responsibilities when implementing these unconventional solutions.

Throughout the project, collaborative efforts were fostered among the architect, contractor, and clients (SINTEF and NTNU). While the contractor had the formal contract with the client, the architect and other parties held contracts with the contractor. This collaborative approach facilitated effective communication and coordination among all stakeholders.

Overall, the ZEB laboratory project presented both the architect and contractor with opportunities for growth and development. The architect's expertise in sustainability and adaptability to collaborative processes, combined with the contractor's proficiency in process, project, and cost management, were essential for fulfilling their respective responsibilities. Balancing architectural qualities and sustainability remained a challenge for the architect, while the contractor faced risks associated with a novel project delivery model and resource allocation. Nevertheless, the collaborative nature of the project fostered value co-creation, resulting in innovative and tangible outcomes. By utilizing the value blueprint, a comprehensive understanding of the value flow is gained, enabling us to navigate crucial relationships, tensions, and opportunities more effectively in the future projects.

Regarding value capture or value appropriation, both parties share similar outcomes. They both benefit financially, gain reputation, enhance their skills, experience personal growth, and derive job satisfaction. These aspects encompass human values in achievement and enjoyment, as well as economic value in terms of monetary gains and reputation.

The value co-creation area in the ZEB laboratory project showcases the successful integration of expertise and collaboration between the architect and contractor. It demonstrates the importance of aligning skills and capabilities to generate value for the project's stakeholders. Furthermore, the value capture aspect emphasizes the significance of financial benefits and intangible gains for both the architect and contractor, contributing to their long-term success and growth.

As discussed in section 2.5.2, project-based firms often face the challenge of balancing different values when pursuing value capture in their interactions with clients. This is because the goals of value creation and value capture can sometimes diverge at various levels within the organization. Within the firm itself, projects serve not only as a means to generate financial revenues but also as a way to achieve other strategic objectives, which may sometimes compete with one another. Therefore, it is crucial for firms to consider non-monetary dimensions of value in order to ensure long-term organizational sustainability. These dimensions include project quality, client satisfaction, learning and knowledge development, knowledge sharing, societal influence, and enjoyment. To navigate these tradeoffs and reconcile different values, project-based firms must develop value capture strategies that effectively address and integrate various value dimensions within and across their projects.

The process of capturing value in project-based settings is complex and dynamic, often resulting in value slipping from one actor to another. This phenomenon, referred to as "value slippage", occurs when actors are unable to fully capture the monetary equivalent of the value they co-create. Value slippage arises when the use value created is high, but the exchange value remains low. In such situations, clients or other stakeholders may benefit from the utility and quality of a product or service without providing adequate payment.

In the ZEB Laboratory project, the interviews revealed a clear pattern of value slippage, with most of the knowledge sharing occurring from the clients, NTNU and SINTEF, to other stakeholders. These clients possessed valuable expertise in sustainable buildings and innovative methods that could be implemented. Moreover, they willingly took on the risks associated with implementing these innovative methods, thereby reducing the risks for the contractor and architect. Notably, NTNU, being a publicly owned university, had a strategic goal of enhancing the campus and promoting sustainability knowledge among all stakeholders. Consequently, they did not consider value slippage to be contradictory to their strategies. However, it is important to note that this may not be the case for privately owned clients, who may have different priorities. Additionally, the collaborative design and delivery model employed in this project fostered an open approach when addressing conflicts. This approach proved beneficial in ensuring that the value created was distributed in a manner that allowed all parties involved to capture the value they had co-created, and potentially even more. By employing this open approach, conflicts were resolved in a way that maximized the distribution of value among stakeholders.

5.3 Post Occupancy Evaluation Results

Post-occupancy evaluation (POE) , presented in section 2.9, serves as a valuable tool for assessing a building's performance and capturing the users' perspective after a period of occupancy. In the case of the ZEB laboratory, the POE aims to measure the use value, which holds significance for all parties involved in the project.

Furthermore, the ZEB laboratory holds a unique position as the only zero-emission building within the NTNU campus. As the campus development team is currently engaged in constructing new buildings, it becomes crucial to understand the user experience and use value of the ZEB laboratory, both as an office building and a living lab within the campus environment. This highlights the importance of studying the use value of the facility. By conducting a post-occupancy evaluation, we can gather valuable insights directly from the building occupants and end-users regarding their experience with the ZEB laboratory and the building's use value considering different factors. Understanding the use value of the ZEB laboratory will aid the campus development team in making informed decisions about future building projects. Insights from the evaluation can be used to enhance the design, functionality, and user experience of upcoming buildings, ensuring that they meet the evolving needs and expectations of the users.

By considering all the results and feedback from both the survey and walkthrough, we can draw a comprehensive conclusion regarding the ZEB laboratory's performance and occupant experiences. The survey results indicate that a majority of respondents (86%) expressed satisfaction with the ZEB laboratory building as a workplace. When examining different aspects, satisfaction percentages varied, with sustainability (90%), safety and security (86.6%), amenities (85%), and physical environment (79.16%) receiving relatively high satisfaction ratings. However, there were areas for improvement identified, such as functionality (70%), productivity (73.3%), and learning and development (46.6%). The walkthrough results further supported the positive user satisfaction results from survey.

5.3.1 Survey Results

Based on the survey, the users expressed a high level of satisfaction with the physical environment of the ZEB Laboratory. The cleanliness and maintenance of the laboratory received the highest satisfaction ratings, indicating that the management has been successful in creating a clean and well-maintained environment. This is crucial for a positive user experience, especially considering that the building is a living laboratory where malfunctions can affect data collection. Access to natural light was another aspect that received high satisfaction ratings. This highlights the importance of natural light in the workplace, as it has been linked to improved well-being, productivity, and overall satisfaction. The presence of ample natural light within the laboratory contributes to a pleasant and comfortable working environment, positively impacting the user experience.

Indoor air quality received positive feedback from the majority of respondents, suggesting that the ZEB Laboratory has implemented effective measures to ensure a healthy indoor environment. Good indoor air quality is vital for occupant health, comfort, and productivity. The high satisfaction rating in this aspect reflects the successful implementation of proper ventilation and air filtration systems. Acoustics, comfort of furniture and equipment, and lighting also received relatively high satisfaction ratings. Acoustics play a significant role in creating a conducive work environment by minimizing noise disturbances and ensuring adequate speech intelligibility. The positive ratings in this aspect indicate that measures have been taken to address acoustical concerns within the laboratory. The satisfaction ratings for comfort of furniture and equipment highlight the importance of ergonomics in supporting the well-being and productivity of laboratory users. Adequate lighting is essential for visual comfort and task performance, and the high satisfaction ratings suggest that the laboratory provides appropriate lighting levels and quality.

However, some aspects of the physical environment received lower satisfaction ratings. Solar shading and access to outdoor spaces received moderate satisfaction ratings, indicating that improvements may be needed in these areas. The users expressed the need for better control over solar shading to mitigate glare and excessive solar heat gain. Access to outdoor spaces provides opportunities for relaxation and connection with nature, which can contribute to overall well-being and satisfaction.

Regarding temperature and air quality, the survey results indicate generally positive feedback. The majority of respondents rated the temperature as "just right" during both the summer and winter seasons, indicating a comfortable indoor environment. However, there were some individuals who reported feeling somewhat hot or cold, suggesting potential areas for improvement in the cooling and heating systems. Temperature stability received positive ratings overall, but minor fluctuations were mentioned by some respondents, suggesting the need for ongoing monitoring and fine-tuning of the systems especially in the south side of the building. Indoor air quality was generally satisfactory, with the majority of respondents reporting no noticeable issues. However, concerns were raised by a portion of the respondents regarding "heavy" air quality and insufficient ventilation, particularly in some of the meeting rooms. Addressing these concerns by increasing ventilation rates and ensuring proper air circulation would contribute to a healthier and more comfortable indoor environment.

Based on the survey results, the users of the ZEB Laboratory expressed a relatively high level of satisfaction with the building systems. The survey results indicate that respondents were satisfied with the plumbing system and electrical system of the laboratory. These systems received high satisfaction ratings, suggesting that they are functioning well and meeting the expectations of the occupants. This is crucial because reliable plumbing and electrical systems are essential for the smooth operation of a laboratory facility. The HVAC systems, responsible for maintaining comfortable indoor temperatures and air quality, also received positive ratings from the majority of respondents. This suggests that the temperature control and air circulation within the laboratory were satisfactory for most users. However, a small percentage of respondents expressed some level of dissatisfaction with these systems. Further investigation is necessary to understand the specific concerns and areas for improvement. It is important to address these concerns promptly to ensure optimal thermal comfort and air quality for the laboratory occupants.

The effectiveness and speed of maintenance and repairs were rated moderately by the respondents. While the majority of respondents expressed satisfaction in this regard, there is room for improvement in terms of addressing maintenance and repair issues promptly and efficiently. The feedback from users who reported disruptions or malfunctions in the building systems emphasizes the need for proactive maintenance practices and effective communication channels between occupants and maintenance personnel. Timely resolution of issues is crucial to minimize any negative impact on productivity and occupant comfort. Specific issues with the building systems, such as the HDMI input problem, malfunctioning ZEB app, heat pumps, and solar shadings, were identified. These issues should be addressed promptly as they can disrupt work processes, hinder user experience, and potentially affect the overall productivity of the laboratory. It is recommended to prioritize the resolution of these issues and establish a system for reporting and tracking malfunctioning ZEB app requests. By addressing these specific problems, the laboratory can ensure a smoother and more efficient operation, leading to an enhanced user experience.

The survey findings indicate that respondents were generally satisfied with the amenities provided in the ZEB Laboratory. Several factors contributed to their satisfaction. Firstly, the high satisfaction ratings for the quality of common areas and amenities, availability and access to common areas, availability and quality of technology and equipment, and the color theme used in the building positively reflect on the user experience. These factors suggest that the laboratory offers comfortable and well-equipped spaces for work and collaboration, which contributes to user satisfaction. However, it is important to note that a small percentage of respondents expressed some level of dissatisfaction with certain aspects of the amenities. Specifically, the quality of meeting rooms received a lower rating, with 20% of respondents reporting some level of dissatisfaction. Additionally, 13% of respondents were somewhat dissatisfied with the quality of workspace. These findings highlight specific areas where improvements or adjustments may be needed to enhance user satisfaction. To address the concerns raised by dissatisfied respondents, it is recommended to improve the meeting rooms and workspace quality. This can be achieved by conducting further assessments and engaging with laboratory occupants to gather specific feedback and suggestions. By actively seeking feedback, the laboratory management can identify the specific issues causing dissatisfaction and take appropriate measures to address them. This may involve upgrading the meeting room facilities, ensuring comfortable and functional workspaces, and considering the preferences and needs of the users.

The survey also identified several issues and inconveniences reported by respondents regarding the amenities. These included elevator malfunctions, difficulties with accessing specific areas like the lunch room on the first floor, minor inconveniences with rubbish bin placements, and challenges with the app used for booking meeting rooms. It is crucial to address these issues promptly to ensure that the amenities function effectively and provide a seamless experience for laboratory occupants. Improving communication channels and addressing technical difficulties with booking systems by adding check-in features or other technologies can contribute to a more user-friendly environment. Regular maintenance and periodic updates to the amenities are also important for their longevity and functionality. By ensuring that the amenities are well-maintained, the laboratory management can create a positive and consistent user experience. This includes addressing issues such as elevator malfunctions, which can cause inconvenience and disrupt the smooth functioning of the laboratory.

The survey results indicate that respondents generally expressed satisfaction with the functionality of the ZEB Laboratory. There were several factors contributing to their satisfaction, as well as areas for improvement. Regarding access to resources and technology, respondents reported a high level of satisfaction. This suggests that the laboratory provides the necessary tools and infrastructure to support their work effectively. The availability of resources and technology is crucial for users to perform their tasks efficiently and achieve their goals. However, when it comes to the layout and design of the laboratory, satisfaction ratings were moderate, with 73% of respondents reporting some level of satisfaction. It is important to note that 13% of respondents expressed dissatisfaction with the layout and design. This indicates that there may be room for improvement in optimizing the spatial arrangement and design elements to better cater to the needs and preferences of the laboratory occupants. By addressing these concerns, such as considering the flow of movement, creating ergonomic workstations, and enhancing the overall aesthetics, the laboratory can create a more user-friendly and visually appealing environment.

One significant area for improvement identified in the survey is the level of privacy and quietness in the laboratory. The satisfaction rating for this aspect was the lowest, with 26% of respondents reporting some level of dissatisfaction. Privacy and a quiet working environment are essential for concentration and productivity. To address this concern, incorporating designated quiet areas or implementing acoustic treatments within the building can help minimize noise disturbances and provide spaces that support focused work.

The survey also revealed varying preferences regarding the open landscape design versus individual offices. While 60% of participants preferred the open landscape design for its collaborative and social benefits, the remaining 40% expressed a preference for individual offices, citing concentration and privacy advantages. This indicates the importance of considering a flexible design approach that accommodates both options. Providing a mix of open collaborative spaces and private work areas, along with meeting rooms for private conversations and work meetings, can cater to different work styles and tasks. This flexibility allows individuals to choose the environment that suits their needs, ultimately enhancing their satisfaction and productivity.

The survey results indicate that the majority of respondents (86.6%) were satisfied with the level of safety and security in the ZEB Laboratory building. This suggests that the current safety measures in place have generally been effective in providing a secure environment for the occupants. The satisfaction in this aspect reflects positively on the user experience, as individuals feel safe and protected within the facility. However, it is important to address the concerns of the 6.7% of respondents who expressed dissatisfaction or neutrality regarding safety and security. Additionally, 26.7% of respondents indicated that there are areas where safety and security could be improved.

These responses highlight the need for further attention to address the concerns of those who were not entirely satisfied. One common issue raised by respondents was the accessibility and design of the building. Some respondents suggested finding a balance between security measures and a less exaggerated approach. This feedback emphasizes the importance of implementing security measures that are effective while not causing inconvenience or hindrance to the occupants. Striking this balance is crucial to ensure that the security measures do not negatively impact the user experience. Respondents also mentioned concerns about the universal design of the building, particularly in the context of fire emergencies. Improving the universal design aspects can contribute to enhancing the safety and accessibility of the building for all occupants, including those with disabilities or mobility limitations. Addressing these concerns can help create an inclusive and safe environment for everyone. Specific suggestions were made to address certain issues raised by respondents. For example, improving the functionality of the gate to the open landscape area, implementing smarter sensor technology to control the duration in which the entrance door stays open, and enhancing access control measures to office spaces where valuable items are kept. These suggestions highlight the importance of continuously evaluating and updating the security infrastructure to address specific vulnerabilities or areas that require improvement.

Respondents also mentioned a safety hazard related to a slippery area near the back door of the NINA building side. Placing a doormat in that area can mitigate the risk and improve safety. This demonstrates the significance of promptly addressing identified safety hazards and taking appropriate measures to prevent accidents or injuries. To enhance the overall safety and security of the ZEB Laboratory, it is essential for the building management to carefully evaluate and implement measures that strike a balance between security, accessibility, and user convenience. Regular reviews and updates of safety protocols and infrastructure are important to maintain and improve the safety standards of the laboratory over time. By addressing the suggestions provided by respondents and addressing the mentioned areas for improvement, the ZEB Laboratory can ensure a safe and secure environment that contributes to a positive user experience. Prioritizing the well-being and security of the occupants fosters trust, productivity, and peace of mind within the facility.

Based on the survey results, there is a high level of satisfaction with the sustainability features of the ZEB Laboratory. The tangible aspects of the building, such as the use of renewable energy sources and efficient heating systems, have met the needs and expectations of the occupants, with 93% of respondents reporting satisfaction in this aspect. This indicates that the sustainable design elements and practices implemented in the building have contributed to a positive user experience. Furthermore, the survey results show that the sustainability image of the building was well-received, with 86% of respondents expressing satisfaction. The marketing efforts and communication regarding the building's sustainability message have been effective in conveying its green credentials. This positive perception of the building's sustainability branding contributes to the overall satisfaction of the occupants.

The ZEB Laboratory has also influenced sustainable living practices among the occupants. Many respondents acknowledged the building as a positive example of sustainable construction practices and technologies. The use of renewable technologies, carefully selected materials, and the availability of performance data have inspired occupants to adopt sustainable behaviors. Some respondents mentioned personal changes in behavior, such as reducing air travel or being more conscious of energy use, influenced by the building. This demonstrates the positive impact that the ZEB Laboratory has had on promoting sustainable living practices among its occupants. However, it is important to note that not all respondents felt a significant influence on their behavior, particularly if they were already highly focused on sustainability. This suggests that there may be opportunities to further educate and engage occupants in incorporating sustainable behaviors beyond the immediate environment of the ZEB Laboratory. By providing additional resources and information, the building management can encourage occupants to extend sustainable practices to other aspects of their lives and existing buildings.

In terms of comparison with traditional office buildings, survey respondents had mixed opinions. While a significant portion (53.3%) felt that working in a zero-emission building like the ZEB Laboratory was better than or slightly better than traditional office buildings, 46.7% of respondents felt that the experience was about the same. No respondents felt that working in a zero-emission building was worse than traditional office buildings. These results indicate an overall positive perception of working in a zero-emission building, highlighting the environmental and health benefits, energy savings, and thermal comfort that are appreciated by the occupants. The majority of participants (93.3%) expressed their willingness to recommend a zero-emission building like the ZEB Laboratory to others seeking a sustainable workplace. The reasons for this recommendation include the environmental and health benefits, energy savings, thermal comfort, and the inspiration to live more sustainably. However, there was some feedback regarding the outside appearance of the building, with concerns about its attractiveness and the visual impact of the black panels. Addressing these concerns can contribute to enhancing the overall user experience and satisfaction.

The survey results regarding productivity in the ZEB Laboratory indicate a generally positive user experience. The availability of necessary resources and technology for work received high satisfaction ratings, with 86% of respondents expressing satisfaction. This suggests that the laboratory provides the required tools and infrastructure to support productivity effectively. The impact of the environment in the ZEB Laboratory on productivity and work performance was also rated positively by 66% of respondents. This indicates that the design and functionality of the laboratory contribute to a conducive work environment that enhances work performance. The positive influence of the laboratory environment is further supported by the reported changes in work habits, where a third of the respondents experienced positive changes since moving to the ZEB Laboratory. These changes included feeling inspired by the technologies and facilities, improved satisfaction, better workspace organization, and increased success in selling projects when meetings are held in the laboratory. These responses highlight the positive impact the laboratory environment has had on work habits and overall job satisfaction.

The concept of working in a living laboratory was generally well-received, with 86.7% of respondents expressing positive sentiments. Being part of a living laboratory, where research and work take place simultaneously, was appreciated by the occupants, indicating that they perceive the living laboratory concept as valuable and beneficial to their work. While the concept of the living laboratory is recognized by most respondents, it does not appear to be the primary focus of their thoughts during work. However, disturbances in the living laboratory environment were reported by 40% of respondents. These disruptions included seminars or meetings in common spaces, noise from visitors, and occasional workshops during lunch hours. It is important for the management of the ZEB Laboratory to address these disturbances effectively to minimize their impact on work performance and maintain a conducive work environment.

Regarding learning and development opportunities, the survey results indicate a mixed response among the respondents. Only 50% of participants reported satisfaction with educational and training opportunities in the laboratory, suggesting that there is room for improvement in providing meaningful learning experiences within the ZEB Laboratory. While 53.3% of respondents indicated that they did not learn new skills or technologies as a result of working in the ZEB Laboratory, the remaining 46.7% reported acquiring new knowledge. The specific skills and technologies mentioned varied, ranging from photovoltaics (PV) and energy technology to building-integrated photovoltaics (BIPV), ventilation, indoor environment, stormwater management, and more. Some respondents learned through discussions with co-workers or by viewing the lobby screen, while others gained a comprehensive understanding of zero-emission building technologies or the complexity of technical operations.

Inspiration was reported by a majority of respondents (66.7%), indicating that the ZEB Laboratory building had inspired them with new ideas related to sustainability or other areas. The building sparked ideas related to research possibilities, stormwater management systems, performance requirements for BIPV, solar shading functionality, and more. It also generated new research possibilities and collaborative projects with previously uncooperative individuals. Based on these findings, it is evident that while learning and development opportunities in the ZEB Laboratory received mixed reviews, the building served as a source of inspiration for many respondents. To enhance the educational and training aspects, the ZEB Laboratory can expand the range of skills and technologies offered, provide more structured learning opportunities, and foster a collaborative environment. This will better meet the needs and expectations of the occupants and promote professional growth and personal development among the users of the ZEB Laboratory.

The survey results indicate a mixed response regarding occupants' satisfaction with the overall comfort in the building. While 47% of respondents expressed strong satisfaction with temperature and noise levels, 27% were somewhat satisfied, and 20% remained neutral. Additionally, 7% expressed dissatisfaction, highlighting the importance of addressing concerns related to temperature and noise levels. The majority of respondents (60%) reported being satisfied with air quality, with 27% expressing strong satisfaction. However, 7% were somewhat dissatisfied, indicating the existence of issues that may need attention. Ensuring consistent and high-quality air quality throughout the building is crucial for the health and comfort of the occupants.

Regarding facilities for rest and relaxation, 60% of respondents expressed satisfaction, while 20% remained neutral, and 13% expressed some level of dissatisfaction. This suggests that there is room for improvement to better meet the needs and preferences of occupants who expressed neutrality or dissatisfaction.

Conducting further research or engaging with the occupants to understand their specific expectations and preferences could provide insights for enhancing these spaces. The survey results indicate a generally positive reception to the building's approach to reducing stress and promoting well-being in the workplace. Almost half of the respondents (47%) reported being strongly satisfied, and an additional 47% were somewhat satisfied. This suggests that the building's initiatives and strategies for promoting well-being are appreciated by the occupants and have had a positive impact on their work experience. While there are areas of satisfaction related to well-being in the ZEB laboratory building, such as air quality and initiatives promoting well-being, improvements can be made in terms of temperature and noise levels, facilities for rest and relaxation, and catering to the specific preferences and needs of the occupants. Continual assessment, feedback collection, and targeted improvements are essential to ensure the building's environment optimally supports the well-being and productivity of its occupants.

The survey responses indicate that the level of community and interaction among occupants of the ZEB laboratory building is generally positive. A significant majority of respondents (66.7%) reported being satisfied or strongly satisfied with the level of community and interaction, reflecting a positive sense of belonging and engagement within the building. However, a small minority (10%) expressed dissatisfaction, suggesting that some individuals may feel disconnected or less engaged in the community aspect. Regarding the building's approach to promoting a sense of community and encouraging collaboration, the results were more mixed. While 57.1% of respondents reported being satisfied or strongly satisfied, a notable portion (28.6%) expressed neutrality, and 14.3% reported being dissatisfied or somewhat dissatisfied. This indicates that there is room for improvement in terms of fostering collaboration and strengthening the community atmosphere.

The majority of respondents (63.3%) reported being satisfied or strongly satisfied with the level of interaction and cooperation between occupants of different departments or organizations within the building. However, a significant minority (26.7%) expressed dissatisfaction or somewhat dissatisfaction, suggesting challenges or barriers to effective collaboration between different groups. Addressing these challenges and fostering a more inclusive and collaborative environment can lead to enhanced interactions and synergies among occupants. In terms of supporting and promoting diversity, equity, and inclusiveness within the community of occupants, the majority of respondents (60%) expressed satisfaction or strong satisfaction. However, there were still some respondents who expressed dissatisfaction (10%) or neutrality (10%), indicating the need for continued attention to ensure that all occupants feel included and valued within the community.

The sense of community and interaction in the ZEB laboratory building can be attributed to various factors mentioned in the survey responses. The mix of PhD candidates, NTNU and SINTEF employees was highlighted as a positive aspect that promotes interaction and collaboration, as it brings together individuals from different backgrounds and expertise. The availability of common areas such as the staircase and lunchroom as meeting points also contributes to the sense of community and provides opportunities for informal interactions. The open and flexible spaces, shared meeting rooms, and connected but separate open offices were mentioned as factors fostering collaboration and communication within the building. The joint ownership of the building by NTNU and SINTEF was identified as a facilitating factor for cooperation on data and control, emphasizing that shared ownership and goals can promote organizational collaboration. Events and activities organized within the building, along with the presence of collaborative spaces, were recognized as important aspects that foster interaction and collaboration among occupants. These findings highlight the importance of creating opportunities for socialization, knowledge sharing, and networking within the building to strengthen the sense of community and promote collaboration.

Based on the survey results, user engagement in the design, construction, and maintenance phases of the ZEB laboratory building showed varying levels of satisfaction among respondents. A relatively low percentage of respondents (26.7%) expressed satisfaction or strong satisfaction with their involvement in the design phase. This indicates that there might have been limitations or challenges in providing meaningful opportunities for user engagement during this phase. It is important to address this issue because involving users in the design process can lead to a higher level of satisfaction and a sense of ownership. Suggestions provided by respondents, such as workshops, co-creation sessions, and clearer definition of expected user input, highlight the importance of creating structured opportunities for user engagement during the early stages of building projects.

Communication and feedback during the design and construction phases received relatively low satisfaction ratings. Only 33.4% of respondents found this applicable, and among those, only 33.4% expressed satisfaction or strong satisfaction. The majority of respondents (53.3%) did not find this applicable showing they might not have been employed by NTNU or SINTEF at that time. Improving communication channels and providing regular updates to users throughout the different phases of the building project is crucial. Timely and transparent communication about progress, challenges, and opportunities for user input can enhance user engagement and satisfaction.

The data reveals that a low percentage of respondents found opportunities for providing input and making suggestions applicable (33.4%), and only 33.4% expressed satisfaction. A significant majority (53.3%) did not find this applicable. To improve user engagement, it is important to create more avenues for users to contribute their ideas and suggestions during the design and construction phases. Incorporating user input can lead to better functionality, productivity, and learning and development within the building.

Access to information about the design and construction phases received a higher satisfaction rating, with 60% of respondents finding it applicable and expressing satisfaction or strong satisfaction. This suggests that providing transparent and accessible information about the design and construction processes positively impacts users' perception of the building project. Enhancing information sharing can contribute to a higher level of occupant satisfaction and a sense of involvement.

Respondents showed a higher level of satisfaction (53.3%) when it came to transparency and open communication from the building management team about the ongoing operation and maintenance of the building. This indicates that occupants value clear and open communication regarding the upkeep of the building. However, opportunities for providing feedback and input into the operation and maintenance received mixed results, with 40% of respondents expressing satisfaction or strong satisfaction. There is room for improvement in incorporating user input into the ongoing operation and maintenance processes to ensure occupants' feedback is valued and acted upon.

The survey results highlight the need for improved user engagement and participation throughout the design, construction, and maintenance phases of building projects. Clear communication channels, meaningful involvement, and transparent information sharing are essential for enhancing user experience and fostering a sense of ownership. Future building projects can benefit from defining clear user roles and expectations, incorporating user feedback at every stage, and utilizing innovative tools to facilitate communication and understanding.

Despite the identified areas for improvement, respondents did not report any significant changes in their perceptions or experiences of the ZEB laboratory building during the two years of occupancy. This stability in user satisfaction suggests that the building has consistently met their expectations. However, respondents provided valuable suggestions for enhancing the overall experience as occupants, which can be considered for future improvements.

5.3.2 Walkthrough Results

The walkthrough results further supported the positive user satisfaction findings. The meeting rooms were generally found to meet occupants' requirements in terms of availability, size, comfort, lighting, temperature, and technology. However, concerns were raised regarding a meeting room without windows, which led to poor air quality after lunch. This feedback highlights the need for improvements in ventilation and air circulation to ensure a healthy environment in all meeting spaces. Additionally, suggestions were made to improve the utilization of the rooms and address specific issues, such as unused booked rooms, which can enhance efficiency and accessibility for occupants. This can be solved by adding a check in feature to the meeting room booking system, and leads to a more effiecient use of meeting rooms for all the occupants.

In terms of the living lab environment, occupants expressed overall satisfaction, appreciating the immediate response to equipment maintenance and feeling comfortable with the level of monitoring. The availability of data and the learning opportunities provided by the technology within the building were also positively acknowledged. These findings indicate that the ZEB laboratory building successfully functions as a living lab, supporting research and innovation activities effectively.

Regarding the ZEB Laboratory app, occupants found it valuable for controlling various building settings. However, concerns were raised about app malfunctions and the lack of clarity in reporting issues regarding the app itself. This feedback highlights the importance of addressing technical issues promptly and improving communication channels for issue reporting to the app developers. Suggestions included incorporating a dedicated "report issue" button and providing more detailed contact information within the app, which can enhance user experience and facilitate problem resolution.

Discussions with occupants regarding solar shading and movement sensors revealed valuable insights into their experiences and perspectives. While occupants appreciated the benefits of solar shading for controlling lighting conditions, concerns were raised about the aggressive behavior of the shadings, frequent manual overrides, and the need for adjustments in specific areas. Regarding movement sensors, their effectiveness was acknowledged, but occasional temporary light turn-offs were mentioned. Suggestions for improvement included reducing sensitivity, enhancing manual control options, and introducing app features for greater customization when overriding them manually. These findings can guide future enhancements to the building's solar shading and movement sensor systems, aiming to enhance user experience, improve energy efficiency, and strike a balance between natural and artificial lighting in the workspace.

Discussions with occupants regarding open offices revealed that they generally appreciated the collaborative environment and the opportunity for interaction. Noise levels, privacy, lighting, temperature, and air quality were discussed, with occupants sharing their strategies to address concerns. The absence of specific requests for additional features suggests that the open offices meet the occupants' current needs. However, a mix of open landscape offices and individual private offices would give the opportunity to the users to choose the best option for them.

Based on the discussions, the shared waiting areas by the staircase were found to be useful and versatile spaces for informal meetings, gatherings, and social interactions. Occupants did not report any significant concerns related to comfort, functionality, or acoustics in these areas. The availability of solar shadings for controlling lighting conditions was appreciated. Additionally, the presence of a kitchen in the fourth-floor shared waiting area was acknowledged as a valuable feature. Occupants did not express a need for additional amenities in these spaces, indicating that the current design and functionality of the shared waiting areas meet their requirements and contribute to a satisfactory user experience.

Regarding the staircase, occupants generally regarded it positively and preferred using it over the elevator. While the presence of sharp corners was mentioned as a minor concern, it did not significantly impact the overall experience. Lighting, noise, and echoes were not major issues. Suggestions for improvement included the addition of artwork and potential safety enhancements. However, these suggestions were not deemed critical, as the current design and functionality of the staircase were already satisfactory.

The quit boxes were frequently used by occupants for various purposes, including meetings and phone calls. Suggestions for improvement included larger desks, the ability to connect computers to larger screens, and better chairs. Concerns were raised regarding insufficient lighting inside the phone boxes, as well as limited soundproofing, which could impact privacy and confidentiality. Overall, occupants were generally satisfied with the ventilation, air quality, and lack of distractions from nearby areas. These insights can help guide future enhancements to the quit boxes to better meet the occupants' needs and improve their overall experience.

The lunchroom was generally considered well-designed and functional. However, suggestions were made to improve the arrangement of the sink, paper dispenser, and waste bins for increased convenience during hand-washing and cleaning up. Concerns were raised about the aggressiveness of the solar shading when closed, but the availability of natural light when the shadings were up was appreciated. The temperature and air quality were generally satisfactory, with minor adjustments suggested for better control. These insights can help guide future improvements to the lunchroom and enhance the overall experience for occupants.

Overall, the survey and walkthrough results provide a comprehensive understanding of the use value and user satisfaction of the ZEB laboratory building. While there are areas for improvement, the majority of respondents expressed satisfaction with the building as a workplace. The feedback and suggestions from occupants highlight the importance of addressing specific issues, such as air quality, ventilation, and technical functionality, to enhance user experience and optimize the building's performance.

The suggestions provided by the occupants, such as providing a mix of individual and open office spaces, sending reminders for meeting room bookings, improving solar shading and natural lighting, and promoting more opportunities for collaboration and knowledge sharing, can guide future enhancements and updates to the building's design, functionality, and amenities. By considering and implementing these suggestions, the ZEB laboratory building can continue to serve as a valuable zero-emission office building and a living lab within the NTNU campus. The insights gathered from user experiences and perspectives can inform the campus development team's decision-making process for future building projects, ensuring that user satisfaction and use value remain key considerations in creating an optimal work environment.

5.4 Lessons from Case Studies

In this section, we delve into the lessons learned from a series of case studies, focusing on the experiences and insights shared by the informants involved in these projects. The approach used in this section is storytelling, aiming to convey the knowledge and wisdom gained by the informants through their direct involvement in the projects. It is important to note that the lessons presented here are subjective, based on the informants' opinions, experiences, and conclusions. While these case studies provide valuable insights, it is essential to recognize that each project is unique, and generalizing the results across all projects may not be appropriate.

During the interviews with the informants, an open question was posed regarding the lessons learned from their involvement in the case studies and how they intend to apply those lessons to their future projects. This question served as a catalyst for the informants to reflect on their experiences and articulate the valuable insights they gained throughout the projects. Their responses provide a glimpse into their aspirations, strategies, and the knowledge they wish to carry forward into their upcoming endeavors.

The informants, representing various roles such as architect, contractor, advisor and clients, openly share their reflections on the projects they were part of, discussing the challenges they faced, the strategies they employed, and the lessons they learned along the way. Their experiences, rooted in real-world scenarios, shed light on the complexities and intricacies of the projects, providing valuable insights into what worked well and what could have been improved.

It is important to acknowledge that the conclusions drawn from these case studies cannot be broadly applied to all projects. Each project is a unique combination of circumstances, stakeholders, and objectives. Nonetheless, the informants' experiences and perspectives provide a valuable resource for industry professionals seeking to gain insights, explore new approaches, and adapt lessons learned to their specific projects.

In the following sections, we will delve into the case studies, examining the lessons learned from informants representing different project perspectives. Through their perspectiv es, we aim to provide a rich tapestry of knowledge, experiences, and reflections that can inform and inspire future projects.

5.4.1 ZEB Laboratory

ZEB Laboratory, with its innovative methods and collaborative project delivery model, serves as a valuable source of learning and inspiration. The project stands out for its pioneering approach, bringing together stakeholders from the early stages to jointly develop the building. This unique experience was unfamiliar to all parties involved, offering a fertile ground for knowledge exchange and experimentation. Notably, the sustainability solutions implemented in the laboratory's construction set a new standard in the industry, making it an exemplary case for learning purposes.

Within the context of ZEB Laboratory, three informants actively participated in this research, generously sharing their experiences and insights gained from their involvement in the project. It is important to note that their lessons learned are based on their respective roles in the project and reflect their subjective opinions and perspectives. Nevertheless, these individual perspectives contribute to the collective pool of knowledge, further enriching the industry's understanding and providing valuable insights for future projects.

In the following sections, we will delve into the lessons learned from ZEB Laboratory, drawing from the valuable experiences and insights shared by the informants, representative of the client, architect and contractor, involved in the project.

5.4.1.1 Lessons learned from the client's perspective:

In this section, we gain valuable insights from the client representative who played a pivotal role in the Zeb Laboratory project. As the representative of both SINTEF and NTNU, their responsibility extended beyond conventional client duties. They actively participated in the collaborative process, ensuring the involvement of researchers and end-users throughout the project. This unique position granted them a deep understanding of the project's intricacies and made their insights invaluable.

Importance of early involvement of stakeholders: According to Informant 1N, one of the most important lessons learned from the project was the significance of involving stakeholders early on. They emphasized the need to organize and set the stage for the project before engaging contractors. This involved clear communication of the process, objectives, and expectations to the organization and stakeholders. Byminvolving stakeholders from the beginning, they believe that projects can be better aligned with the needs and expectations of the end-users. This approach ensures that the project starts on the right track and avoids potential conflicts or issues down the line. However, they also acknowledged that this approach may not be suitable for every client and project, as it demands a higher level of engagement and follow-up compared to traditional projects.

Importance of Pre-project organization and planning phase: Informant 1N expressed the belief that the lessons learned from the Zeb Laboratory project should be applied by emphasizing the pre-project organization and planning phase in future projects. They highlighted the importance of expertise in project management and technical aspects, as well as the need for active involvement and support from the organization. By investing time and effort in thorough planning and organization, they believe that projects can be executed more efficiently and effectively.

Informant 1N believes that the lessons learned from their project, particularly in building trust between the organization and the people involved, would be valuable for future projects. While they recognize that each project may have its own unique characteristics and requirements, they emphasize that the underlying principles of collaboration and early involvement of stakeholders remain crucial. By applying the lessons learned from the Zeb Laboratory project, they believe that future campus development projects can benefit from improved collaboration, stakeholder involvement, and overall project outcomes.

5.4.1.2 Lessons learned from the architects's perspective:

In the section, we gain valuable insights from the architect representative involved in the Zeb Laboratory project. This discussion encompasses not only the lessons they have learned throughout the project but also their reflections on what they would have done differently given the opportunity. By delving into their experiences and perspectives, we can uncover a wealth of knowledge regarding the challenges faced, the importance of collaboration, the impact of budget constraints, and the desire for greater creative freedom.

Design Possibilities with a Larger Budget: Informant 2A mentioned that if there were no budget constraints, the design of ZEB laboratory could have included more space and additional features that would benefit the users. They expressed the potential for a larger structure with features like a large atrium, which could have had a greater impact and provided additional benefits beyond the primary function of the building.

Challenges and Opportunities in Collaborative Process: Informant 2A discussed the challenges in maintaining architectural quality and integrity during the collaborative process. They mentioned the influence of multiple stakeholders and restrictions on the final result. The architect felt that having too many decision-makers could hinder their ability to express creativity and achieve a clear architectural concept. They desired more input and space to do their job effectively.

Knowledge of Sustainability and Communication Skills: Informant 2A highlighted the acquired knowledge of sustainability, particularly working with materials like massive wood and brick construction. They also mentioned the development of communication and collaboration skills through this project. The architect intends to apply their sustainability knowledge and enhance their communication and collaboration skills in future projects.

The architect acknowledged valuable lessons learned from the project for their future endeavors. They recognized the importance of finding a balance between working independently and collaborating with stakeholders. Effective collaboration and active expression of thoughts and ideas were emphasized. They also mentioned the need for a different organization of the initial project phase, allowing more time for independent thinking and sketching before engaging in large group meetings.

5.4.1.3 Lessons learned from the contractor's perspective:

This section focuses on the lessons learned from the ZEB Laboratory project, as shared by Informant 3C, a representative of the contractor involved in the project. These lessons highlight the importance of early involvement, collaboration, trust-building, and a sustainable mindset in maximizing project potential and achieving shared goals.

Importance of Early contractor Involvement and Collaboration: Informant 3C highlighted the significance of early involvement and collaboration in maximizing the project's potential. They emphasized that this approach, although not typically common in other projects, played a crucial role in the success of the Zeb Laboratory project. Informant 3C emphasized the need for a contract and project structure that enables everyone involved to work towards the same sustainability goals, fostering alignment and shared purpose to overcome obstacles. Building and maintaining trust throughout the collaborative process was identified as a critical but challenging aspect. It required open communication, honesty, and a genuine willingness to work in the best interests of the project. Informant 3C acknowledged that discussions and compromises were inevitable but stressed the importance of ensuring that all parties benefited from the project's success. They recognized that trust was a key factor and that being clever or playing games had no place in a project of this nature. Informant 3C expressed how the Zeb Laboratory project necessitated a different mindset compared to traditional contracts. Rather than solely focusing on personal gain, they realized the importance of considering the best interests of all stakeholders involved. This shift in mindset required the right kind of people who were willing to work collaboratively and prioritize the success of the entire project.

Different Mindset for Sustainable Projects: Through the sustainable features and goals achieved in the building project, Informant 3C learned that many sustainability solutions are not complex or groundbreaking. Instead, they are often based on basic principles and common-sense thinking. The key lies in having a strong focus on sustainability and maintaining that commitment throughout the project, even in the face of challenges.

Collective Focus and Mindset: Informant 3C's key takeaway from the Zeb Laboratory project was the realization that the focus and mindset of the project team are more important than relying solely on individual geniuses or experts. They recognized that success lies in the collective desire to work towards a common direction and goal. This perspective extends beyond sustainability and applies to other main project objectives as well. Informant 3C intends to bring this understanding of the importance of focus and shared goals to future projects. They acknowledge that maintaining a consistent focus on sustainability or any other key objective requires ongoing effort and dedication from the project team. By emphasizing this collective focus and working together towards a common purpose, significant achievements can be made in sustainability and other project goals.

Implementing Successful Elements in Mainstream Projects: Informant 3C expressed a desire to see the successful elements of the Zeb Laboratory project implemented in more mainstream projects. They believe that while the current project may be viewed as unique and specialized, similar sustainability-focused approaches and collaborative based project delivery models could be applied to commercial office buildings, kindergartens, or other mainstream projects. Informant 3C sees this as an opportunity to push the boundaries of sustainability and procurement management further and demonstrate its potential in different contexts. Additionally, they highlighted the importance of the contract structure used in the Zeb Laboratory project. Informant 3C wishes to see more projects adopting a similar collaborative project delivery model with early contractor involvement, as it proved successful in this case. They find it surprising that the client is not implementing this model in their other projects despite the positive outcomes observed. Informant 3C believes that embracing such a contract structure could lead to even better projects in the future.

Barriers and Resistance to Change: Informant 3C recognized the barriers and resistance to change that exist in the construction industry regarding collaborative project delivery models. They pointed out a lack of knowledge and familiarity with such approaches. They mentioned that since only a small part of client organization was involved in this successful project, there may be limited awareness of the benefits and potential of such contracts. Informant 3C explained that many people in the construction business are more accustomed to traditional contract models, and there may be a perception of risk associated with venturing into something new. They emphasized that the collaborative and trust-based contract model, which reduces risks for both the client and the contractor, needs to be better understood and embraced. They highlighted the need to increase knowledge and awareness about the benefits of early contractor involvement and collaborative contract models, paving the way for their wider adoption in future projects.

Building Trust: Informant 3C provided insights into the process of building trust as a contractor. They emphasized the importance of adopting an open book approach, where contractors transparently share their costs and financial information with the client. This transparency helps establish trust and demonstrates a commitment to working collaboratively. Additionally, they stressed the significance of personal interactions and investing time in getting to know the client on a human level. Informant 3C also emphasized the importance of being willing to give and take, being flexible and accommodating in finding mutually beneficial solutions throughout the project. This collaborative mindset fosters trust and creates a positive working relationship.

Informant 3C expressed their intention to apply the lessons learned from the Zeb Laboratory project to future projects. They recognized the value of early involvement, trust-building, open communication, and a collaborative mindset in fostering successful project outcomes. Informant 3C emphasized that these principles would likely be incorporated into their future projects to achieve similar positive results. They understood that maintaining a consistent focus on these aspects, such as early involvement and trust-building, required ongoing effort and dedication from the project team.

5.4.2 Energy Academy Europe

Energy Academy Europe, renowned as the first building in the Netherlands to achieve the prestigious BREEAM Outstanding certification, serves as an exceptional source of learning and inspiration. This innovative establishment showcases cutting-edge technical sustainable solutions and holds the distinction of being the first building to implement unique solar panel designs. Moreover, the procurement process for this remarkable building followed a traditional contract structure, where contractors competed based on price and quality. To ensure user involvement and drive the project's concept and sustainability goals, an advisory company specializing in educational buildings played a crucial role. The sustainability solutions implemented in Energy Academy Europe are trailblazing within the construction sector, making it an exemplary case study for future learning.

This research engaged four informants, including two from the client's perspective and two from the advisory company, to share their experiences and insights derived from their involvement in the Energy Academy Europe project. It is important to note that the lessons learned are deeply influenced by the roles each individual played in the project, resulting in subjective opinions and unique viewpoints. However, these diverse perspectives offer a wealth of knowledge and understanding that continues to benefit the industry, guiding future projects towards greater sustainability and innovation.

In the following sections, we will delve into the lessons learned from Energy Academy Europe, drawing from the valuable experiences and insights shared by the informants involved in the project. By exploring their stories and reflections, we aim to provide a deeper understanding of the innovative sustainable solutions, collaborative procurement approaches, and user involvement strategies employed in the construction of this exceptional building. These lessons learned stand as valuable resources for professionals, fostering innovation, inspiring sustainable design practices, and driving the industry towards a greener and more prosperous future.

5.4.2.1 Lessons learned from the client's perspective:

This section provides a comprehensive overview of the lessons learned from the project, as shared by Informants 6G and 7G, who represented the client in the Energy Academy Europe project.

Importance of Choosing Sustainable Materials: Informant 6G emphasized the significance of selecting the right materials, such as concrete and wood, while avoiding plastic or aluminum. The choice of materials had a profound impact on sustainability and environmental factors, promoting responsible resource utilization and minimizing the project's carbon footprint.

Energy Consumption Reduction: One of the key lessons learned was the constant need to question and minimize energy needs in building design. Informant 7G highlighted the importance of utilizing natural elements effectively, such as orientation, solar heating, geothermal energy, and optimizing air circulation. These considerations played a vital role in reducing energy consumption and enhancing the building's overall energy efficiency.

Thoughtful Functional Layout: Informant 6G emphasized the significance of the functional layout within the building. For instance, locating laboratories on the north side of the building reduced the need for excessive cooling due to sun exposure. This lesson underscores the importance of thoughtful placement of different functions to optimize energy usage and create an efficient working environment.

The Importance of Total Cost of Ownership: Informant 6G highlighted the concept of total cost of ownership as a crucial lesson learned from the project. By calculating the overall costs of an investment over the building's lifespan (typically around 40 to 50 years), it was recognized that investing more upfront could lead to lower costs over time. This approach took into account long-term financial implications, aligning with the idea of assessing costs throughout the building's entire lifespan.

Goal-Oriented Engineering for Minimal Energy Consumption: Informant 6G emphasized the importance of setting a goal for the engineering team to create a building with minimal energy consumption. This objective guided the engineers in calculating and proposing solutions that aligned with the goal of energy efficiency. Choices were made based on selecting options with the lowest energy consumption for the building, ensuring a sustainable and eco-friendly design.

BREEAM Certification Considerations: Both informants discussed the integration of BREEAM certification, albeit with some adaptations for their future projects. Informant 6G explained that, due to the projects' large size and associated costs, seeking full BREEAM certification was not pursued. However, elements of BREEAM were still incorporated into the project, considering sustainability, health, and energy efficiency aspects.

Importance of Communication and Stakeholder Engagement: Informant 6G emphasized the significance of effective communication and stakeholder engagement throughout the project. Internal and external communication, including publications and discussions on the building's energy efficiency and construction, were crucial. Sharing information with various stakeholders helped educate them about the building's energy consumption and operational processes, fostering a culture of sustainability and environmental awareness.

Accessibility Considerations: Informant 7G highlighted the importance of accessibility in building design. They acknowledged that the Energy Academy building's design, with different floor heights, may not be optimal for individuals using wheelchairs or with impairments. This lesson identified the need for improvement in accessibility considerations in future projects, ensuring inclusivity and equal access for all.

The lessons learned from the Energy Academy Europe project offer valuable insights for future projects in terms of material selection, energy consumption reduction, functional layout optimization, cost considerations, BREEAM certification integration, communication, and accessibility. By applying these lessons, future projects can strive towards sustainable and energy-efficient designs, minimize environmental impact, and promote inclusivity.

5.4.2.2 Lessons learned from the advisors's perspective:

This section focuses on the lessons learned from the Energy Academy Europe project, as shared by Informants 4A and 5A, who represented the advisors in the project.

Broadening the Sustainability Perspective: Informant 4A and Informant 5A emphasized the need to broaden the sustainability perspective beyond energy efficiency. While the Energy Academy project primarily focused on energy efficiency, Informant 4A suggested considering aspects such as circularity and building materials. They raised questions about whether minor considerations had been made in these areas. Informant 5A supported this viewpoint, advocating for the inclusion of circularity, biodiversity, health, and water management in future sustainability efforts.

Prioritizing Building Physics: Informant 5A stressed the vital role of building physics in various projects. They highlighted the common oversight by architects regarding the importance of building physics, assuming they can handle it themselves. However, building physics significantly influences the overall building experience, including temperature regulation, air quality, daylighting, and user comfort. Informant 5A recommended prioritizing building physics from the beginning of a project to ensure a high level of user satisfaction and eliminate potential complaints related to the indoor environment.

Low-Tech Solutions and Building Physics: Informant 5A emphasized the effectiveness of low-tech solutions combined with proper insulation and building physics. They recommended starting with building physics and then addressing the remaining challenges using installation techniques. Low-tech solutions were seen as making buildings more robust, requiring less maintenance, and having longer lifespans compared to installation-intensive approaches. This approach can contribute to sustainable and durable building designs.

Integrating Building Physics in Architectural Choices: Informant 4A highlighted the influence of building physics on architectural choices. They referred to a school building in the Netherlands built like pyramids, which faced issues of overheating and rainwater leakage due to inadequate consideration of building physics. This example underscored the importance of integrating building physics early in the design process to ensure efficient and functional architectural designs.

Teamwork and Collaboration: Informant 5A emphasized the significance of teamwork and collaboration in achieving successful project outcomes. They attributed the success of the Energy Academy project to a collective team effort that exceeded initial expectations. They recommended prioritizing teamwork and fostering a collaborative environment from the project's inception. Investing in team dynamics and collaboration can significantly enhance the project's value and final results.

The lessons learned from the Energy Academy Europe project, as shared by

Informants 4A and 5A, highlight the importance of broadening the sustainability perspective, prioritizing building physics, adopting low-tech solutions, and fostering teamwork and collaboration. By considering these lessons in future projects, it is possible to create sustainable buildings that not only prioritize energy efficiency but also encompass circularity, biodiversity, health, and water management. Furthermore, integrating building physics early in the design process ensures optimal functionality and user satisfaction, while teamwork and collaboration contribute to successful project outcomes. These lessons serve as valuable insights for the construction industry, promoting sustainable practices and holistic approaches in building design and construction.

CHAPTER

SIX

CONCLUSIONS

The main objectives of this study were to investigate the key activities in the early phases of building projects that contribute to their successful realization in terms of value for users and building performance during the occupancy phase. Additionally, the study aimed to conduct a post-occupancy evaluation of the ZEB Laboratory, assessing user satisfaction with the building's performance and overall use value. The research also aimed to derive lessons and recommendations from the case studies to improve early phase activities and enhance outcomes, while contributing to the existing knowledge about the connection between early phase activities and results in the occupancy and use phase of buildings.

To achieve these objectives, the research questions guiding the investigation were carefully formulated. These research questions served as a compass throughout this thesis, guiding the exploration and analysis of the data. In the following section, the answers to these research questions will be summarized, shedding light on the key findings and insights obtained from the study. By addressing these research questions, this thesis aims to contribute to the understanding of the topic and provide valuable recommendations for future building projects.

6.1 Summary of Findings

6.1.1 Research Question 1:

"What are the key activities/factors in early phases that contribute to the successful realization of building projects, specifically in terms of value for users and building performance in the occupancy phase?"

The research aimed to identify key activities/factors in the early phases of building projects that contribute to their successful realization, specifically focusing on value for users and building performance during the occupancy phase. The following ten activities/factors were identified:

- Defining Clear Goals and Objectives: Defining clear goals and objectives in the early phases of building projects is crucial for achieving optimal use value. The case studies of the ZEB Laboratory and the Energy Academy Europe project highlight the positive impact of clear ambitions and expectations. By setting specific goals, these projects were able to align decision-making processes, optimize design choices, and enhance user satisfaction. The research findings align with previous studies that emphasize the importance of early goal-setting in the construction industry. By defining clear objectives, projects can effectively address challenges, incorporate sustainability considerations, and improve overall project outcomes. These findings contribute to the construction industry by emphasizing the significance of early goal-setting in guiding successful project realization and enhancing the overall use value of the built environment.

- Users Involvement: User involvement in the early stages of building projects is crucial for ensuring enhanced user experiences. In projects like the ZEB Laboratory and Energy Academy Europe, students, researchers, and clients actively participated in the design process, contributing valuable insights and innovative ideas. The involvement of users facilitated the identification of challenges, successes, and best practices, which could be shared to benefit future projects and advance sustainable building practices. Regular evaluations, feedback sessions, and leadership structures were established to manage user involvement effectively. Challenges included uncertainties regarding specific occupants and balancing input from multiple stakeholders. Despite these challenges, user involvement led to optimized energy usage, visually appealing designs, and user satisfaction. Overall, involving users in the early phases of building projects contributes to better outcomes and user experiences.

- Effective Communication Methods: Effective communication methods are crucial for maintaining user satisfaction and optimal building performance. The direct reporting system, as demonstrated in the ZEB laboratory project, facilitates transparent and accountable communication between building management and users, allowing for timely feedback and issue resolution. Regular updates and newsletters, as seen in the Energy Academy Europe project, keep stakeholders informed and engaged, minimizing misunderstandings and managing conflicts. Considering the building's concept and goals when making decisions helps stakeholders understand the rationale behind design choices. These case studies highlight the importance of effective communication in fostering user-centered practices, resolving conflicts, and aligning stakeholders with the project's vision.

- Collaborative Project Delivery Model: Collaborative project delivery models involving key stakeholders such as contractors, architects, consultants, researchers, and building operators facilitate effective communication, information exchange, and decision-making throughout the project. This approach ensures clear definition and understanding of project goals, leading to a holistic and integrated design process. Involving researchers and building operators in the early phase integrates their expertise, improving functionality and building performance. Regular meetings, workshops, and clear communication channels foster collaboration, while tools like BIM enable real-time coordination. Early engagement of contractors enhances design feasibility, cost evaluation, and reduces the need for redesigns. Trust-based contracts align stakeholders towards shared sustainability goals. Overall, collaborative project delivery models optimize building performance and enhance user satisfaction through inclusive decision-making and a focus on common objectives.

- Building Trust: The role of trust in construction projects is crucial for managing diverse stakeholders and achieving effective collaboration and decision-making. Trust fosters open communication, mutual understanding, and transparent discussions among contractors, clients, designers, and users. It creates an environment where stakeholders feel comfortable expressing their opinions and engaging in problem-solving activities, leading to innovation and shared responsibility. Building trust requires continuous effort, open communication, honesty, and a collaborative mindset that prioritizes the project's success. Transparency, personal interactions, and finding mutually beneficial solutions are essential in establishing and maintaining trust. Prior research confirms the significance of trust in collaborative construction projects, highlighting its role in deepening relationships and improving project outcomes. Trust-building efforts contribute to cooperative relationships, better collaboration, and the successful execution of construction projects, ultimately delivering value to end-users.

- Utilization of Low-Tech Methods: The utilization of low-tech methods alongside high-tech solutions in building projects offers numerous benefits, including increased user satisfaction, improved building performance, and enhanced sustainability. Incorporating low-tech technologies such as natural ventilation, daylighting, and passive heating and cooling strategies creates a comfortable indoor environment, while also promoting accessibility and ease of use. These solutions require minimal maintenance, contribute to long-term cost savings, and reduce the building's reliance on external resources. By prioritizing sustainability and making informed decisions throughout the project lifecycle, low-tech methods can effectively address sustainability goals while maintaining a focus on user satisfaction and building resilience. The integration of low-tech solutions with high-tech systems creates a balanced approach that optimizes resource utilization, minimizes environmental impacts, and fosters harmonious spaces that prioritize human-centered design principles.

- Visualization: The utilization of visualization techniques in building projects offers numerous benefits throughout the project lifecycle. By relying on 3D models from the early stages, project teams can effectively evaluate and assess the design, enabling better decision-making and collaboration. The immersive and realistic visual representation provided by 3D models allows stakeholders to review and analyze the design from various perspectives, promoting effective communication and enhancing user satisfaction. Furthermore, 3D modeling facilitates a deeper understanding of the design's implications for user satisfaction and building performance, enabling early identification of potential issues and optimization of energy efficiency. The use of visualization tools, such as VR technologies, further enhances communication and decision-making among stakeholders. Overall, these findings validate the significance of incorporating visualization methods in building projects, improving project outcomes and user experiences.

- Involving Experts in Building Physics: The involvement of building physics experts in the early stages of construction projects is crucial for maximizing value for users. Their expertise contributes to optimizing energy usage, integrating sustainable design principles, and enhancing occupant comfort. By considering functional layout and energy optimization strategies, such as placing spaces with higher cooling requirements away from direct sun exposure, the project team can minimize energy consumption and improve sustainability. Prioritizing building physics over architectural considerations ensures a well-regulated indoor environment and eliminates potential issues. This approach, supported by previous research, recognizes the significance of building physics in understanding the impact of buildings on health, well-being, carbon emissions, energy efficiency, and environmental quality. Integrating technological advancements with social, economic, cultural, and policy developments is key to creating sustainable and high-performing built environments.

- Flexibility in Design: Flexibility in design is essential for ensuring user satisfaction and productivity within the Energy Academy building. The involvement of end users in determining their preferred working spaces and providing input on furniture design and layout creates a personalized and comfortable environment. Attention to micro-level considerations, such as acoustics and surroundings arrangement, further enhances the supportive atmosphere. Flexibility also encourages efficient and sustainable building usage by promoting sustainable practices and accommodating changing needs over time. Previous research supports the importance of flexibility in improving users' sense of control and well-being. Incorporating flexibility in design maximizes user satisfaction and contributes to the long-term adaptability of buildings.

- Team Building: Team building in construction projects is crucial for achieving successful outcomes and delivering value to stakeholders. Creating a safe and creative environment within project teams fosters collaboration, enhances creativity, and promotes innovation. Regular evaluation and self-assessment enable the team to identify areas for improvement and optimize performance. Procuring top engineers with creative thinking ensures competence and problem-solving abilities. Team-building activities, such as excursions and social interactions, build strong relationships, facilitate discussions, and enhance the overall quality of the project. Establishing early stakeholder connections and a collaborative work environment fosters teamwork and productivity. By implementing effective team building strategies, construction companies can leverage diverse expertise, stimulate innovation, and achieve project success.

These findings highlight the significance of these ten activities/ factors in delivering value for users and optimizing building performance in the occupancy phase. By implementing these activities, building projects can better meet user needs, enhance user satisfaction, and achieve successful project outcomes.

6.1.2 Research Question 2:

"To what extent do the results of the post-occupancy evaluation of the ZEB Laboratory indicate user satisfaction with the building's performance and overall use value in ZEB laboratory?"

The results of the post-occupancy evaluation of the ZEB Laboratory indicate a generally high level of user satisfaction with the building's performance and overall use value. The evaluation consisted of survey, and walkthrough, including discussions with occupants to gather their feedback and perspectives.

In terms of user satisfaction, the survey findings revealed that a majority of respondents expressed satisfaction with the building as a workplace. The occupants appreciated the availability, size, comfort, lighting, temperature, and technology of the meeting rooms. However, concerns were raised regarding a meeting room without windows, which led to poor air quality after lunch. This highlighted the need for improvements in ventilation and air circulation to ensure a healthy environment in all meeting spaces. Suggestions were also made to improve the utilization of the rooms, such as adding a check-in feature to the meeting room booking system, to enhance efficiency and accessibility for occupants.

The living lab environment of the ZEB Laboratory was positively received by the occupants. They expressed overall satisfaction with the immediate response to equipment maintenance and felt comfortable with the level of monitoring. The availability of data and the learning opportunities provided by the technology within the building were also acknowledged. This indicates that the ZEB Laboratory building effectively functions as a living lab, supporting research and innovation activities.

The ZEB Laboratory app was found valuable by the occupants for controlling various building settings. However, concerns were raised about app malfunctions and the lack of clarity in reporting issues regarding the app itself. Suggestions included incorporating a dedicated "report issue" button and providing more detailed contact information within the app, which can enhance user experience and facilitate problem resolution.

Insights from discussions regarding solar shading and movement sensors revealed that while occupants appreciated the benefits of solar shading for controlling lighting conditions, concerns were raised about aggressive shading behavior, frequent manual overrides, and the need for adjustments in specific areas. The movement sensors were acknowledged as effective but occasional temporary light turn-offs were mentioned. Suggestions for improvement included reducing sensitivity, enhancing manual control options, and introducing app features for greater customization. These findings aim to enhance user experience, improve energy efficiency, and strike a balance between natural and artificial lighting in the workspace.

Occupants generally appreciated the collaborative environment and the opportunity for interaction in the open offices. Noise levels, privacy, lighting, temperature, and air quality were discussed, with occupants sharing their strategies to address concerns. Suggestions were not provided for additional features, indicating that the open offices meet the occupants' current needs. However, a mix of open landscape offices and individual private offices was suggested to provide users with more options.

The shared waiting areas by the staircase were found to be useful and versatile spaces without significant concerns related to comfort, functionality, or acoustics. The availability of solar shading for controlling lighting conditions was appreciated, and the presence of a kitchen in the fourth-floor shared waiting area was acknowledged as valuable. No additional amenities were requested for these spaces, indicating that the current design and functionality meet the occupants' requirements.

Occupants generally regarded the staircase positively and preferred using it over the elevator. Minor concerns were mentioned regarding the presence of sharp corners, but they did not significantly impact the overall experience. Lighting, noise, and echoes were not major issues, and suggestions for improvement included the addition of artwork and potential safety enhancements. However, these suggestions were not deemed critical, as the current design and functionality of the staircase were already satisfactory.

The quit boxes were frequently used by occupants for various purposes, and suggestions for improvement included larger desks, the ability to connect computers to larger screens, and better chairs. Concerns were raised regarding insufficient lighting inside the phone boxes and limited soundproofing, impacting privacy and confidentiality. Overall, occupants were generally satisfied with the ventilation, air quality, and lack of distractions in the quit boxes.

The lunchroom was considered well-designed and functional, with suggestions made to improve the arrangement of certain elements for increased convenience during hand-washing and cleaning up. Concerns were raised about the aggressiveness of the solar shading when closed, but the availability of natural light when the shadings were up was appreciated. The temperature and air quality in the lunchroom were generally satisfactory, with minor adjustments suggested for better control.

Overall, the survey and walkthrough results indicate a positive user satisfaction with the ZEB Laboratory building's performance and overall use value. While there are areas for improvement, such as addressing specific issues related to air quality, ventilation, and technical functionality, the majority of respondents expressed satisfaction with the building as a workplace.

The feedback and suggestions provided by the occupants offer valuable insights for future enhancements and updates to the building's design, functionality, and amenities. Suggestions include providing a mix of individual and open office spaces, sending reminders for meeting room bookings, improving solar shading and natural lighting, and promoting more opportunities for collaboration and knowledge sharing.

By considering and implementing these suggestions, the ZEB Laboratory building can continue to serve as a valuable zero-emission office building and a living lab within the NTNU campus. The insights gathered from user experiences and perspectives can inform the campus development team's decision-making process for future building projects, ensuring that user satisfaction and use value remain key considerations in creating an optimal work and research environment.

6.1.3 Research Question 3:

"What lessons can be learned from the case studies, focusing on the experi- ences and insights shared by the informants involved in these projects?"

6.1.3.1 ZEB Laboratory

The case study of ZEB Laboratory provides valuable insights and lessons for future projects, as shared by the informants involved in the project.

From the client's perspective, early involvement of stakeholders emerged as a crucial lesson. By engaging stakeholders from the beginning and ensuring clear communication of objectives and expectations, projects can be better aligned with end-users' needs. The importance of thorough pre-project organization and planning was also emphasized, along with building trust between the organization and project participants.

The architect highlighted the significance of balancing budget constraints with design possibilities. With a larger budget, the ZEB Laboratory could have included additional features and spaces that would benefit the users. The challenges faced in maintaining architectural quality during the collaborative process were recognized, calling for more input and space for independent creative thinking in collaborative project delivery models.

The contractor stressed the importance of early involvement and collaboration in maximizing project potential. Building and maintaining trust throughout the collaborative process was identified as crucial, requiring open communication and a genuine willingness to work in the best interests of the project. A sustainable mindset was also highlighted, with the understanding that many sustainability solutions are based on basic principles and common-sense thinking. The importance of a collective focus and shared goals, as well as the desire to implement successful elements in mainstream projects, were also emphasized.

In conclusion, the case study of ZEB Laboratory provides valuable lessons for future projects. Early stakeholder involvement, thorough pre-project organization, and building trust are crucial for successful project delivery. Balancing budget constraints with design possibilities and fostering a sustainable mindset are essential for architects. Contractors should emphasize early involvement, collaboration, trust-building, and a collective focus on shared goals. These insights contribute to the industry's understanding and offer valuable guidance for future projects seeking to achieve positive outcomes.

6.1.3.2 Energy Academy Europe

This case study presented valuable insights from the perspectives of both the clients and the advisors involved in the project. These lessons provide practical experiences and insights that can inform future projects in the construction industry.

From the client's perspective, several key lessons were learned. Firstly, the importance of choosing sustainable materials, such as concrete and wood, while avoiding materials like plastic or aluminum for future projects, was emphasized. This decision had a significant impact on sustainability, resource utilization, and the project's carbon footprint. Secondly, there was a constant need to question and minimize energy needs in building design. This involved effectively utilizing natural elements, such as orientation, solar panels, geothermal energy, and optimizing air circulation, to reduce energy consumption and enhance overall energy efficiency. Thirdly, thoughtful functional layout played a crucial role in optimizing energy usage and creating an efficient working environment. The placement of different functions within the building, such as locating laboratories on the north side to reduce excessive cooling, demonstrated the importance of strategic placement. Other lessons included considering the total cost of ownership, setting goal-oriented engineering for minimal energy consumption, prioritizing communication and stakeholder engagement, and improving accessibility in building design.

From the advisors' perspective, lessons focused on broadening the sustainability perspective beyond energy efficiency. This involved considering aspects such as circularity, biodiversity, health, and water management in future sustainability efforts. The vital role of building physics was highlighted, emphasizing the need for architects to prioritize it from the beginning of a project to ensure user satisfaction and eliminate potential complaints related to the indoor environment. Low-tech solutions combined with proper insulation and building physics were deemed effective in creating sustainable and durable building designs. Integrating building physics early in the design process was emphasized to ensure efficient and functional architectural choices. Lastly, the significance of teamwork and collaboration was emphasized as a key factor in achieving successful project outcomes.

By applying these lessons in future projects, the construction industry can strive towards sustainable and energy-efficient designs that encompass broader sustainability considerations.

6.2 Evaluation of Research Outcomes

The main objectives of this research were to identify the critical factors in early phase activities that contribute to the use value in the occupancy phase in case study projects, to conduct a comprehensive post-occupancy evaluation of the ZEB Laboratory in order to gain an insight about user experience and use value of the building, and to derive lessons and recommendations from the case studies of ZEB Laboratory and Energy Academy Europe.

Regarding the first objective, our research involved conducting interviews with informants from different roles in the project, which provided valuable insights into the early phase activities. Through these interviews, we were able to identify ten factors in the early phases that contribute to the use value in the back end of projects. Importantly, many of these factors were consistently mentioned by multiple experts, validating their contribution across different projects and organizations. It is important to note that while the lessons and conclusions drawn from these factors can be valuable for the construction industry, variations in project characteristics should be considered, as results may differ in different situations.

For the second objective, a post-occupancy evaluation (POE) was conducted on the ZEB Laboratory. This evaluation consisted of a survey administered to the occupants and a walkthrough accompanied by a focus group discussion involving individuals working in different locations within the building. Although the survey participation rate was relatively low, at 25% of the total workforce, this was due to the fact that many individuals do not work in the building full-time. Despite this limitation, the survey results aligned with the findings from the walkthrough and discussions, bringing attention to several factors that can be improved while showing overall user satisfaction with the building. It is worth noting that initially, the aim of this research was to conduct a POE evaluation on the Energy Academy Europe as well. However, due to limitations in accessing the necessary individuals, this objective had to be revised, resulting in the elimination of comparisons between the POE results of these buildings.

In evaluating the achievement of the research objectives, it is evident that substantial progress has been made. The identification of critical factors in early phase activities and the comprehensive POE evaluation of the ZEB Laboratory have yielded valuable insights. Although some modifications were necessary, such as the change in the research objective related to the Energy Academy Europe, the research has successfully addressed the stated objectives and provides valuable lessons and recommendations for the construction industry. It is important to consider the limitations and specific circumstances of individual projects when applying these findings. By evaluating the achievement of the research objectives, we can conclude that this study has made a contribution to the field and offers opportunities for future research and improvement in early phase activities and post-occupancy evaluations.

6.3 Broader Implications and Contribution

The significance of this study lies in the recognition that early phase activities have a substantial influence on project outcomes. Existing research highlights that stakeholders involved in the project have greater opportunities to make changes with lower costs during the early phases. Moreover, there is a growing emphasis on the importance of use value and user satisfaction in building projects, as the satisfaction of end users impacts all project stakeholders. However, a knowledge gap exists regarding the specific activities in the early phases that lead to use value in the backend of projects. By identifying these critical factors and activities, the construction industry can benefit from incorporating and prioritizing them in project planning and execution. It is important to note that although scholars recognize a strong connection between activities in the front end and outcomes in the back end, there is no direct and concrete line that can be drawn to connect these two ends of a project. Therefore, further research is necessary to gain a deeper understanding of this relationship especially in quantitative manner.

The results of this study are not only valuable for the broader construction industry but also have specific implications for future campus development projects at NTNU and the University of Groningen. These findings can guide decision-making processes and enable informed choices based on the lessons learned from the research. Additionally, the post-occupancy evaluation (POE) results provide a valuable database for ZEB Laboratory, assisting them in making improvements and better aligning with the needs and expectations of the users. Moreover, the findings serve as a resource for future projects within NTNU or SINTEF, facilitating better design and implementation strategies.

All in all, this research has broader implications for the construction industry, highlighting the significance of early phase activities and their impact on project outcomes regarding use value. It emphasizes the importance of pursuing use value in building projects and the need for further research to better understand the connection between front-end activities and back-end outcomes. The results contribute to filling the existing knowledge gap, provide practical insights for future projects, and offer opportunities for improved decision-making and user satisfaction.

6.4 Discussion of Limitations and Future Research

This research encountered several limitations that should be acknowledged. The focus of this research is on the user experience of the buildings, with a qualitative approach to data collection and analysis. Therefore, it does not delve into technical details about the construction or engineering aspects of the ZEB Laboratory or Energy Academy Europe building. Additionally, the study is limited to the two case studies, and while the findings offer valuable insights, they may not be applicable to other buildings or contexts. It is crucial to note that the subjective nature of the data collected from building occupants, designers, clients, advisors and contractors introduces potential variations in individual perspectives and biases.

One limitation in this study was the difficulty in accessing and contacting all the stakeholders involved in the Energy Academy Europe project. As a result, it was not possible to conduct a comprehensive post-occupancy evaluation (POE) in the Energy Academy Europe building, which restricted the ability to make direct comparisons between ZEB Laboratory and Energy Academy Europe. Moreover, the value blueprint could not be generated for the Energy Academy Europe project due to a lack of participation from the contractor and designer.

Another limitation was the relatively small number of respondents in the POE survey conducted in ZEB Laboratory. The ZEB Laboratory's unique characteristics, such as a significant number of part-time occupants, influenced the data collection process and limited the survey participants. The study included approximately 15 individuals, representing about 25% of the laboratory's total capacity. While efforts were made to ensure diversity, the small sample size may restrict the generalizability of the findings and the statistical power of the analysis. Despite these limitations, the qualitative data still provide valuable insights into the user experience and perceptions of the ZEB Laboratory. Further research with a larger and more diverse participant pool is recommended to validate and expand upon these findings. Additionally, the limited availability of free time for informants to participate in interviews posed a challenge in gathering comprehensive insights.

Furthermore, the qualitative nature of this study means that the data cannot be easily quantified or measured. However, a rigorous research methodology, including a systematic approach to data collection and analysis, ensured the reliability and robustness of the findings. Although a post-occupancy evaluation could not be conducted for the Energy Academy Europe building due to limitations in accessing the relevant personnel, a guided visit to the building and interviews with key project personnel were carried out to gather data and feedback.

Despite all these limitations, this study contributes to the field of sustainable design by identifying early phase activities contributing to use value in the occupancy phase through qualitative analysis of two case studies. While it has limitations in terms of scope and methodology, the insights gained from this research can inform future research and practice in building design.

Based on findings in this study, there are several potential areas for future research that can build upon this study. Firstly, further research is needed to explore the direct relationship between activities in the early phases of a project and the resulting use value in the use phase. Investigating this relationship can provide a deeper understanding of the impact of early phase activities on the ultimate outcomes of building projects.

Additionally, this research predominantly relied on qualitative data from interviews. Future research can explore the effects of these activities on a quantitative basis, which would provide a more robust analysis of the relationship. This could involve developing quantitative metrics and measurement tools to evaluate the impact of early phase activities on use value and building performance.

Furthermore, establishing a framework for conducting regular POE evaluations, particularly in educational buildings and universities, could be an avenue for future research in Norway. Encouraging building owners to conduct POE evaluations and establishing a comprehensive database of different projects would enable researchers to draw comparisons and facilitate the ongoing learning process for enhancing future projects. This data-driven approach can contribute to the continuous improvement of building performance and user satisfaction both locally and globally.

In conclusion, this research has provided valuable insights into the critical factors in early phase activities, conducted a comprehensive POE evaluation, and derived lessons and recommendations from the case studies. The limitations encountered during the research process highlight potential areas for future research, such as exploring the direct relationship between early phase activities and use value, investigating the effects on a quantitative basis, and establishing a framework for regular POE evaluations in Norwegain educational buildings. The broader implications of this research emphasize the importance of these findings for the construction industry, campus development projects, and the ongoing pursuit of user satisfaction and building performance.

6.5 Reflection on the Research Process

Reflecting on the overall research process, I can say that it has been an exciting and enriching journey for me. I had the opportunity to learn from experts and delve into the technical aspects of sustainable buildings, innovative solutions, and process management in both case studies. The guidance and support I received from my supervisor were invaluable in shaping the direction of my research. In addition to the guidance from my supervisor, I was fortunate to receive help from experts in the field of project management and post-occupancy evaluation (POE). Their contribution played a crucial role in enhancing my thesis and providing valuable insights into potential aspects of research that I had not previously considered.

One of the highlights of this research was the chance to interview experts from various fields of expertise. These interactions provided me with valuable insights and expanded my knowledge base. Additionally, the POE evaluation procedure was intriguing, particularly the discussions with occupants about their experiences with the building. Conducting walk-through for the POE evaluation was both fascinating and challenging, as I navigated through the building, observing and noting various aspects.

Another fascinating aspect of this research was visiting the Energy Academy building, renowned as the most sustainable building in the Netherlands. This first-hand experience allowed me to witness the innovative solutions implemented, such as the labyrinth. I also had the opportunity to closely examine the unique design of the solar panels on the roof, which were specifically tailored for this project. These visits provided valuable insights into sustainable features and further deepened my understanding of early phase activities and user experiences within the building.

Throughout the research process, I had the privilege of meeting and learning from numerous individuals who generously shared their experiences and insights. This exposure to different perspectives was instrumental in broadening my understanding of the subject matter. Furthermore, I gained a deeper appreciation for sustainability features and the importance of considering user experiences when designing and evaluating buildings.

While the research process was undoubtedly rewarding, it was not without its challenges. There were times when I faced obstacles and had to make adjustments to my research plan. These modifications, however, ultimately contributed to the overall effectiveness of the study. By adapting and refining my approach, I was able to overcome hurdles and gather more robust data and findings.

In conclusion, the research process has been a valuable and transformative experience for me. It has allowed me to grow as an engineer and gain a deeper understanding of sustainable buildings, project management, and post-occupancy evaluation. The lessons learned, the insights gained, and the connections made throughout this journey will undoubtedly shape my future endeavors in this field.

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APPENDICES

A - INTERVIEW QUESTIONS

Interview questions to the contractor/architect in ZEB Laboratory project

- Can you tell us about your professional background and how you got involved in the ZEB lab project?

- What unique value did you bring to the ZEB lab project? What quality or utility did you offer the client (NTNU, Sintef), users and other stakeholders in this project? What made your offering different from that of your competitors? (Value for others)

- What professional values did you gain from this project (ex: skill development, status, reputation, work satisfaction, or other aspects)? (Value for yourself)

- What expertise and resources from your company were crucial in realizing the aspired use values? (Expertise)

- What types of partners did you need to realize the aspired use values for others? What activities were necessary to achieve the aspired use value for others? (Partners)

- How did you ensure effective communication with and involvement of building users and stakeholders during the decision-making process? (Stakeholders' involvement)

- What were the challenges you faced in engaging users and stakeholders during the early phases, and how did you overcome them?

- In your opinion, how did the involvement of building users and stakeholders in the early phases of the project contribute to the success of the project, in terms of user satisfaction and building performance? What evidence do you have to support this?

- Can you discuss some key tasks or activities that were crucial in the early phases of the project, before construction began? (Early phase activities)

- Were any innovative or unique approaches taken during the early phases of the project that contributed to the building's success?

- With regard to value for yourself , what financial and professional risks were you prepared to take in this project, and which ones did you want to avoid? (Risks)
- What risks were you prepared to take to deliver value for others, and which ones did you want to avoid?
- What lessons have you learned about front-end activities during a building project, and how will you apply them to future projects?(Future development, Lessons learned)
- What improvements would you like to see in the design, construction, and operation of the ZEB lab in the future?

Interview questions to the client in ZEB Laboratory project

- Can you tell me a bit about your background and how you became involved with the ZEB Laboratory project?
- What were project goals and objectives for the ZEB Laboratory when it was designed and constructed?
- How have the performance and operation of the ZEB Laboratory met or exceeded project expectations, and how have you evaluated the building's success in meeting its intended goals and objectives?
- How satisfied are you with the performance of the building systems, such as HVAC, lighting, and fire safety systems, and how have you evaluated their effectiveness and efficiency?
- What challenges have you faced during the operation of the ZEB Laboratory, and how have you addressed them?
- How has communication been maintained between the building management and the building users, and what opportunities have been provided for feedback and engagement to improve building performance?
- What feedback have you received from the occupants and building managers regarding the building's design and operation, and how have you addressed any issues or concerns raised?
- What improvements would you like to see in the design, construction, and operation of the ZEB Laboratory in the future, and how do you plan to engage building users and other stakeholders in the process?
- What were some of the key tasks or activities that you believe were crucial in the early phases of the project, before the construction started, and how did you involve building users and other stakeholders in the process?
- Were there any challenges you faced during the early phases of engaging users and stakeholders, and how did you overcome them, and what strategies or methods did you use to communicate with and involve the building users in the decision-making process?

- In your opinion, how did the involvement of the building users in the early phases of the project lead to a better result in terms of user satisfaction and building performance, and what evidence do you have to support this?
- How did you manage to balance the needs and desires of the different stakeholders, such as the building users, contractors, and other parties involved in the project, and what lessons have you learned from this experience? did you involve any external parties, such as contractors or consultants, in the early phases of the project, and if so, how were they engaged in the process?
- Can you discuss any innovative or unique approaches that were taken during the early phases of the project that you believe contributed to the success of the Zeb lab?
- Can you discuss any lessons learned regarding the importance of considering user satisfaction during front-end phase of a building project, and how you want to apply these lessons to future projects?

Interview questions to the advisors in EAE project

- Can you tell me a bit about your background and how you became involved with the Energy Academy Building project?
- What were the primary goals and objectives for the Energy Academy Building project, and how were they established?
- How Energy Academy building is integrated in campus development of University of Groningen?
- Can you discuss the building's performance and operation and how it has met or exceeded project expectations? How do they evaluate the building's success in meeting its intended goals and objectives?
- How did you involve building users and other stakeholders in the process?
- What strategies or methods did you use to communicate with and involve the building users in the decision-making process?
- Were there any challenges you faced during the early phases of engaging users and stakeholders, and how did you overcome them? Who will be the end-users?
- In your opinion, how did the involvement of the building users in the early phases of the project lead to a better result in terms of user satisfaction and building performance? What evidence do you have to support this?
- How did you manage to balance the needs and desires of the different stakeholders, such as the building users, contractors, and other parties involved in the project? What lessons have you learned from this experience?
- Did you involve any external parties, such as contractors or consultants, in the early phases of the project, and if so, how were they engaged in the process? (ECI?)

- Can you discuss some of the key tasks or activities that you believe were crucial in the early phases of the project, before the construction started?
- Can you discuss any innovative or unique approaches that were taken during the early phases of the project that you believe contributed to the building's success?
- What unique value did you bring to the Energy Academy Building project, and how did it differentiate you from your competitors?
- Can you discuss any lessons learned regarding the importance of considering user satisfaction during the front-end phase of a building project? How do you plan to apply these lessons to future projects?
- What improvements would you like to see in the design, construction, and operation of the Energy Academy Building in the future? How do they plan to engage building users and other stakeholders in the process?

Interview questions to the client in EAE project

- Can you tell us about your background, and how you became involved with the Energy Academy Building project? (Introduction)
- Can you describe how the building's performance and operation have met or exceeded project expectations? Specifically, how has the building performance been in physical environment (e.g. lighting, acoustics, natural light, indoor air quality, and temperature) and building systems (e.g. HVAC systems, electrical and plumbing systems) and in general, user experience?(User experience)
- How do you evaluate the building's success in meeting its intended goals and objectives?
- How does the Energy Academy Building perform in terms of sustainability features, such as energy usage?
- How does the Energy Academy Building communicate its sustainability message to occupants and other stakeholders? (Sustainability image)
- Have you faced any challenges in managing the facilities in the operation phase of the building because of its sustainable and BREEAM certified design? How have you addressed these challenges, and what lessons have you learned from them?
- Can you discuss any strategies or methods that have been used to engage building users and other stakeholders in decision-making in front-end and operation phase? (Stakeholder involvement)
- What challenges have you faced in engaging stakeholders in the project, and how have you overcome these challenges? Can you discuss any specific examples of stakeholder involvement that have led to a better result in terms of user satisfaction and building performance?

- How have you managed to balance the needs and desires of different stakeholders, such as building users, contractors, and other parties involved in the project? Can you discuss any specific strategies or approaches that have been used to ensure stakeholder satisfaction and successful project outcomes?

- Can you discuss some of the key tasks or activities that were crucial in the early phases of the Energy Academy Building project, before construction began? How did these activities contribute to the project's success? (Early phase activities)

- Can you discuss any innovative or unique approaches that were taken during the early phases of the Energy Academy Building project that contributed to its success?

- What lessons have you learned from the Energy Academy Building project especially about the methods/strategies that can be used in front-end phase of a building project? How do you plan to apply these lessons to future projects? (Future development and lessons learned)

- What improvements would you like to see in the design, construction, and operation of the Energy Academy Building in the future? How do you plan to engage building users and other stakeholders in the process of implementing these improvements?

B - INTERVIEW TRANSCRIPTS

Insights from the client, ZEB Laboratory

Informant 1N, who represents the client in the ZEB Laboratory project, shared valuable insights regarding their background and involvement in the project. As an engineer with a Ph.D. in civil engineering, Informant 1N has a diverse professional history that includes work experiences at both NTNU and SINTEF, as well as in the industry. Informant 1N's involvement in the ZEB Laboratory project began not from its inception but during the project's pursuit of funding from the Research Council. Despite facing initial financial constraints, the project's compelling description caught the attention of the Research Council, who acknowledged its merit.

It was at this juncture that Informant 1N reentered SINTEF and assumed the role of project manager responsible for developing and constructing the laboratory. Notably, Informant 1N had the opportunity to participate in the selection and hiring process of the project's contractor, indicating their involvement even before the initial phases of construction commenced. This early engagement demonstrates Informant 1N's crucial role in shaping the project's direction and highlights their comprehensive involvement throughout its various stages. Informant 1N's background, which includes a combination of academic expertise and industry experience, made them particularly suited to assume the responsibilities associated with such a complex undertaking. Their familiarity with both SINTEF and NTNU, along with their industry background, provided the necessary skills and knowledge to effectively oversee the development and construction of the ZEB Laboratory.

Project Goals and Objectives
Informant 1N, the client representative in the ZEB Laboratory project, shared information regarding the project's goals and objectives during the early phases of design. According to Informant 1N, the main document outlining the project's ambitions at that stage was called the "Ambition Note." This document was shared with the interviewer to provide a more comprehensive understanding of the specific goals and objectives that were considered during the early design phases and was used in writting this thesis. The Ambition Note aimed to provide a broad overview of the project's vision before finalizing the contract with the contractors. Informant 1N mentioned that the note did not contain specific details but outlined several key aspirations. The project aimed to be sustainable, incorporat-

ing elements such as energy efficiency and climate adaptation. It also intended to showcase innovative materials and future-oriented solutions for the building industry. Additionally, Informant 1N emphasized the desire for an aesthetically pleasing design, moving away from the conventional perception of unattractive lab buildings. The Ambition Note recognized that the ZEB Laboratory served a dual purpose as both a research facility and an office building. *Performance and operation*

Informant 1N, the client representative, provided insights into the evaluation of the ZEB Laboratory's performance and operation compared to their expectations at the time. According to Informant 1N, the performance evaluation criteria for the laboratory were established during the project's progress and were also included in the Ambition Note. One of the main criteria was the achievement of a sustainable and energy-efficient building, as indicated by the zebcom standard. However, the evaluation process for the operational phase of the building is still ongoing, as the necessary data and values for assessing its performance have not been fully obtained.

Informant 1N mentioned some issues that still need to be addressed, such as heating pumps and energy consumption related to water circulation. These issues are being followed up to identify the underlying causes and find appropriate solutions. However, in terms of economic performance, the project was considered a significant success, meeting or exceeding the client's expectations. Additionally, the project was successfully completed within the expected time frame, indicating another aspect of its success.

Furthermore, informant 1N elaborated on the expectations they had for the ZEB Laboratory project. According to Informant 1N, one of the key expectations was related to the research capabilities and opportunities offered by the building. They anticipated that the laboratory would provide a suitable environment for conducting various types of research. This could include exploring new technologies, testing energy-efficient solutions, and studying sustainable building practices. The aim was to create a facility that would facilitate valuable research outcomes and contribute to the knowledge base in the field.

Additionally, Informant 1N highlighted the importance of learning and gathering lessons during the development and construction of the building. This implied that the project was expected to offer valuable insights for the client, the students involved, and the wider construction industry. The intention was to identify and document the challenges, successes, and best practices encountered throughout the project's life-cycle. This knowledge could then be shared to benefit future projects and contribute to the overall advancement of sustainable building practices.

Informant 1N acknowledged the concerns raised regarding the occupancy characteristics of the ZEB Laboratory, particularly regarding the temperature during summer. They explained that the building does not have mechanical cooling and relies on the opening of windows to regulate temperature. However, the process of opening windows is a part of the building's steering system, which is designed to anticipate and address temperature issues before occupants perceive them.

Informant 1N mentioned that the algorithm used for operating the system was developed by students, and to test its effectiveness, two students were hired for a summer job. However, during that particular summer, the outside temperature did not reach levels that required the windows to be opened, preventing a comprehensive evaluation of the system's performance.

Informant 1N emphasized the subjective nature of temperature perception, with individuals having different preferences and comfort levels. They mentioned that while some occupants might feel the building is too hot, others might perceive it as too cold. Informant 1N expressed the need to gather more feedback on this matter, as not everyone has provided specific complaints or comments. They recognized the importance of addressing these concerns and exploring potential improvements to ensure occupant comfort.

Informant 1N explained that the evaluation of the ZEB Laboratory's performance in areas such as heating, ventilation, air conditioning, lighting, and fire safety was conducted using a specialized equipment placed on top of cupboards. The equipment, developed by a PhD student, monitored various indoor climate parameters including temperature, CO2 levels, and relative humidity. This data collection allowed for a more comprehensive assessment of the indoor climate compared to many other buildings in Norway, excluding certain hospitals.

Informant 1N acknowledged the unique aspects of the ZEB Laboratory, such as the presence of wood and the potential concerns related to its smell or moisture levels. They expressed curiosity about the impact of these factors on occupant experiences and health. However, Informant 1N reassured that the level of these potential concerns was minimal and not detrimental to health. They emphasized that the ZEB Laboratory was subject to more detailed monitoring and follow-up regarding the indoor climate compared to other buildings.

Informant 1N acknowledged that there have been some major problems identified while following up and checking the building systems. Specifically, they mentioned issues with the heat pumps not functioning as expected. This indicates a concern with the performance or efficiency of the heat pump system within the laboratory.

Additionally, Informant 1N expressed dissatisfaction with the automated solar shading system, particularly for the south and east-facing areas. They stated that the shading does not meet their expectations and they are not fully satisfied with the solution in place. However, Informant 1N noted that they have not yet gathered feedback from others involved in the project, so further insights from different perspectives are still pending.

Informant 1N provided further information about the problems with the heat pumps in the ZEB Laboratory. They mentioned that there are technical complexities involved, and they are currently in the process of writing a report together with a researcher to address these issues. The report will cover various technical aspects, with the section on heat pumps constituting one-third of the overall report. Informant 1N explained that the main problem with the heat pumps is their high electricity consumption. The defrosting process occurs too frequently, leading to interruptions in operation and instability. As a result, the heat pumps are not able to produce the expected amount of energy, resulting in lower energy harvesting efficiency than anticipated.

Informant 1N explained that the problems with the heat pumps have an impact on the users' experience within the building, particularly in relation to research activities. They mentioned that certain research projects are being affected because of the heat pumps' malfunctioning. This indicates that the unreliable operation of the heat pumps is hindering the progress and execution of specific research endeavors.

Informant 1N further highlighted the inconvenience caused by the dependency on external energy sources. While the ambition of the ZEB Laboratory is to produce its own energy, the current issues with the heat pumps require them to purchase energy from the rest of the campus. This reliance on external energy sources not only affects the sustainability goals of the laboratory but also adds an additional operational challenge and potential cost.

Informant 1N highlighted some of the challenges faced during the operation of the building. They mentioned that the technical installations, including the steering system, did not work properly from the beginning. As a result, they had to spend an extended period, more than a year and a half, optimizing and resolving these issues. This indicates that the initial functionality and performance of the technical systems posed significant challenges and required substantial efforts to rectify.

To address these challenges, Informant 1N mentioned that they have their own technician who oversees the technical aspects of the building. This technician specializes in the steering system and is responsible for managing and resolving any related issues. They collaborate with the contractor as needed to address the challenges effectively.

In the context of achieving zero-emission goals, Informant 1N explained that through the expertise and involvement of their technician, they are able to facilitate the monitoring and management of the building systems more comprehensively. They have a system in place with numerous measuring points and data logging to track and analyze the performance of the systems. This thorough follow-up and data analysis allow them to have a deeper understanding of the building's operations compared to typical building owners.

Informant 1N asserts that there are certain areas where improvements in the design, construction, and operation of the laboratory are desired. According to their perspective, one significant aspect that requires improvement is the solar shading system. They believe that the current system's control and optimization need to be enhanced to ensure effective management of shading in the building.

Additionally, Informant 1N highlights the need for an improved booking and reservation system for meeting rooms. They express that the existing system, where different buildings have separate reservation systems, leads to inconvenience and inefficiency. Informant 1N suggests the development of an integrated ZEB-app that can streamline the booking process across different buildings, making it more user-friendly and efficient.

User involvement

In the context of communication between building management and users, Informant 1N highlights the direct reporting system as a means of maintaining effective communication channels. This system allows users to report any concerns or issues directly to the management, facilitating timely feedback and engagement. Although the number of reports received has not been extensive, Informant 1N acknowledges the existence of some feedback from users.

Regarding user feedback, Informant 1N notes that most users seem to be satisfied with the building. However, they also acknowledge that there have been some minor issues reported. For instance, one user discovered an unexpected power source, and there have been claims about the length of the buyer. Informant 1N considers these issues as relatively small in nature, not posing significant challenges to the overall functioning of the building.

When asked about major issues or problems, Informant 1N mentions two examples. Firstly, the storm water management tank was reported to be leaking, which could impact the collection and utilization of rainwater. Secondly, on the fourth floor, there were ventilation channels that were insufficiently insulated, resulting in the cooling down of the entire floor during winter. Addressing this issue required a significant effort, with insulation work carried out over an entire summer to rectify the situation.

Informant 1N believes that the primary focus for engaging building users and stakeholders is through research projects. They explain that research projects within the laboratory often come up with ideas and suggestions for improvements, which are then implemented to enhance the building's operation. This indicates that researchers, who have a direct involvement with the laboratory and its facilities, are given a platform to provide valuable feedback and contribute to the ongoing development of the building.

In terms of office users, Informant 1N acknowledges that there may be fewer opportunities for direct engagement and feedback compared to researchers. They mention that the laboratory primarily accommodates around 70 office users, implying that their input may not be as extensive as that of the researchers who actively utilize the lab space. However, this does not negate the possibility of gathering feedback from office users altogether.

When it comes to involving users in the design phase, the primary users in this case were the researchers who would be utilizing the facility. While not all researchers were directly involved in the collaboration process, their input and feedback were sought through regular communication channels. A specific group of researchers was identified and consulted when needed, providing valuable information and insights for the design process.

Additionally, other user groups such as the building operators, cleaning staff, and technical system operators were also engaged during the design phase. Their input was sought through meetings and discussions to ensure that the design considerations aligned with their operational requirements.

However, the users, who were expected to occupy the building, were not extensively involved in the design phase. This was primarily due to the uncertainty regarding the specific individuals who would be using the office. While the occupancy by NTNU and SINTEF was known, the exact individuals were not identified at that stage. Nonetheless, some researchers who were expected to have office desks in the building, including the informant themselves, had the opportunity to provide input and feedback.

Informant 1N believed that there were indeed challenges in engaging users and other stakeholders during the project. One significant challenge was ensuring effective communication and collaboration among the various groups involved. The collaborative process required regular evaluations and feedback sessions, often conducted through interviews and speed dates. External evaluators were also brought in to provide insights and suggestions for improvement. These measures helped identify issues early on and allowed for necessary changes to be implemented before problems escalated.

One particular challenge was managing the involvement of researchers who were focused on their individual work. Integrating their activities within the collaboration group while also engaging students and other external contributors without disrupting the progress of the design process proved to be difficult. The project involved around 2,200 students, whose input was valuable but had to be carefully managed to avoid disrupting the overall workflow.

To handle the influx of input and ideas without disturbing the core group's work, a leadership structure was established, consisting of the contractor and SINTEF representatives. Regular meetings were held to discuss the relevance and significance of different initiatives and decide whether larger presentations or further actions were necessary. The students' contributions were reviewed and controlled by the core group, ensuring that only relevant and appropriate ideas were integrated into the project.

In the opinion of Informant 1N, the involvement of users, students, and researchers in the early phase of the project had a significant impact on user satisfaction and building performance. The engagement of students allowed for innovative ideas to be incorporated into the building's design. For example, in the case of color selection, the students participated in a competition where they proposed color templates for various elements of the building. The feedback received from the students helped create a visually appealing and user-friendly environment, promoting relaxation and ease of navigation within the building.

Regarding the researchers and future occupants, their involvement was crucial throughout the project. Prior to signing the contract, several meetings were held to gather their input and requirements. This collaboration continued during the construction process, with regular check-ins to ensure that the project was aligned with their needs. The researchers shared their solutions and suggestions, which helped in refining the design and incorporating innovative systems.

An example of such collaboration is the implementation of a novel heating storage system on the first floor. This system involved storing heat collected from the indoor climate and heat pumps in a special tank with a phase-changing material (PCM) with a melting point of 38 degrees Celsius. This allowed for the collection and storage of excess heat during the day, which could be utilized to heat the building in the morning, reducing the need for additional energy from external sources. The PCM system enabled the dimensioning of the heating system based on average energy demands rather than peak energy demands, resulting in optimized energy usage.

Furthermore, the integration of solar panels on the building's roof was another innovation that emerged from the collaborative process. While solar panels themselves are not new, their integration into the building's design showcased the commitment to sustainability and renewable energy.

Early phase activities

Informant 1N asserts that one of the key tasks or activities crucial in the early phase of the project was the organization and collaboration ("samspill") between stakeholders. They highlight the importance of establishing a collaborative project approach that involved key participants such as the contractor, architect, consultant, researchers, and building operator. The collaboration between these stakeholders facilitated effective communication, information exchange, and decision-making throughout the project's life-cycle. By involving all relevant parties from the beginning, it ensured that the project goals, requirements, and objectives were clearly defined and understood by everyone involved.

They believed that this collaborative approach in the early phase had a significant impact on the subsequent stages and the occupation of the building. It allowed for a more holistic and integrated design and construction process, ensuring that the building's systems and features met the specific needs and expectations of the occupants. Furthermore, involving researchers and building operators in the early phase ensured that their input and expertise were integrated into the design and operational aspects of the building. This inclusion likely contributed to a better understanding of the users' requirements, improved functionality, and enhanced building performance.

Informant 1N asserts that the design phase involved a collaborative effort among various stakeholders. The client, contractor, architect, plumbers, electricians, and other relevant parties were all present in the same room, actively participating in the design process. This collaborative approach allowed for direct communication and coordination among the team members, ensuring that everyone's expertise and input were considered during the design phase.

According to Informant 1N, managing the needs and desires of different stakeholders involved in the project, such as contractors, designers, clients, students, and researchers, was achieved through excellent project management and the establishment of trust among the parties involved.

Trust played a crucial role in fostering effective collaboration. Trust between the contractor and the client, as well as between the project leader and the research group, formed the foundation for open communication and mutual understanding. This trust allowed for the exchange of ideas, feedback, and constructive discussions, which contributed to better decision-making and problem-solving throughout the project.

In addition to trust, the management of the project's budget was also important. Informant 1N mentioned that they had allocated the budget in a way that allowed for flexibility and the possibility of making changes without significant constraints. This flexibility provided the opportunity to incorporate new ideas, address emerging challenges, and adapt the project as needed while still remaining within the budgetary limits.

Lessons learned

According to Informant 1N, one of the most important lessons learned from the project was the significance of considering user satisfaction and involving stakeholders early on. They emphasized the importance of organizing and setting the stage for the project before engaging contractors. This involved clearly communicating the process, objectives, and expectations to the organization and stakeholders.

In terms of future projects, Informant 1N expressed the belief that the lessons learned should be applied by emphasizing the pre-project organization and planning phase. They highlighted the need for expertise in project management and technical aspects, as well as the requirement for active involvement and support from the organization. Informant 1N acknowledged that this approach may not be suitable for every client and project, as it demands a higher level of engagement and follow-up compared to traditional projects.

Informant 1N believes that the lessons learned from their project, particularly in building trust between the organization and the people involved, would be valuable for future campus development projects. They acknowledge that each project may have its own unique characteristics and requirements, but the underlying principles of collaboration and early organization remain crucial.

Informant 1N also notes that it is important for others to understand the specific steps and processes that were undertaken before the project started, as this played a significant role in their success. While it may not be possible to replicate the exact same approach, the lessons learned can serve as valuable guidelines and inspiration for future projects.

Insights from the architect, ZEB Laboratory

Informant 2A, an architect involved in the laboratory project, has a professional background in architecture. They joined the project in 2017 as part of the team led by their company. As a relatively fresh architect at the time, they collaborated closely with the team leader and contributed to the development of the ZEB laboratory project. Informant 2A mentions that their company was involved in the laboratory project after winning the commission. However, they were not personally involved in the acquisition process and therefore do not have detailed information regarding the selection of their company or the competitors involved.

Value for others

According to Informant 2A, their company brought several unique values to the project. Firstly, their company had a dedicated sustainability department, and they brought in an expert from that department to handle energy calculations, simulations, and maintain sustainability records throughout the early phase of the project. This expertise in sustainability was considered a valuable contribution to the project.

In addition, as architects, they highlighted their ability to be creative, improvise, and adapt to changes. They emphasized the importance of flexibility in adjusting their designs and accommodating new inputs as the project progressed. They mentioned that they started the process with no predetermined input, allowing them to approach the project with a fresh perspective. They described how their designs and sketches were continuously evaluated and optimized by the entire project team, working together to ensure the highest level of optimization in every aspect of the building.

The primary focus of the project was to create the world's most sustainable building within a tight budget. Informant 2A acknowledged that this challenge influenced and shaped their role in the project. Balancing sustainability objectives with budget constraints was a significant aspect that their company had to navigate throughout the process.

According to Informant 2A, their company offered several qualities to the client, users, and other stakeholders in relation to the groundbreaking features of the building in sustainability and research potential. One key quality they mentioned was their ability to work together with everyone involved in the project from the early stages. They emphasized the importance of collaboration, flexibility, and creativity throughout the process. This allowed them to effectively incorporate input and feedback from various stakeholders, ensuring that all perspectives were considered and integrated into the project. The ability to collaborate with different parties was seen as a valuable quality that their company brought to the project, particularly in the context of a unique development process where multiple individuals were involved in the architectural work.

Informant 2A also acknowledged the challenges that arose from this collaborative approach. Balancing the input from various stakeholders while maintaining architectural quality was a demanding task. However, their company's ability to be flexible and adapt to the input from others was seen as essential in ensuring the successful integration of groundbreaking features related to sustainability and research potential.

Regarding the qualities offered to the users, Informant 2A emphasized their company's ability to collaborate with everyone involved in the project. Their focus on collaboration suggests that the aim was to create a building that would meet the needs and aspirations of the users. By actively involving stakeholders and considering their input, their company aimed to deliver a project that would provide a positive and functional experience for the users.

Value for themselves
Informant 2A believed that their company gained several professional values from their participation in the project. These values encompassed skill development, enhanced reputation, and work satisfaction.

Firstly, the project provided valuable experience, enabling both the company and Informant 2A personally to acquire new knowledge and skills. The unique collaborative structure of the project, where they worked together with experts from various disciplines, allowed for a comprehensive understanding of sustainability in building design and the exploration of different technologies. Informant 2A expressed a sense of personal growth and highlighted the significance of the learning process facilitated by working closely with experts.

Moreover, the project contributed to enhancing the company's reputation. Being involved in the development of the world's most sustainable building added prestige to the company's portfolio. The project's recognition as a significant achievement within the field of architecture allowed the company to establish itself as a reputable and innovative organization. Informant 2A emphasized that sustainability is currently a highly regarded topic, making their participation in the project a valuable reference for future endeavors.

Overall, the project brought about a sense of professional satisfaction for Informant 2A and their company. The opportunity to work collaboratively from the project's inception, engaging in regular workshops and continuous learning, fostered a fulfilling work environment. The ability to contribute to groundbreaking research and sustainable design while being part of a collaborative team was personally rewarding for Informant 2A.

Expertise

According to informant 2A, the expertise and resources from their company that were crucial in the project included their sustainability department. The sustainability department played a significant role, particularly in the early phases of the project. Their extensive knowledge and ability to work well with different stakeholders were valuable assets, enabling effective collaboration and responsiveness to the project's designs and requirements.

Furthermore, as architects, the company offered their architectural skills and demonstrated the ability to adapt to the unique challenges of the project. Informant 2A emphasized their company's capacity to improvise and be flexible throughout the process. This adaptability was particularly important as the project involved a non-traditional development process that could be chaotic but ultimately engaging.

Partners

According to informant 2A, there were several external partners involved in the project. These partners included building engineers and experts from SINTEF, as well as the clients themselves who brought important knowledge related to sustainability aspects. Their contributions and collaboration were essential to the project's success.

When asked specifically about partners for their own tasks, informant 2A mentioned that the nature of the project was such that collaboration and teamwork were emphasized from the beginning. The traditional roles and responsibilities of the architects were blurred, and the project involved a collective effort rather than individual tasks. The team, including architects, experts, and stakeholders, worked together in workshops and review sessions to evolve the design concept. informant 2A mentioned that they did not hire external advisors or separate partners specifically for their own tasks. Instead, the collaboration involved close interaction and involvement from the entire team.

Stakeholders' involvement

Informant 2A explained that effective communication with the stakeholders was ensured through frequent in-person meetings and workshops rather than relying on electronic means of communication like emails or online platforms. The team met on a weekly basis, engaging in workshops where they discussed various aspects of the project. Additionally, there were additional meetings in between to further enhance communication. This approach allowed for direct interaction and facilitated meaningful discussions among the stakeholders.

In terms of involving stakeholders in the decision-making process, Informant 2A highlighted the collaborative nature of the project. All stakeholders were actively involved in every phase of the work, and the decision-making process was highly inclusive. Rather than working in isolation and developing ideas independently, the team received continuous input from the other stakeholders. They had to adapt and make changes based on the feedback received, continually reevaluating their designs and proposals. This iterative process involved flexibility and open-mindedness, as they had to reconsider and revise concepts based on the various restrictions, requirements, and sustainability aspects provided by the other stakeholders. The goal was to align all elements, including economic viability and sustainability considerations, to achieve the desired outcomes.

Informant 2A mentioned that there were some efforts to involve end users, particularly students, in the project. These students had assignments related to the project and were informed about the ongoing work. They observed the collaborative process and conducted research on the project's development.

Informant 2A explained that direct interactions with students or other end users were limited. However, the clients themselves were considered end users, and their involvement from the beginning of the project was crucial. The clients brought valuable knowledge and insights to the project, and their active participation in the workshops and collaborative discussions allowed for continuous development and evaluation of the design.

Informant 2A also highlighted the unique approach of the project, where the information provided to the team was not comprehensive from the start. Instead, the team proposed designs, and the clients provided feedback on what didn't work, allowing for an iterative process of refinement and improvement. In this context, the involvement of the clients from the beginning was essential to ensure a successful outcome.

Informant 2A highlighted the significant contribution of the client group, particularly the individuals from SINTEF. Their involvement from the beginning of the project was deemed essential, as they brought the project brief and important knowledge related to sustainability aspects. Additionally, they conducted informative lectures that educated the project team on their research fields and further emphasized the significance of incorporating sustainability into the design.

Early phase activities

Informant 2A mentioned that various activities were necessary to achieve the use value. One crucial activity was the organization of regular workshops. Instead of relying solely on digital communication methods such as team meetings or emails, the project team emphasized the importance of face-to-face interaction. These workshops brought together experts from different fields, dividing them into groups focused on interior and exterior design. The purpose of these interactive sessions was to facilitate discussions and find solutions to concrete problems related to the project. The constant communication and collaborative nature of these workshops played a significant role in achieving the desired goals.

Informant 2A emphasized the importance of engaging in extensive discussions and receiving input from SINTEF and users. This enabled the project team to explore different approaches and challenge established workspace regulations, ultimately leading to the design of innovative ways of working within the building.

According to Informant 2A, an interior architect from their company played a significant role in the project. They collaborated with users to develop the best possible concept, which involved creating flexible workspaces that catered to diverse needs. This concept encompassed a range of spaces, including open and noisy areas, as well as more closed and private spaces, considering various aspects of the work environment.

Informant 2A also highlighted the significance of considering lighting design during the early phase. They recognized that lighting plays a crucial role in work productivity and well-being, and therefore, it was an important aspect to address in the project.

Moreover, informant 2A emphasized the active involvement of users throughout the process. They mentioned the integration of Siemens Wizard technology, an interactive app system designed to measure user activity within the building. This technology aimed to enhance the user experience and contribute to the project's success.

Informant 2A believed that there were indeed innovation and unique approaches taken during the early phase of the project, both in the process and design aspects. From an architectural perspective, Informant sA mentioned that while the overall field of architecture may not be entirely new, the project involved innovative elements. One notable aspect was the emphasis on achieving top sustainability by carefully considering every choice made in terms of materials. This approach aimed to ensure that each material used served a secondary purpose or had a sustainability benefit.

The use of solar facades for exterior cladding was highlighted as an innovative feature. These solar facades contributed to the building's sustainability goals, but their usage was limited to areas where they would be most effective in terms of sun exposure. In locations where the solar facades were not efficient, an alternative approach was taken, utilizing burnt wood. Burnt wood was chosen for its durability, low maintenance requirements, and minimal energy and resource consumption during production.

Another unique approach mentioned by Informant 2A was the combination of high-tech and low-tech technologies. This integration aimed to achieve the best possible sustainability outcomes by incorporating both advanced and traditional techniques.

Informant 2A highlighted another unique and innovative approach in the process of developing the project. They mentioned that the team relied heavily on a 3D model from the very beginning, which was a departure from their usual approach. Instead of sketching ideas individually, the team needed a concrete 3D model to evaluate and assess each step of the design process. This allowed for immediate feedback and evaluation from project team.

They believed that the iterative process was quite rapid, with concepts being presented, evaluated, and adjusted within short time frames. The team had to be efficient in using software tools to quickly generate new concepts and models for each meeting. This process involved receiving input from various stakeholders, including calculations on cost and feasibility, which influenced the design decisions.

Informant 2A described this work process as innovative because it required them to navigate the challenges of maintaining a strong architectural concept while accommodating the feedback and constraints provided by other stakeholders. Instead of continuously adjusting the initial concept, the team had to be willing to start from scratch and develop entirely new ideas if the previous ones did not meet the requirements or were deemed unfeasible.

According to Informant 2A, collaborating closely with the contractor from the beginning of the project was not only necessary but also a valuable learning experience for everyone involved. They mentioned that it was important to have the expertise of all the different parties early on in the design process and to incorporate their input to adjust the building accordingly. This approach allowed for a more integrated and collaborative workflow.

Informant 2A also highlighted that the traditional way of working, where the contractor comes after the design process is complete, is becoming less common. It is now more typical for architects to engage with other stakeholders early on to ensure that their input and expertise are considered in the design. While the specific approach may vary depending on the project, Informant 2A acknowledged the benefits of collaborating closely with contractors and other experts from the beginning and suggested that a balance between different approaches could be considered for future projects.

From Informant 2A's perspective as a designer, having the contractor present in the early phase of the project is valuable as long as they allow the architects to do their job and provide timely input. Informant 2A emphasized the importance of having clear input regarding the budget and cost evaluation. By having the contractor's involvement early on, the architects can design with a better understanding of the project's financial constraints and avoid redesigning elements later due to cost issues.

Informant 2A also mentioned that in their experience, projects that involved collaborations between architects and contractors from the early stages had more successful outcomes. This collaborative approach allows for regular follow-ups, cost evaluation, and pricing of the design, which helps prevent surprises or major changes later in the project.

Risks

Regarding the financial and professional risks, Informant 2A mentioned that evaluating those risks and their impact on the company was not their personal role in the project. However, they did discuss the importance of maintaining architectural quality throughout the process. As an architecture firm, they are concerned with upholding a certain level of quality in their work, which contributes to their reputation. The end result of the project reflects on their abilities as architects, so it was important to them to ensure that the outcome met their standards.

Informant 2A acknowledged that challenges and disagreements can arise during a project, such as clashes with the contractors or instances where the team's recommendations were not followed. They mentioned a specific example with the interior staircase, where the contractor disregarded their advice and went with their own preferences. This situation was challenging because the architecture team's name was associated with the final result, even though they were not able to dictate the decision-making process. The contractor engaged a team that had limited experience in constructing staircases, which led to some discussions and concerns along the way.

Despite these challenges, Informant 2A mentioned that overall, it was a good collaboration, and they valued the experience gained from the project. They also highlighted the benefit of having such a project on their resume, which would contribute to their professional growth.

According to Informant 2A, they did not perceive any significant risks associated with delivering value to the clients or end users. The client was described as open-minded and satisfied with their work throughout the project, and there was a shared understanding of the desired outcomes. The main challenges arose from balancing the energy and sustainability requirements of the building with the project budget. These challenges were difficult for all parties involved, but there were no significant disagreements or conflicts with the client.

Regarding the alignment of users' opinions with the company's perspective, Informant 2A did not mention any specific risks or conflicts. They noted that there were no quarrels or difficulties with the interior workspaces, and the final design reflected the team's vision. While individual users may have had different thoughts on how the spaces should function, it didn't create any major issues during the project.

Lessons learned
According to Informant 2A, if there were no budget constraints,they believe that the design could have included more space and additional features that would benefit the users. The current size of the building is considered necessary for its purpose as a research building, but with a larger budget, there could have been more possibilities for creating a bigger structure with potential features like a large atrium that could serve as a focal point for the campus. This would have allowed the building to have a greater impact and provide additional benefits beyond its primary function.

Informant 2A also mentioned that with a larger budget, there could have been more opportunities to explore innovative architectural elements or materials that might have enhanced the overall design. However, specific details about what those elements or materials might be were not provided.

In terms of design decisions, if budget constraints were not a factor, Informant 2A believed there could have been more opportunities to explore and implement different materials or systems. They mentioned that the solar facade, which was a high-tech and sustainable feature, was used selectively due to its cost and production considerations. With a larger budget, it's possible that more extensive use of the solar facade or other sustainable materials could have been incorporated into the design.

Additionally, Informant 2A expressed that the collaborative process, while valuable, also presented challenges in maintaining the architectural quality and integrity of their work. With multiple stakeholders and restrictions along the way, it was difficult to have complete influence over the final result. If there were no constraints, they might have had more freedom to fully explore and refine their design without compromise.

Informant 2A believed that the contributions from various stakeholders, including non-architects, had an impact on their ability to fully contribute as architects and maintain the desired architectural quality. While the collaborative process was necessary for this project, they feel that having too many decision-makers can sometimes hinder the architect's ability to express their creativity and achieve a clear architectural concept.

They expressed a desire for more input and space to do their job as architects, suggesting that a more balanced approach could have allowed for a better outcome. They mention that architecture is a creative profession that is not easily quantifiable, making it harder to explain or justify certain design choices to non-architects who may prioritize other factors.

Informant 2A states that they have learned valuable lessons from this process for their future projects. They mention that finding a balance between working independently, like in competitions, and collaborating with other stakeholders is important. They enjoy the independence and focus on architectural quality in competition projects but acknowledge that it may not always result in the most optimized design for the users. On the other hand, for projects like the ZEB laboratory, collaboration was essential to achieve the desired sustainability goals.

Informant 2A also emphasizes the importance of effective collaboration with other stakeholders and expressing their thoughts and ideas actively. They have learned to reach out and engage in discussions to solve problems together.

Informant 2A mentioned that given a second chance, they would have organized the initial phase of the project differently. They found the process to be intense and felt that they could have benefited from more time to think and sketch as architects before engaging in large group meetings. The frequency of meetings and the constant need for adjustments limited their ability to think creatively and catch their breath. They express the desire for more space and time to develop the architectural concept before receiving input and making adjustments.

Informant 2A mentioned that they learned a lot about sustainability through this project, particularly in working with materials like massive wood and brick construction. They also gained valuable experience in communicating and collaborating with other parties involved in the project. As an early career professional, this project provided them with new opportunities and shaped their understanding of the interactive process involved in architectural projects.

In future projects, Informant 2A intends to apply their knowledge of sustainability and continue to enhance their communication and collaboration skills. They will draw upon their experiences from this project to inform their approach and contribute to the success of future endeavors.

Insights from the contractor, ZEB Laboratory

Informant 3C, a representative from the contractor company, possesses a comprehensive professional background in civil engineering and valuable experience by contributing to a significant projects. Since 2015, Informant 3C has been an integral part of their company, assuming the role of project manager with a focus on project development during the initial stages, specifically from a design standpoint. In the context of the zeb laboratory project, Informant 3C served as the designated design manager, overseeing the project's second phase, while acknowledging that a colleague had initially been involved in the project's initial phase.

Value for others
Informant 3C highlighted that their company brought unique value to the Zeb Laboratory project through their expertise in managing processes and controlling costs. They excelled in effectively organizing and overseeing project activities, ensuring smooth operations. Their proficiency in accurately calculating and managing project expenses played a crucial role in the project's success. Furthermore, their collaborative approach, working closely with the architect and key advisors, fostered a cohesive team dynamic. Their extensive knowledge of efficient construction practices further enhanced their contribution to the project.

Informant 3C also mentioned that their entry into the project was at an early stage, prior to the development of any design. The decision to proceed with the project had already been made, but at that point, there were only ambitious goals and intentions without any concrete drawings or plans. Their involvement began when they were assigned to be part of the project team to help shape and realize those ambitions.

Informant 3C explained that their company's value proposition was not based on specific groundbreaking features or innovations, but rather on the expertise and management processes they brought to the project. They emphasized the importance of effectively integrating the expertise of the project team, including the involvement of NTNU and SINTEF. Their offering focused on describing the processes they would implement to foster innovation and collaboration. In terms of differentiation from competitors, informant 3C mentioned that they were not privy to the specific details of their competitors' offers. However, they mentioned that their company performed well in various evaluation criteria, including the process management, the team composition, and the economic aspects of the project.

Value for themselves

Informant 3C highlighted several professional values that their company gained from the project. They mentioned that the project provided a valuable learning experience, particularly in terms of early involvement in contracts and the unique way of working. The project's focus on sustainability and environmental considerations also contributed to their company's knowledge and expertise in that area. These learnings have been instrumental in branding their company and winning similar projects. Additionally, they emphasized the importance of sharing the knowledge gained from the project with other parts of their organization, further enhancing their capabilities.

Regarding the early involvement of the contractor, Informant 3C expressed several positive aspects. They mentioned that early involvement helped mitigate conflicts among stakeholders and fostered a sense of trust and effective communication. They also highlighted the satisfaction of working towards a shared goal and the ability to drive the project forward more efficiently by considering multiple aspects simultaneously, including cost and stakeholder needs. Informant 3C believed that the early involvement and collaborative contract structure were crucial for achieving the project's innovative goals.

Expertise

In realizing the use value and overall project values, Informant 3C emphasized the expertise and resources their company provided. They highlighted project management and process management as crucial contributions, ensuring that the project could be successfully built within the allocated resources. Cost management was also a key aspect that their company brought to the table.

Regarding the use value, Informant 3C acknowledged the importance of early involvement and collaboration with external partners, particularly NTNU and SINTEF, who brought sustainability and research knowledge to the project. Workshops and extensive involvement were conducted to ensure that the right expertise was incorporated. Informant 3C mentioned that finding the right balance of involvement was a challenge, but over time, they were able to establish a productive collaboration between the design team, users, and researchers. This integration of different knowledge domains was essential for the project's success.

Partners

To realize the use value and overall project values, Informant 3C mentioned the various partners they collaborated with. These partners included architects, construction advisors, technical advisors, specialists in sustainability, and contractors specializing in electrical systems. These partners played a crucial role in designing and integrating the building's features, such as its solar power system. The collaboration extended to specialists from organizations like SINTEF, with whom the technical contractors communicated to ensure the project aligned with the scientific objectives. The involvement of these partners was instrumental in ensuring that the building could be utilized effectively for research purposes by SINTEF and NTNU.

Stakeholders' involvement
Informant 3C explained that effective communication and user involvement were ensured through the project manager from NTNU. NTNU played a crucial role in teaching the project team about the expertise and knowledge required for the project. Researchers from NTNU were involved in the decision-making processes both in the front end and during the execution phase. Their involvement helped in implementing the expertise into the project and asking challenging questions during the design and planning stages.

The technical advisors were also key contributors to effective communication and user involvement. While they initially faced challenges as they were accustomed to being the experts in their respective fields, they learned a lot from the project and the experts involved. Their involvement throughout the project allowed for continuous questioning and adjustments to the design, ensuring that user needs were met.

It was important to strike a balance in involving the experts. They were not full-time members of the project team, but rather acted as advisors who could provide valuable insights and guidance when needed. This approach allowed the project team to have autonomy in solving problems while benefiting from the expertise and input of the users and advisors.

Regarding the challenges faced in engaging users during the early phases, informant 3C mentioned that one of the main challenges was establishing the right boundaries between the users and the project. It was important to involve the users at the right time and to the right extent, ensuring that their expertise and perspectives were heard and utilized. However, it was also crucial to maintain a balance that allowed the project team to have creative freedom and space to develop their ideas.

Informant 3C acknowledged that finding this balance was difficult in the beginning, as the boundaries were not initially well-defined. Open communication and dialogue between the project manager, the team, and the users played a significant role in addressing these challenges and establishing effective engagement strategies.

Informant 3C emphasized the significant contribution of the involvement of building users and stakeholders to the success of the project, particularly in terms of user satisfaction and building performance. The project management team from NTNU and SINTEF, being the actual users of the building, had valuable insights into their own needs and requirements. This insider knowledge played a crucial role in ensuring that the project aligned with the expectations and requirements of the end-users. Informant 3C believed that if someone without that level of understanding and proximity to the user group had been the project manager, the project might not have been as successful.

Additionally, informant 3C highlighted the close involvement of students in the project. They were engaged in various tasks such as measuring temperature and moisture levels during the construction phase, which provided valuable data for decision-making. The collaboration with students extended to laboratory tests for designing components in the best possible way. This involvement was mutually beneficial, as it offered students a unique learning experience while also providing valuable support to the project. When asked about any negative aspects of students involvement, informant 3C did not recall any specific negative experiences. However, they acknowledged that the involvement of students and the frequent visits to the construction site did consume a significant amount of time and effort. Despite the time-consuming nature, informant 3C viewed it as mostly positive, as it generated interest in the project and instilled a sense of pride among the participants.

Early phase activities
Informant 3C highlighted that regular team meetings were crucial in achieving the use value for all stakeholders in the project. These meetings provided a platform for the entire team to gather on a weekly basis and work together towards the project goals. Additionally, Thematic group sessions were conducted, allowing different designers and advisors to focus on specific aspects of the project in a parallel manner. This approach facilitated innovation and made it easier to address the project's challenges effectively.

The use of visualization tools such as beam and virtual reality (VR) was emphasized by the informant 3C. These tools helped in visualizing the project and engaging stakeholders in the decision-making process. Furthermore, the involvement of scientists and students played a significant role in achieving the use value. Their participation not only contributed to the project's research objectives but also brought fresh perspectives and ideas to the table.

In formant 3C believed that workshops which were organized to address specific areas of the project, such as the ZEB com component and solar power provided opportunities for learning and skill development, enabling the team to overcome project-related challenges effectively. Informant 3C also mentioned the importance of team building and creating a safe and creative environment. Activities were conducted to foster collaboration, strengthen relationships, and ensure that everyone in the team was aligned with the main project goals. Continuous evaluation was emphasized as a vital aspect of team building. In every meeting, the team would evaluate their progress, identifying what was working well and what needed improvement. This constant focus on self-assessment and seeking ways to enhance performance contributed to the overall success of the project.

Informant3C explained that during the early phases of the project a process of iteration and considering various factors led to the building's success.Also, the energy aspect of the project played a crucial role in determining the design decisions. Solar power was identified early on as the chosen energy source, and the building was designed to maximize energy production from solar panels while minimizing other energy consumption and material waste during construction and operation.

One of the significant design decisions was the extensive use of wood instead of traditional materials like concrete and steel. This choice was aligned with the objective of sustainability and had implications for the overall building design. The building had to be specifically designed to accommodate wood construction methods, rather than simply inserting wood into an existing design. Another important aspect was the placement of solar panels and how it influenced the overall design and the balancing act of optimizing solar power production.

Informant 3C also mentioned exploring other options for heating the building, but the focus was on maintaining a minimalist approach and ensuring that energy input did not exceed output. This emphasis on balance and minimizing unnecessary elements played a role in the decision-making process.

Risks

Informant3C mentioned that there were financial and professional risks associated with the project. From a financial perspective, the contract type was new for their company, and the size of the project was relatively small compared to the resources allocated to it. However, they saw it as an opportunity to learn and gain experience in sustainable building and craftsmanship. Managing the contract, particularly transitioning from the design phase to the actual construction phase, was challenging and carried financial risks.

Informant 3C emphasized that the main goal for their company was the successful completion of the project rather than the financial aspect. They wanted to ensure that they could deliver and solve the project effectively, which was a crucial goal for them.

Regarding risks that were avoided, informant 3C mentioned the importance of knowing the project's budget or limits. In some projects, the company may not have access to that information as customers tend to withhold it to maximize their profit. However, in this project, the customer was open about the budget, which helped mitigate that risk. Additionally, there was a one-year break in the project due to external factors, which required changing the personnel involved. While it posed a risk, it was more of a concern for the customer, as their company had to adjust their team accordingly.

Informant 3C mentioned that they were willing to take certain risks to deliver value for other stakeholders involved in the project. Unconventional solutions and scientific projects were implemented, which would not have been possible in normal projects due to technical approvals. However, in this project, the client and other stakeholders were open to taking risks because it was a scientific project. The contractor company was also willing to go along with these unconventional approaches because the client wanted them to.

There were discussions and agreements made regarding the responsibilities and boundaries between the contractor and the scientific aspects of the project.

It was important to define where the company's responsibility ended and where the scientific research took over. While there were challenges in determining these boundaries, the informant 3C stated that it worked out fine through discussions and agreements.

Lessons learned

From this project, informant 3C has learned the importance of early involvement and collaboration to maximize the project's potential. They mentioned that this approach was not typically feasible in other types of contracts. Informant 3C emphasized that building and maintaining trust throughout the project was crucial but also challenging. It required open communication, honesty, and a genuine willingness to work for the project's best interests.

Informant 3C also highlighted the need for continuous effort in maintaining trust, as it was not something that could be taken for granted. They mentioned that being clever or playing games was not suitable for a project like this, as trust was a key factor. The speaker acknowledged that discussions and compromises were inevitable, but it was essential to ensure that all parties benefited from the project's success.

Furthermore, informant 3C noted that this project required a different mindset compared to traditional contracts. Instead of solely focusing on personal gain, they recognized the importance of considering the best interests of all stakeholders involved. This approach required the right kind of people who were willing to work collaboratively and prioritize the success of the entire project.

From the sustainable features and goals achieved in this building project, informant 3C has learned that many of the solutions for sustainability are not complex or groundbreaking. Instead, they are often based on basic principles and commonsense thinking. The key lies in having a strong focus on sustainability and being committed to it throughout the project, even when faced with challenges. Informant 3C emphasized the importance of having a contract and project structure that enables everyone involved to work towards the same sustainability goals. This alignment and shared purpose make it easier to achieve those goals and overcome obstacles along the way.

Informant 3C's key takeaway is that the focus and mindset of the project team are more important than relying on individual geniuses or experts. It is about the collective desire to work towards a common direction and goal. This applies not only to sustainability but also to other main project objectives.

In future projects, informant 3C intends to bring this understanding of the importance of focus and shared goals. They recognize that maintaining a consistent focus on sustainability or any other key objective requires ongoing effort and dedication from the project team. By emphasizing this focus and working together towards a common purpose, informant 3C believes that significant achievements can be made in sustainability and other project goals.

Informant 3C expressed a desire to see the successful elements of this project implemented in more mainstream projects. While the current project is often viewed as unique and specialized, informant 3C believes that similar sustainability-focused approaches could be applied to commercial office buildings, kindergartens, or other mainstream projects. They see it as an opportunity to push the boundaries of sustainability further and demonstrate its potential in different contexts.

Additionally, informant 3C mentioned the importance of the contract structure used in this project. They expressed a wish to see more projects adopting a similar collaborative and trust-based contract model, as it proved successful in this case. Informant 3C finds it surprising that the client, is not implementing this model in their other projects, despite the positive outcomes observed. They believe that embracing such a contract structure could lead to even better projects in the future.

Informant 3C believes that one of the barriers for SINTEF, the client, and other companies in adopting this type of contract is a lack of knowledge and familiarity with the approach. Since it's a relatively small part of SINTEF that has been involved in this successful project, there might be limited awareness within the company about the benefits and potential of such contracts. Many people in the construction business are more accustomed to traditional contract models, and there may be a perception of risk in venturing into something new.

Informant 3C highlights that the whole point of this collaborative and trust-based contract model is to reduce risks for both the client and the contractor. However, some individuals may not fully realize this and view early involvement of contractors as risky. The issue of trust also plays a role, as there may be concerns about sharing control and decision-making with the contractor early in the project.

Furthermore, Informant 3C suggests that the construction industry needs to work through these barriers and overcome the resistance to change. Increasing knowledge and awareness about the benefits of early contractor involvement and collaborative contract models can help pave the way for their wider adoption in future projects.

Informant 3C explains that building trust as a contractor involves several key aspects. One important factor is adopting an open book approach, where contractors transparently share their costs and financial information with the client. This transparency helps establish trust and demonstrates a commitment to working collaboratively.

Additionally, they believed that trust-building extends beyond the numbers and involves personal interactions. Contractors need to invest time and effort in getting to know the client and building relationships on a human level. This includes effective communication, ensuring that information is clearly conveyed and understood by all parties. Finding the right balance in communication, providing the necessary information without overwhelming the client, is crucial.

According to the informant 3C, another aspect of building trust is being willing to give and take. This means being flexible and accommodating in finding mutually beneficial solutions throughout the project. It may involve making small compromises in certain areas while expecting reciprocation in others. This collaborative mindset helps foster trust and creates a positive working relationship.

Informant 3C explained that the lessons learned from this project, such as early involvement, trust-building, open communication, and a collaborative mindset will be applied to future projects. Informant 3C expressed that they understand the value of these principles in fostering successful project outcomes and will likely seek to incorporate them into their future projects to achieve similar positive results.

Insights from the client, Energy Academy Europe

This section presents the insights and perspectives gained from the interview conducted with the project managers involved in the construction of the Energy Academy Building Europe project. The construction managers, referred to as Informant 6G and Informant 7G, provided valuable information regarding their experiences, beliefs, and contributions to the project during this critical phase. Informant 6G, a project manager representing the Groningen campus development team, shared details about their background and engagement in the Energy Academy Europe project. They explained that they currently hold the role of project manager for another ongoing construction project. As part of their responsibilities, they have been involved throughout the engineering and realization stages of the EAEB project. In response to the question about the connection between the Energy Academy building and the new construction project, Informant 6G clarified that there is indeed a connection. Both projects are linked through their affiliation with the same faculty, namely the Faculty of Science and Engineering.

Informant 7G introduced themselves as an integral part of the project, along with Informant 6G. Their primary responsibility revolved around guiding communications related to the Energy Academy Europe project. They mentioned various mediums through which they have shared information, such as videos, web content, magazines, and other publications. The aim was to provide comprehensive information to both future users of the building and the wider public. During the construction phase of the EAEB, Informant 7G's role was focused on ensuring that the building's users had access to relevant information. They aimed to enhance understanding of the building's features and to showcase the design process and construction progress to the world. Their efforts played a crucial role in keeping stakeholders informed and engaged throughout the project.

Performance and operation

Informant 6G expressed satisfaction with the building's performance and mentioned that it has met or even exceeded their initial expectations. However, they noted that the building's performance is subject to fluctuations based on the climate, particularly regarding solar panels and weather conditions. In the Netherlands, where the building is located, they experience cold winters, which necessitate more heating. Comparatively, they mentioned that Norway has a colder winter climate, but summers are similar to those in the Netherlands. Informant 6G then initiated a discussion on the heating and cooling system used in the building, highlighting the use of water for this purpose. Informant 6G explained that the building's performance is dependent on the climate conditions of each year. If there is a sunny summer, the building's performance is expected to be higher. Similarly, if the winters are warmer than usual, the performance is also improved since less heating is required.

Informant 6G emphasized the importance of the natural ventilation system in the Energy Academy Europe building. They explained that fresh air is drawn from the outside and passes through a labyrinth system within the building. Additionally, there is a solar chimney located on the top of the building, which aids in maintaining a natural flow of air. This natural flow of ventilation is crucial for the building's operation and ensures a continuous supply of fresh air. Informant 6G further highlighted that when wind blows over the building, it helps in expelling stale air from within, contributing to a healthier indoor environment.

Informant 7G acknowledged that there were aspects of the project that could have been designed differently. They mentioned the atrium stairs, which were slightly too steep, making it challenging for people in wheelchairs to navigate comfortably. In hindsight, they expressed the need for better design considerations in that area.

Informant 6G mentioned that they have implemented a monitoring system in the building, including electricity meters and other measuring devices, to evaluate its performance and functionality. These meters allow them to track and monitor various aspects of the building's operations, such as energy consumption. By closely monitoring these metrics, they can assess whether the building is working as intended and meeting its goals in terms of energy efficiency and overall performance.

Informant 6G highlighted the positive sustainability features and energy usage of the building. According to Informant 7G, the building has exceeded expectations in terms of energy consumption, especially after optimization efforts. Even with the inclusion of laboratories, which are known to consume significant electricity, the building still generates more energy than it consumes. This outstanding performance has contributed to the building's reputation as an energy-efficient and sustainable icon for the university, campus, and the city. The building's image is widely recognized, both locally and internationally, and it has gained significant attention and admiration through online searches and social media platforms. The unique design with solar panels in a distinctive form, allowing sunlight to enter the building, has generated curiosity and discussions among people. The building's sustainability features and innovative solar panel design have made it a topic of interest and discussion among the community.

Informant 7G mentioned that the overall impression of everyone who enters the building is very positive, with many expressing admiration for the design and particularly the atrium. However, one common complaint relates to excessive air suction in the offices. In these cases, air flows from the labyrinth system into the offices, creating a strong draft that some find uncomfortable while working. As a result, people tend to close the vents to block the airflow, which restricts the supply of fresh air to the offices. This issue is seen as a drawback by those who work in the building and is a recurring complaint.

Informant 7G addressed the challenges faced in managing the facilities and operations of a sustainable building. Informant 7G mentioned the behavior of the staff as one of the challenges. Informant 6G explained that working hours in the university setting differed from regular working hours in the Netherlands. The extended working hours for research and education activities led to higher energy consumption, highlighting the need to manage energy usage effectively.

Informant 7G mentioned another challenge regarding the design aspects of the building. They stated that the intention to encourage people to take the stairs rather than using elevators failed. While people did use the stairs on the lower floors, they tended to rely on the elevators to access the higher floors. Informant 6G expressed concern about the energy implications of relying on elevators instead of taking the stairs.

Another challenge mentioned by Informant 7G was related to the winter garden, which had a distinct climate from the rest of the building and the external environment. Finding suitable plants and trees that thrived in this specific climate proved to be a difficult task. Informant 7G noted that the selection of plants and trees had undergone multiple changes before finding the right ones, but the options remained more limited than initially hoped for during the design phase.

Early phase activities

Informant 6G emphasized the significance of determining the desired level of sustainability in the early phases, whether it is outstanding or excellent, as it directly impacts the engineering process. Informant 6G provided an example related to materials selection. When aiming for an outstanding level of sustainability, more considerations and requirements must be addressed during the building phase compared to lower levels. Informant 7G further explained that the building utilized daylight to reduce energy consumption from LED lights as another example. However, solar panels work most efficiently when placed flat on the roof, which obstructs the access of natural daylight. Finding the best solution to balance these conflicting requirements was necessary. Informant 7G added that the current design of the solar panels provided more evenly spread energy throughout the day, with increased energy production in the morning and evening. This was achieved by optimizing the orientation and angle of the solar panels. Informant 6G highlighted that mounting the panels flat on the roof would result in peak energy production at noon, which is less desirable.

Informant 6G clarified that there are two distinct engineering processes: one focuses on understanding how users will interact with the building, while the other involves technical aspects such as energy solutions. While users' feedback on functionality is valuable, their input regarding technical installations may be limited.

Users may not have detailed knowledge of energy systems like solar chimneys but can provide insights on their experience within the building.

During the early phases of the project, some innovative and unique approaches were taken that contributed to its success. Informant 6G mentioned the importance of the labyrinth in the ventilation system, as well as the combination of LED lighting, windows, and solar panels. This integration of natural light and solar energy generation was considered a unique method and a source of pride in solving the problem. The focus on simplicity and utilizing natural elements in the design philosophy, with the principle of "less is more," was considered important from the beginning of the project

Informant 7G emphasized the significance of the large atrium in the building, which serves both as a functional room and a crucial component of the ventilation concept. The natural flow of warm air from the atrium to the rooftop is essential for efficient ventilation, and it also enhances the overall experience for people entering the building.

Informant 6G acknowledged that conflicts can arise in any project, particularly when different stakeholders have varying perspectives and desires. To manage these conflicts, effective communication is key. By ensuring that all stakeholders are well-informed and involved, conflicts can be addressed and resolved. Informant 6G emphasized the importance of information and communication in resolving conflicts. Providing regular updates, newsletters, or other forms of communication helps keep stakeholders informed and reduces misunderstandings.

Informant 7G provided an example of conflicting preferences regarding large windows. While some people may prefer more privacy and window coverage, the concept of the building prioritizes transparency and large windows. In this case, the concept takes precedence over individual preferences, and the building team communicates this clearly to stakeholders. Informant 6G further emphasized that the concept and overall goals of the building, such as energy efficiency, are considered when making decisions. If a user's request conflicts with the building's concept and energy consumption goals, the team explains the reasons why the request cannot be accommodated.

Lessons learned

From the Energy Academy building project, several lessons were learned that can be applied to future projects. Informant 6G emphasized the importance of choosing the right materials, such as concrete, wood, and avoiding plastic or aluminum. This choice of materials has implications for sustainability and environmental impact.

Another key lesson is focused on reducing energy consumption in building design. Informant 7G mentioned the importance of constantly questioning how to minimize energy needs and finding ways to utilize natural elements effectively. This includes considering factors like orientation, solar heating, geothermal energy, and optimizing air circulation.

Additionally, considering the functional layout of the building was highlighted. Informant 6G provided an example of locating laboratories on the north side of the building to reduce the need for excessive cooling due to sun exposure. This highlights the significance of thoughtful placement of different functions within a building to optimize energy usage.

In terms of cost considerations, Informant 6G mentioned the concept of total cost of ownership. This approach involves calculating the overall costs of an investment over the lifespan of the building, typically around 40 to 50 years. This perspective emphasizes the long-term financial implications of design and engineering choices, where investing more upfront may lead to lower costs over the building's lifespan. They mentioned that in their context, life cycle costs are considered, which aligns with the idea of assessing costs over the entire lifespan of the building.

Informant 6G emphasized the importance of setting a goal for the engineering team to create a building with minimal energy consumption. This objective guides the engineers to calculate and propose solutions that align with the goal of energy efficiency. Choices are made based on selecting options with the lowest energy consumption for the building.

Informant 6G acknowledged that the building indeed had an inspiring effect for other projects. However, Informant 6G clarified that they decided not to seek BREEAM certification for this subsequent building due to its large size and associated costs. They explained that BREEAM certification, while an excellent process, is expensive. Informant 6G highlighted that certain aspects of BREEAM were utilized in the new project, but not the entire certification process. They further expressed that not all aspects of BREEAM were deemed necessary for their projects, implying that only advantageous elements were incorporated.

Informant 7G added to the discussion by emphasizing the time-consuming nature of the complete BREEAM management process. They mentioned that fulfilling the entire process was no longer advantageous for other buildings. Consequently, they currently focus on utilizing the beneficial aspects of BREEAM for design purposes rather than engaging in the entire management process. In order to provide a better understanding of the BREEAM certification process, Informant 6G proceeded to showcase a credit list prepared by the BREEAM advisor. They explained that the credit list outlined the points and credits achieved for the Energy Academy building. Informant 6G emphasized that the building had received an outstanding evaluation based on the credit list. They highlighted the involvement of various stakeholders in the project, including building construction, architects, constructors, and more. Informant 6G stressed the importance of utilizing such a list throughout the project, from engineering to implementation. They further elaborated on the categories covered by BREEAM certification, such as management, health and well-being, energy, logistics, transport, water, materials, waste, and ecology.

Informant 6G discussed the importance of points in achieving an outstanding certification. They mentioned that the Energy Academy building received

9 points, resulting in a five-star outstanding rating. They emphasized that any changes in the engineering or realization process had to be carefully evaluated to ensure they contributed enough points for outstanding certification. Informant 6G provided examples of improvements made during the realization phase, such as better LED lights and improved warm and cold cooling systems, which contributed to gaining additional points. Communication and engagement were highlighted as crucial aspects of BREEAM. Informant 6G discussed the significance of internal and external communication, including publications and discussions about the building's energy efficiency and construction. They emphasized the importance of sharing information with various stakeholders to educate them about the building's energy consumption and operations. They acknowledged that while some points may have been lost during the process, overall, the building achieved an outstanding certification.

Informant 7G also pointed out a lesson learned regarding accessibility. The building's design, with different heights for each floor, may not be optimal for individuals using wheelchairs or with impairments. They recognized the need for improvement in this aspect in future projects.

Insights from the advisors in the design phase, Energy Academy Europe

This section presents the insights and perspectives gained from the interview conducted with the advisors involved in the design phase of the Energy Academy Building Europe project. The advisors, referred to as Informant 4A and Informant 5A, provided valuable information regarding their experiences, beliefs, and contributions to the project during this critical phase. Regarding their professional background, Informant 4A shared their firm's specialization in developing innovative concepts and their reputation for providing comprehensive project management services. They highlighted the unique approach of combining end user participation and project realization, along with project and process management. This approach was deemed crucial for accurately capturing the project requirements and ensuring the delivery of maximum quality within the allocated budget.

During the interview, Informant 4A drew parallels between the Energy Academy Building Europe project and a previous project they had worked on, called Eriba. The success of the Eriba project, which involved the European Research Institute on the Biology of Healthy Aging, likely played a significant role in their selection as advisors for the Energy Academy Building Europe. The urgency to establish the project promptly, as mandated by politicians, further emphasized the need for efficient organization and swift execution. In addition, Informant 5A emphasized the importance of collaboration and connecting various stakeholders during the design phase. They highlighted their firm's strong connection with the university and successful collaboration on the previous projects. This experience created a favorable impression that their firm was capable of bringing together diverse stakeholders in a new building. Moreover, Informant 5A stressed the significance of creating a space that effectively connects different users in the Energy Academy

Building Europe. By drawing upon their previous collaboration and understanding of user integration, Informant 5A's firm was well-equipped to facilitate the integration of users with distinct needs and expectations. The aim was to create an environment that fosters collaboration, innovation, and a sense of community among building occupants.

Project goals and objectives
Informant 4A emphasized that the Energy Academy building was not solely an office space for students and researchers, but also incorporated high-tech laboratories. Informant 4A mentioned that the previous building, similar to the current one, featured classified laboratory rooms combined with working spaces and meeting areas. These facilities were designed to cater to the needs of professors, visitors, and companies, showcasing the diverse nature of the building's functionalities.

Informant 4A provided additional insights into the design process of the Energy Academy building, specifically regarding the brief and its objectives. They mentioned that the brief, which was approximately 10 years old, aimed to bring together various parties involved in the energy transition. The primary goals were to foster innovation and facilitate the circulation of knowledge between education, companies, and research institutes.

Informant 4A shared a summary of the brief, indicating that the Energy Academy building encompassed around 10,000 square meters. The design process involved a group of stakeholders from different organizations, with a particular emphasis on the collaboration between the university of Groningen and the Hanze University of Applied Sciences, both of which shared a campus. Several meetings were conducted with these stakeholders to write the brief and gather their input. Informant 4A mentioned the use of intensive pressure cookers, a study trip, and interviews with various parties involved.

Informant 4A provided an overview of the Energy Academy building and its strategic positioning within the campus. They emphasized the importance of capturing the bigger picture in the initial brief and avoiding excessive detail. The goal was to create a building that would serve as an icon for the energy transition and practice what it preached.

Informant 4A explained that the campus had undergone a shift in its organizational structure. Rather than focusing on individual buildings for each faculty, they aimed to create a more interconnected and flexible environment. The main movement through the campus was redesigned, and hotspots and meeting points were strategically placed to facilitate collaboration and interaction among users. The location of the Energy Academy building was chosen to maximize its visibility and impact, serving as a focal point upon entering the campus.

Informant 4A further described the goals and functions of the Energy Academy building. It was intended to support entrepreneurship, serve as a research institute for both fundamental and applied research, and provide an educational environment. The building aimed to attract various users, including incubators, companies, researchers, and educators, fostering a vibrant and diverse community. The design concept of the building involved two interconnected spaces, one focused on conferencing, workspace, and showcases, and the other dedicated to research and laboratories. The Plaza played a central role in connecting these spaces and facilitating interaction. Informant 4A emphasized the importance of creating a welcoming and inclusive atmosphere by avoiding the prominent display of university names on the facade and instead branding it as the Energy Academy, open to all.

In terms of sustainability, Informant 4A mentioned that the Energy Academy building was designed to meet BREEAM (Building Research Establishment Environmental Assessment Method) outstanding standards, reflecting their commitment to environmentally friendly practices. Informant 5A provided insights into the sustainability aspects of the Energy Academy building. He mentioned that their focus was on realizing a sustainable building and reducing energy consumption. Instead of immediately delving into HVAC systems and other installations, they prioritized building physics, which helped in minimizing the need for additional energy-consuming components. Informant 5A highlighted the importance of a holistic approach to sustainability, going beyond just energy considerations. During discussions on sustainability, they suggested using BREEAM (Building Research Establishment Environmental Assessment Method) as a measurement standard, considering it to be the highest benchmark for sustainability at that time. They aimed to achieve the BREEAM Outstanding rating, which was unprecedented in the Netherlands, given the Energy Academy's stature as a top institute. By setting such an ambitious goal, the design team was motivated to create the most sustainable building in the country. Informant 5A emphasized that sustainability encompasses various aspects, including biodiversity, water management, transportation, and circularity. Therefore, their efforts extended beyond energy efficiency to address these broader sustainability goals.

Performance and operation

Informant 4A explains that many innovative solutions were developed for the Energy Academy building, some of which had never been done before. One example is the air cooling system inspired by ancient Iranian architecture, where a pond and underground tunnel were used to cool the air before circulating it through the building. This combination of high-tech and low-tech solutions created a hybrid system. Informant 5A added that the sustainability of the building was measured using the BREEAM method, which required the installations to perform well even when the climate conditions were not ideal. By incorporating low-tech solutions such as the solar chimney and labyrinths, the building achieved a high level of sustainability. The certification process for sustainability also included the evaluation of the entire installation system.

Informant 4A explained that in their projects, they believe in providing a mixture of different spaces to accommodate the diverse needs and preferences of users. Some individuals may prefer open spaces, while others may require their own private offices. The decision on the interior design of the building is not based on a strict dogma of having everything open or closed, but rather on understanding and respecting the needs of the users. They mention the field of environmental psychology which focuses on how the perception of the environment affects individuals. Research in this field suggests guidelines such as having a limited number of people visible from a desk, incorporating plants or other elements of interest, and considering different spatial arrangements based on the activities performed.

Informant 5A mentioned that the users of the Energy Academy building are generally happy with the ventilation system, transparency of the building, and the efficient provision of fresh air. The energy use of the building has been lower than designed, and the solar panels generate more energy than needed, making the building energy-supplying rather than energy-consuming. The high standards achieved through BREEAM certification also contributed to the success of the installation concept.

The evidence of user satisfaction comes from personal interactions and feedback. For example, Informant 5A mentioned a conversation with someone attending a course at the Energy Academy who expressed pride in being associated with such a special building. The building itself becomes an icon and creates a sense of pride and connection for both permanent and frequent users. Informant 4A further elaborates on the idea of connecting oneself to a special place, using the example of the Viking Museum in Oslo. Being associated with an important place like that can enhance one's personal significance or sense of belonging, even if it doesn't necessarily make the individual more important in a general sense. It highlights the value of creating spaces that hold significance and foster a sense of pride and connection for the users.

Informant 4A emphasized that the success of the building is not solely attributed to the design and functionality, but also to the broader context and focus points set by the city government and other stakeholders. The Energy Academy serves as an icon for the energy transition focus point, which was a key priority for the city. By aligning the building's purpose with the city's goals, it became eligible for subsidies and support. This, in turn, attracted professionals from various fields who were interested in working on energy transition-related projects and securing funding. The success of the building is thus a result of a combination of factors, including its design, functionality, alignment with key focus points, and the availability of subsidies and support.

User involvement

Informant 4A explained that user involvement in the early phase, particularly in the context of school buildings and cultural buildings, has been a long-standing practice in their firm and is part of the Dutch culture. The involvement of users is seen as important to counterbalance the influence of architects and constructors and to ensure better building outcomes. They mention that their firm has been involved in various projects and collaborations related to user participation. Informant 4A emphasized that their involvement in the Energy Academy building was crucial because they understood the types of questions and needs that the users would have. By incorporating user experience and addressing user expectations, they were able to design and prepare the building for proper use and user satisfaction. Informant 4A added that although sometimes they have to convince clients about the importance of user involvement, the budget allocated for it is relatively small compared to the overall project budget. The impact, however, is significant as it contributes to user happiness and the successful utilization of the building. They also mention that studying trips and team-building activities have been effective in the process.

Informant 4A explained that in the early phase of a project, there is an opportunity to have the most influence and set the right course for the building's construction and design. By setting clear goals and direction from the beginning, they ensure that the building meets the needs and expectations of the users.

Inquiring about the communication and stakeholder involvement strategies used in the Energy Academy project, Informant 4A and Informant 5A provided valuable insights. Informant 4A mentioned that while the project was somewhat unique, it shared similarities with a previous project called ERIBA. Typically, in their projects, they have a clear understanding of the end users. However, in the case of the Energy Academy, the team didn't have a specific group of end users requesting the building. Instead, the aim was to create a space that would attract end users.

To initiate the process, Informant 4A stated the first step was to define the project's stakeholders, which initially was not straightforward. The main stakeholders identified were the university of Groningen, and the Hanze University of Applied Sciences, and several research organizations. It's important to note that these stakeholders were planning to rent the space rather than own it, which added a different dynamic to the project. A project organization was formed, often referred to as a development group or learning environment group, which comprised individuals who focused on understanding the stakeholders' needs rather than solely concentrating on design aspects. This group met a few times in pressure cooker sessions, although time was limited due to the involvement of different organizations, which posed challenges in organizing meetings.

To ensure the stakeholders' input was validated and made sense, Informant 4A emphasized the importance of a validation meeting. This involved seeking feedback from external parties or individuals who could provide an objective perspective on the stakeholders' requirements. By mirroring the stakeholders' input with validation from outsiders, the team aimed to ensure the feasibility and reasonableness of the proposed solutions.

Informant 5A highlighted the significance of validation meetings within the project and how they were designed to facilitate the process. During these meetings, Informant 4A, and the designer, presented drawings showcasing the organizational layout of the building. This visual representation prompted everyone to consider their position within the building and whether their needs were adequately addressed in the conceptual design. The visualization greatly enhanced clarity for the end users, allowing them to better understand how the building would accommodate their requirements. Furthermore, Informant 5A mentioned that when the designers became involved, they faced the challenge of aligning the energy ambitions of the project with the users' needs. The initial design possibilities included variations such as a building integrated with the dome, a square meeting area, or a multi-level structure. The designers had to navigate these technical considerations to achieve the highest energy ambitions while simultaneously fulfilling the functional requirements outlined in the user brief. By visualizing the potential layouts and showing where the end users would be situated in the building, the designers played a crucial role in translating the project's initial ambitions into the final design of the Energy Academy.

Informant 4A explained that one of the challenges they faced during the design phase was dealing with the diverse ambitions and perspectives of the different stakeholders. The end users, who held high positions in the hierarchy such as top professors and researchers, had varying priorities. For example, some were primarily focused on their own laboratory needs and research, while others were more interested in creating an iconic building. This diversity of perspectives created potential conflicts and challenges in aligning their ambitions. To address these challenges, the design team took a proactive approach. They visited the stakeholders individually, engaging in conversations to understand their specific needs and concerns. By building relationships and demonstrating genuine interest in their perspectives, they were able to foster cooperation and collaboration. In the case of the top professor mentioned, initially disinterested in the iconic aspect of the building, a personal meeting allowed for a change in attitude and increased cooperation. Furthermore, the design team created a conducive environment for communication and dialogue during the validation meetings. Sitting in a circle around a large table, everyone had an equal opportunity to express their thoughts and concerns. This open and inclusive setting allowed for constructive discussions and critical feedback. This demonstrates the successful navigation of the challenge by maintaining open communication and finding common ground. The design team was able to show the researcher that their laboratory needs could be accommodated within the broader design framework, allowing for both impactful research and a sustainable building. The challenges extended beyond conflicting ambitions to the technical aspects of the design. For instance, incorporating solar energy panels presented a challenge in terms of their optimal placement. While a simple solution would be to install them in a field and connect them to the building, this would not align with the requirements of the BREEAM sustainability standards. The design team had to think creatively and find a way to integrate the solar panels into the building's structure, ensuring compliance with BREEAM guidelines.

Informant 4A explained that during the later stages of the project, when the building was nearing completion, the design team allowed a group of end users to determine their preferred working spaces within the open floor fields. The end users had the opportunity to explore the space, envision their working environment, and provide input on the design of the furniture and layout. The end users expressed their preference for an open and flexible workspace, while also recognizing the need for quieter areas when necessary. They proposed the use of special furniture, such as high chairs and designated spaces with plants, to create more secluded and peaceful zones within the open floor plan. Informant 4A explained that the design of the Energy Academy was prepared to accommodate different layout possibilities, whether it be a floor with various rooms or an open floor plan. This flexibility was incorporated into the design phase to ensure that the building could adapt to different needs. However, if a contractor had already been involved in the early stages, making changes to the layout during the construction phase would have been more challenging.

Informant 4A emphasized that when considering end user participation in architectural projects, it is important to understand that the users' interests lie primarily in their immediate working environment. Factors like acoustics, chair and table quality, and the arrangement of their surroundings directly impact their daily work experience. These micro-level considerations are crucial for ensuring user satisfaction and productivity. Informant 5A added a lighthearted remark about the importance of proximity to the coffee machine, highlighting the practical and functional aspects that end users often prioritize.

In terms of involving the users in using the building efficiently and sustainably, Informant 4A explained that the design aimed to make it intuitive for users. For example, the layout of the building encouraged the use of stairs instead of elevators, and there were connections designed to facilitate interactions between different parts of the building. Additionally, the building incorporated energy-saving features such as automatic adjustments to the ventilation system when windows were opened, reducing the need for users to actively think about energy consumption. Informant 4A compared the building's system to a hybrid car, emphasizing the combination of sustainable elements with conventional ones to create an efficient and effective overall solution.

Informant 5A discussed the challenge of managing users in the Energy Academy building, particularly because many users were not initially defined at the project's outset. They explained that the design team had to make educated guesses about which parts of the building would cater to specific user groups. By drawing upon their own experiences and understanding of the organizations involved, the team estimated the size of spaces for different users and crafted a project brief accordingly. This involved comparing the desired size and technical specifications requested by the customers with the team's knowledge of how the organizations operated.

Informant 5A further elaborated on the engagement with end users during the design process. Typically, the design team would have direct contact with end users to understand their specific needs. However, in this instance, they created an environment where end users could be involved later in the process. Workshops were conducted with different parts of the organization to gather their input on office space requirements and design preferences.

Informant 5A highlighted the importance of adopting a flexible approach in the design of the Energy Academy building. He emphasized that the energy transition involves a transition of parties working together. If the design process had been focused solely on one type of user, the building might have ended up tailored specifically to their needs. However, by considering the flexibility of the building, they ensured that it could accommodate the transformation of users over time. The design of the building incorporated this flexibility as a key aspect.

Informant 5A also mentioned that the Energy Academy building marked the first time the Hanze University of Applied Sciences and the university of Groningen collaborated in one shared building. Previously, they had operated from separate buildings. This shared space allowed for increased collaboration and synergy between the two institutions. The decision to bring together different parties and accommodate their changing needs and collaborations reflects a strategic approach to fostering a dynamic and adaptable environment within the Energy Academy building. By providing flexibility in design and facilitating collaboration between previously separate entities, the building aimed to support the evolving nature of the energy transition and promote effective knowledge exchange among stakeholders.

Early phase activities
Informant 5A explained that the contractors were not involved in the initial design phase of the project. The organization followed a traditional approach where the process began with the creation of a project brief, followed by the design phase. The involvement of the contractors came later in the procurement process. Regarding the procurement method, Informant 5A mentions that they were not directly involved in that aspect. However, the procurement was carried out in a traditional manner. At the end of the design phase, the technical information and drawings were sent to the contractors. The contractors then provided a price estimate and proposed an implementation plan or project plan. These proposals were evaluated based on price and the viability of the plan before making a final decision.

Informant 4A stated that procuring top engineers with creative thinking was a unique aspect of the project. They needed to carefully consider how to attract and secure the expertise of these engineers, even though they come at a higher cost. Furthermore, Informant 5A highlights the importance of creating a strong and collaborative team. The team went on a two-day excursion to visit other buildings in Amsterdam and engage in discussions, which not only provided inspiration but also helped foster a sense of camaraderie. This teamwork and open environment allowed for fruitful discussions and exchange of ideas between different specialties, ultimately making the building stronger.

Informant 4A explained that they managed to balance the needs and desires of different stakeholders by investing in team building and being aware of individual dynamics within the team. They organized excursions and activities to foster a sense of unity among team members. Additionally, their experience in procurement helped them identify individuals who were more inclined towards conflict or prioritizing financial gain over collaboration. By being mindful of these dynamics, they were able to select team members who were more likely to be team players and contribute to a harmonious working relationship. This proactive approach helped prevent conflicts from arising and facilitated better collaboration among the stakeholders involved in the project.

Informant 5A emphasizes the importance of connecting with team members as a crucial part of the process. They highlight the team building activities conducted at the beginning of the design phase, which helped foster strong bonds among the team. In addition to team building, they also organized excursions, including one to France for a solar panel exhibition. While in Paris, they found that the connections they made with each other during the excursion greatly facilitated problem-solving and enhanced their design process. Walking through the streets together and engaging in discussions allowed them to collaboratively address challenges and come up with innovative solutions. As a result, their strengthened teamwork led to a better technical solution than they had initially anticipated.

Informant 4A highlighted the importance of establishing connections and building relationships among stakeholders early in the building process. They point out that traditionally, celebrations and social interactions occur at the end of the project during the contract signing and reception. However, they believe that it is more beneficial to have these interactions at the beginning of the process. By starting with a party or social gathering, stakeholders have the opportunity to get to know each other, learn about their hobbies and interests, and establish a rapport. This early connection and shared interest can foster a more collaborative and productive work environment throughout the project. They mentioned that this approach is not limited to this specific project but is something they often practice in other projects as well.

Informant 4A emphasized the importance of clarifying the tasks and activities in the early phases of the project. They mention that understanding the perspective of end users and connecting with their needs is crucial. In addition, they highlight the significance of conducting board room workshops to determine the project's ambitions and focus points within the given budget. This allows for discussions and decisions on themes such as sustainability, quality of learning environment, iconic architecture, and surroundings. By addressing these aspects early on, the project team can allocate the budget accordingly and avoid potential conflicts later in the process. Informant 4A also mentioned the need to manage various budgetary considerations, such as balancing the costs of architectural design elements and other essential components of the project. Having these discussions at the beginning helps align the stakeholders' expectations and ensures a smoother workflow throughout the project.

Informant 5A mentioned that early phase activities and end value creation are interconnected. They explain that having a good set of information and understanding the end user experiences at the beginning of the project contributes to creating value for the stakeholders in the end. Their organization combines the knowledge and experiences from previous projects to inform the design and construction phases of new projects. By using this experience and incorporating it into the initial brief, they can inspire and bring value to new projects from the start. Informant 5A believed that this approach leads to better buildings and ultimately creates more successful outcomes. They provide an example where the knowledge gained from a previous project, ERIBA, was applied to the Energy Academy, resulting in an even better and more successful building.

Informant 4A highlighted several approaches and considerations in the projects in early phases. Firstly, they mention the development plan for the campus, which is updated every five years to adapt to future needs and uncertainties. This flexible approach ensures that the campus remains resilient and fit for the future. They also discuss the concept of end value money in project development, where investing in certain aspects such as schools, playgrounds, and shops can increase the value of properties. This collaborative approach between project developers and the city aims to enhance the overall value and quality of the community.

Informant 4A further introduced the concept of societal impact, exemplified by a situation involving a school and a nearby coffee shop that sells drugs. They raised concerns about potential negative effects on students, such as addiction, crime, and associated costs to society. However, quantifying the exact value or cost of such societal impacts proves challenging, as it is difficult to calculate or predict these outcomes accurately. Informant 4A went on to mention a positive example of investing in free breakfast for children in schools, which has been shown to improve their learning outcomes, energy levels, and focus. This highlights the potential value that can be created by investing in specific areas, even though it may not be easily measurable or quantifiable in a spreadsheet.

Lessons learned

Regarding the lessons learned from this project, Informant 4A acknowledged that the Energy Academy project primarily emphasized energy efficiency. However, they believed that sustainability should be approached more broadly, considering aspects such as circularity and building materials. They noted that these elements were not extensively addressed in the Energy Academy building but questioned if some minor considerations had been made.

Informant 5A concurred with Informant 4A's viewpoint, acknowledging the project's energy-focused approach due to the use of BREEAM certification. They highlighted the need to expand sustainability efforts to include circularity, biodiversity, health, and water management. They stated that during their preparations for the interview, they were convinced of the effectiveness of basic techniques, such as underground ventilation and low-tech energy solutions, combined with proper insulation and building physics. They emphasized that such low-tech solutions make buildings more robust, require less maintenance, and have longer lifespans compared to installation-intensive approaches. They recommended adopting this approach in future projects, starting with building physics and then addressing the remaining challenges using installation techniques.

Informant 4A emphasized the crucial role of Informant 5A and building physics in various projects. They acknowledged that architects often overlook the importance of building physics, assuming that they can handle it themselves. However, Informant 4A highlighted that building physics plays a vital role and should be given due consideration right from the beginning of a project. Informant 5A shared a valuable tip during the presentation about the building, emphasizing the need to prioritize building physics over selecting an architect. They emphasized that building physics, as a specialty, defines and shapes the overall experience of the building. It encompasses factors such as temperature regulation, air quality, daylighting, and user comfort. They stressed that approximately 80% of the user experience is influenced by how the building functions in relation to its climate conditions. If the building's internal environment is well-regulated and comfortable, it eliminates potential complaints from users, allowing them to focus on their work. They suggested that placing building physics at the forefront of the project ensures a high level of user satisfaction. Informant 5A further highlighted the significance of the layout and connectivity within the building but emphasized that building physics takes precedence over architectural considerations. While people may have initial thoughts or opinions about the architectural design, once they are inside the building, their primary concern becomes the indoor environmental quality. They emphasized that a well-functioning building with optimal building physics eliminates discomfort and complaints related to the indoor environment, enhancing user satisfaction.

Informant 4A emphasized that building physics not only defines the functionality of a building but also influences architectural choices. They mentioned a school building in the Netherlands that was built like pyramids, causing several issues due to improper consideration of building physics. The sun's direct exposure made the building uncomfortably hot, and rainwater leakage was a persistent problem. Informant 4A emphasized that this is a prime example of incorrect building physics and highlights the importance of integrating building physics early in the design process. They suggested that proper consideration of building physics would have led to a more efficient and functional architectural design.

Informant 5A also emphasized the importance of teamwork and its impact on project outcomes. They stated that the Energy Academy project's success was a result of a collective team effort, surpassing initial expectations. They suggested that investing in team dynamics and fostering collaboration from the project's inception significantly enhances the project's value and final results. They further recommended applying this lesson to future projects, prioritizing teamwork and fostering a collaborative environment during the initial design stages.

C - POE SURVEY- ZEB LABORATORY

Post Occupancy Evaluation of ZEB Laboratory, NTNU - Nettskjema 06/06/2023, 04:16

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Post Occupancy Evaluation of ZEB Laboratory, NTNU

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Dear Participants

As part of our ongoing efforts to ensure that the ZEB Laboratory continues to meet your needs and expectations, we are conducting a Post Occupancy Evaluation (POE) survey. This survey is designed to gather feedback from all of the building's occupants regarding their experience with the building.

Your participation in this survey is important to us, as it will help us identify areas where improvements can be made to enhance your overall experience in the building. The survey is anonymous, so your responses will be kept confidential, and your input will be valuable in helping us better understand the building's strengths and weaknesses.

We encourage you to take the time to complete the survey in its entirety, as your feedback will be critical in helping us improve the ZEB Laboratory for everyone.

Thank you in advance for your participation in this survey. Your input is greatly appreciated.

○ I consent to my data being processed until the project is completed.

E-mail address (optional)

Your email address and job information will be used for the sole purpose of enhancing the accuracy and validity of our survey results. In the event that we require additional information or clarification, we will reach out to you via email. Rest assured, your privacy is of utmost importance to us and your information will be handled with the strictest confidentiality. Your participation in this survey will contribute to the advancement of knowledge and understanding in our field of study, and we thank you in advance for your valuable time and effort.

Age *

Select ...

Employer *

Select ...

years of work experience *

Select ...

How long have you been working in ZEB laboratory? *

What is your typical work schedule in ZEB laboratory? *

Physical Environment

How satisfied are you with

	Extremely dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Extremely satisfied
the lighting *	○	○	○	○	○
the acoustics *	○	○	○	○	○
the access to natural light *	○	○	○	○	○
the access to outdoor spaces *	○	○	○	○	○
the indoor air quality *	○	○	○	○	○
the overall cleanliness and maintenance *	○	○	○	○	○
the ergonomics and comfort of the furniture and equipment *	○	○	○	○	○
solar shading *	○	○	○	○	○

How would you rate the temperature inside the ZEB laboratory building during the summer season? *

- Too cold.
- Somewhat cold.
- Just right.
- Somewhat hot.
- Too hot.

How stable do you feel the temperature inside the ZEB laboratory building during summer time? *

- Very unstable, with significant fluctuations.
- Somewhat unstable, with noticeable fluctuations.
- Moderately stable, with some minor fluctuations.
- Mostly stable, with only occasional fluctuations.
- Very stable, with no noticeable fluctuations.

How would you describe your overall level of comfort with the temperature inside the ZEB laboratory building during the summer season? *

Very uncomfortable		Neither comfortable		Very comfortable
I	I	I	I	I

Value

How would you rate the temperature inside the ZEB laboratory building during the winter season? *

- ◯ Too cold.
- ◯ Somewhat cold.
- ◯ Just right.
- ◯ Somewhat hot.
- ◯ Too hot.

How stable do you feel the temperature inside the ZEB laboratory building during winter time? *

- ◯ Very unstable, with significant fluctuations.
- ◯ Somewhat unstable, with noticeable fluctuations.
- ◯ Moderately stable, with some minor fluctuations.
- ◯ Mostly stable, with only occasional fluctuations.
- ◯ Very stable, with no noticeable fluctuations.

How would you describe your overall level of comfort with the temperature inside the ZEB laboratory building during the winter season? *

Very uncomfortable		Neither comfortable		Very comfortable
|	|	|	|	|

Value [ ]

Are there any noticeable indoor air quality issues in ZEB labratory? *

This question is designed to gather information on the indoor air quality of the ZEB labratory. Your response will help identify any noticeable issues with the air quality in the building, such as unpleasant odors or excessive dust.

Please indicate if you have experienced any indoor air quality issues during your time in the building, and if so, please provide a brief description of the issue. If you have not experienced any indoor air quality issues, please select "No" and proceed to the next question.

- ◯ Yes
- ◯ No

Building Systems

How satisfied are you with

	Extremely dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Extremely satisfied
the HVAC (heating, ventilation, and air conditioning) system *	◯	◯	◯	◯	◯
the electrical system *	◯	◯	◯	◯	◯
the plumbing system *	◯	◯	◯	◯	◯
the speed of maintenance and repairs *	◯	◯	◯	◯	◯
the effectiveness of maintenance and repairs *	◯	◯	◯	◯	◯

Have you experienced any disruptions or malfunctions with the building systems in ZEB laboratory? *

This question is designed to gather information on the building systems of the ZEB laboratory. Your response will help identify any disruptions or malfunctions that you may have experienced with the building systems during your time in the building.

Please indicate if you have experienced any issues with the building systems, such as the HVAC (heating, ventilation, and air conditioning), the electrical system, the plumbing system, and the speed and effectiveness of maintenance and repairs, and if so, please provide a brief description of the issue. If you have not experienced any disruptions or malfunctions with the building systems, please select "No" and proceed to the next question.

- ○ Yes
- ○ No

Amenities

How satisfied are you with

	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied
the availability and access to common areas and amenities *	○	○	○	○	○
the availability of technology and equipment *	○	○	○	○	○
the quality of technology and equipment *	○	○	○	○	○
the quality of workspace *	○	○	○	○	○
the quality of common areas and amenities *	○	○	○	○	○
the silent space, Plenty Pod *	○	○	○	○	○
the availability of meeting rooms *	○	○	○	○	○
the quality of meeting rooms *	○	○	○	○	○
colour theme used in the building *	○	○	○	○	○

Have any of the amenities in the building caused any inconvenience or issues during your time in the building? *

This question is designed to gather information on the amenities in ZEB laboratory. Your response will help identify any amenities that may have caused inconvenience or issues during your time in the building.

Please indicate if you have experienced any issues with the amenities in the building, such as restrooms, kitchen facilities, elevators, or other amenities, and if so, please provide a brief description of the issue. If you have not experienced any issues with the amenities in the building, please select "No" and proceed to the next question.

- ◯ Yes
- ◯ No

Functionality

How satisfied are you with

	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied
the layout and design *	◯	◯	◯	◯	◯
the access to resources and technology *	◯	◯	◯	◯	◯
the level of privacy and quietness *	◯	◯	◯	◯	◯
with the extent to which the ZEB Laboratory meets your current work requirements *	◯	◯	◯	◯	◯

Would you prefer to have individual offices or do you prefer the open landscape design? Please explain your reasoning for your preference. *

We would like to know your preference regarding workspace design. Would you prefer to have individual offices or do you prefer the open landscape design? Please explain your reasoning for your preference. Your feedback will help us better understand your needs and preferences as occupants of the ZEB laboratory building.

- ○ individual offices
- ○ open landscape design

Safety and Security

How satisfied are you with

The question asks the occupants to rate their level of satisfaction with the safety and security measures in place. This could include measures such as emergency exits, fire safety equipment, and other relevant safety and security measures. The goal is to understand how effective these measures are in providing a safe and secure environment for the occupants.

	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied
the level of safety and security for occupants *	○	○	○	○	○

Are there any areas in the ZEB Laboratory where you feel the safety and security could be improved? *

This question is designed to gather information on the safety and security of the ZEB Laboratory. Your response will help identify any areas of the building that may need improvement to ensure a safe and secure environment for the occupants.

Please indicate if there are any areas in the ZEB Laboratory where you feel the safety and security could be improved, such as lighting, access control, emergency procedures, or other safety and security concerns. If there are specific areas that could be improved, please provide a brief description of the issue and any suggestions you may have for improvement.

- Yes
- No

Sustainability

How satisfied are you with

The first question is asking specifically about the tangible, practical aspects of the building that make it more environmentally friendly and resource-efficient. Examples of sustainability features could include the use of renewable energy sources, efficient heating and cooling systems, or recycling and waste management programs. By asking about satisfaction with these features, you can gauge how effective they are at meeting the needs and expectations of building occupants.

The second question is asking specifically about the branding or perception of the building as being environmentally sustainable. Examples of sustainability images could include the use of marketing language that highlights the building's green credentials, or the use of sustainable materials in the building's design. By asking about satisfaction with the sustainability image, you can gauge how effective the building's marketing efforts are at communicating its sustainability message to occupants and other stakeholders.

	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied
the sustainability features *	○	○	○	○	○
the sustainability images *	○	○	○	○	○

In what ways do you feel that the ZEB laboratory building has inspired or influenced sustainable living practices, either within the building or in your personal life? *

How do you feel about working in a ZERO emission building compared to other traditional office buildings you have worked in? *

This question aims to gauge the respondent's overall impression of working in a zero emission building compared to more traditional office buildings. This information will be used to understand the extent to which zero emission and sustainable design may positively impact the overall work environment and occupant experience.

- 1-Much worse than traditional office buildings
- 2 - Slightly worse than traditional office buildings
- 3 - About the same as traditional office buildings
- 4 - Slightly better than traditional office buildings
- 5 - Much better than traditional office buildings

Would you recommend a zero emission building to others looking for a sustainable workplace? Why or why not? *

Please answer based on your personal experience and opinion. If you select "Yes" or "No," please briefly explain your reasoning for your answer. Your response will help us understand your opinion and identify areas for improvement in the building's sustainability and user experience.

- Yes
- No

Productivity

How satisfied are you with

	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied
the impact of the environment in the ZEB Laboratory building on your productivity and work performance *	○	○	○	○	○
the availability of the necessary resources and technology for you to be productive in your work *	○	○	○	○	○

Have you noticed any changes in your work habits since moving to the ZEB Laboratory building? *

The following question is about your personal experience working in the ZEB Laboratory. Please answer based on your personal experience and opinion.

If you select "Yes," please briefly explain the changes you have noticed. Your response will help us understand the impact of the building's design on user behavior and identify areas for improvement in the building's functionality and user experience.

- ○ Yes
- ○ No

How do you reflect about having your office in a living laboratory? *

Very negative **Neutral** **Very positive**

Value

To what extent do you think about working in a living laboratory environment while you work? *

Never		Occasionally		Always
|	|	|	|	|

Value

Have you ever been disturbed by any activities or events taking place in the living lab environment? (for example by guided tours within ZEB laboratory building) *

Last year, there were typically two group visits to the ZEB laboratory building per day. Did these guided tours/ or other venets and activities impact your working conditions in terms of noise and disturbances? If you answered "yes," please describe the impact and any specific examples you can provide.

- Yes
- No

Do you use the laboratory facilities for your work or research? *

Never		Occasionally		Very frequently
|	|	|	|	|

Value

In what ways has the living laboratory environment provided new possibilities for your research or work? *

Learning and Development

How satisfied are you with

	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied
the educational and training opportunities in the ZEB Laboratory *	◯	◯	◯	◯	◯
the extent to which the ZEB Laboratory has allowed you to advance your professional or personal goals *	◯	◯	◯	◯	◯

Have you learned new skills or technologies because of working in the ZEB Laboratory building? *

The following question is about your experience working in the ZEB Laboratory. Please answer based on your personal experience and opinion.

If you select "Yes," please briefly explain what skills or technologies you have learned. Your response will help us understand the building's role in fostering a learning environment and promoting professional development among its users. It will also inform our efforts to enhance the building's educational and training resources to better support its occupants.

◯ Yes

◯ No

Have you found the ZEB laboratory building to be an inspiration for new ideas related to sustainability or other areas? *

If yes, please describe in what ways the building has inspired you and how it has influenced your work or research.

- ○ Yes
- ○ No
- ○ Not applicable

Well-being

How satisfied are you with

	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied
the overall level of comfort in the building regarding temperature noi-se levels *	○	○	○	○	○
the overall level of comfort in the building regarding air quality *	○	○	○	○	○
the overall level of comfort in the building regarding noise levels *	○	○	○	○	○
the building's facilities for rest and relaxation, such as break rooms or quiet areas *	○	○	○	○	○
the building's approach to reducing stress and promoting well-being in the workplace *	○	○	○	○	○

Community

How satisfied are you with

	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied
the level of community and interaction among occupants *	○	○	○	○	○
the building's approach to promoting a sense of community and encouraging collaboration among occupants *	○	○	○	○	○
the level of interaction and cooperation between occupants of different departments or organizations within the building *	○	○	○	○	○
the building's efforts to support and promote diversity, equity, and inclusiveness within the community of occupants *	○	○	○	○	○

What aspects of the ZEB Laboratory do you believe contribute most to the building's sense of community and interaction among occupants? *

This question aims to gather information on the aspects of the ZEB Laboratory that contribute to creating a sense of community and interaction among occupants. The question is designed to explore the social aspects of the building that affect the users' experience. Possible answers could include the layout and design of the building, the availability of shared spaces, the frequency and nature of events and activities held in the building, and other factors that influence interaction and socialization. By understanding what occupants appreciate about the building's social environment, it can inform future design and development decisions and help create a more welcoming and engaging workplace.

User Engagement

How satisfied are you with

If you were not employed at Sintef or NTNU during the phase mentioned in the questions, please select 'Not Applicable'.

	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied	Not Applicable
the level of involvement and participation in the design phase of the building *	○	○	○	○	○	○
the level of communication and feedback provided during the design and construction phases of the building *	○	○	○	○	○	○
the opportunities for providing input and making suggestions during the design and construction phases of the building *	○	○	○	○	○	○
the level of access to information about the design and construction phases of the building *	○	○	○	○	○	○
with the level of transparency and open communication from the building management team about the operation and maintenance of the building *	○	○	○	○	○	○
the opportunities for providing feedback and input into the operation and maintenance of the building *	○	○	○	○	○	○

To what extent do you feel that your involvement in the different phases of the ZEB laboratory building project, and your feedback after completion of the project, was valued and mattered? *

Not valued at all		Neutral		Highly valued
I	I	I	I	I

Value

What suggestions do you have for improving the level of user engagement and participation during the design and construction phases of future buildings? *

This question aims to gather insights from occupants of the ZEB Laboratory about how to improve the design and construction phases of future buildings. The question asks the respondents to provide suggestions on how to increase the level of user engagement and participation during these phases. This information can be valuable in ensuring that future buildings are designed with the needs and preferences of the occupants in mind, which could ultimately lead to higher levels of satisfaction and productivity. The responses could also provide guidance on how to foster a sense of ownership and pride among the occupants in the building, which could promote a positive and collaborative working environment.

Overall Satisfaction

How satisfied are you with

	Strongly dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Strongly satisfied
overall with the ZEB laboratory building as a workplace *	○	○	○	○	○

Have you experienced any changes in your perceptions or experiences of the ZEB laboratory building over the two years of occupancy? Please describe any changes you have noticed and whether you feel that these changes have been positive or negative. *

This question aims to gather feedback from building occupants on whether their perceptions or experiences of the building have changed over time. By asking occupants to describe the changes they have noticed, we can gain insight into whether the building has met their evolving needs and expectations, and identify areas for improvement.

- ○ Yes
- ○ No

What suggestions do you have for enhancing your overall experience and satisfaction as an occupant of the ZEB Laboratory building? *

This question is designed to gather feedback from occupants of the ZEB Laboratory building about their overall experience and satisfaction with the building. The question seeks to identify areas for improvement in terms of the building's design, amenities, and overall functionality. It invites occupants to share their suggestions on how the building can better meet their needs and enhance their overall experience as occupants. Possible responses could include suggestions for improving the building's air quality, lighting, acoustics, or thermal comfort, as well as recommendations for additional amenities or services that could be provided to enhance occupants' experience and satisfaction.

D - WALKTHROUGH PLAN

Stop 1: Meeting Rooms

Plan:

- Meet the occupants in one of the meeting rooms and introduce me and POE method
- Ask the occupants about their overall experience with the building
- Walk through the meeting rooms and ask the occupants about their experience with these spaces
- Ask about any issues or concerns they may have had related to lighting, temperature, noise, or air quality
- Ask about any suggestions they have for improving the meeting rooms

Sample questions:

- How often do you use the meeting rooms?
- How is the availability of meeting rooms? How about the size and numbers?
- Have you experienced any issues with the comfort or functionality of the meeting rooms, such as inadequate seating or insufficient lighting, bad air quality or malfunction of equipment,. . . ?
- How do you feel about the acoustics in the meeting rooms?
- How do you feel about the lighting in the meeting rooms? Is it sufficient for your needs?
- How do you feel about the temperature and air quality in the meeting rooms? Do you find them comfortable for holding meetings?
- Have you noticed any difficulties with technology or AV equipment in the meeting rooms?
- Have you faced any difficulties in booking meeting rooms?
- Would you like to see any additional features in the meeting rooms?

Stop 2: Living Lab Experience

Plan:

- Ask the occupants about their experience working in a living lab environment
- Ask about any advantages or disadvantages of working in a living lab environment
- Ask about any concerns they may have had about the data collected and how it is being used
- Ask if they feel comfortable with the level of monitoring in the lab and if they have any privacy concerns
- Ask if they have any suggestions for improving the living lab experience and making it more comfortable or efficient for the occupants.

Sample questions:

- What has been your experience working in a living lab environment?
- Have you notice any experiments around you?
- Are there any advantages or disadvantages of working in a living lab environment that you have noticed?
- Do you have any concerns about the data collected in the lab and how it is being used?
- How comfortable do you feel with the level of monitoring in the lab? Do you have any privacy concerns?
- Are there any suggestions you have for improving the living lab experience and making it more comfortable or efficient for the occupants?
- Do you feel that working in a living lab environment has helped you in your work or research? If yes, can you provide some examples?
- Are there any areas where you think the living lab could be improved or expanded to better meet the needs of the occupants and the research being conducted?

Stop 3: ZEB Laboratory App:

Plan:

- Walk through the areas while using the ZEB Laboratory app and testing its features
- Ask the occupants about their experience using the app to control the physical environment

- Ask about any issues or concerns they may have had with the app not working or malfunctioning
- Ask if they have reported any issues with the app and how those issues were addressed
- Ask if they have any suggestions for improving the app and making it more user-friendly and reliable for controlling the physical environment

Sample questions:

- How have been your experience with the app?
- What kind of features or functions are available on the app?
- Have you ever encountered any problems with the app, such as it not working properly or crashing?
- Have you reported any issues or concerns with the app to the appropriate channels? If yes, how were they addressed?
- How important is the ZEB Laboratory app in your daily work or activities in the building?
- Are there any suggestions you have for improving the app's usability or functionality?

Stop 4: Solar Shadings and Movement Sensors

Plan:

- Walk through the areas where occupants have reported problems regarding solar shadings and movement sensors for lighting
- Ask the occupants about their experience with these features
- Ask about any issues or concerns they may have had related to these features
- Ask about any suggestions they have for improving these features

Sample questions:

- Have you experienced any issues with the solar shadings, such as difficulty operating them or inadequate coverage from the sun?
- How do you feel about the level of daylight that enters the building? Is it too bright, too dark, or just right?
- Would you like to see any changes or improvements made to the solar shading system?

Stop 5 : Movement Sensors

Plan:

- Walk through the areas where occupants have reported problems regarding movement sensors for lighting
- Ask the occupants about their experience with these features
- Ask about any issues or concerns they may have had related to these features
- Ask about any suggestions they have for improving these features

Sample questions:

- Have you experienced any issues with the movement sensors for lighting, such as inadequate coverage or over-sensitivity?
- How do you feel about the lighting levels in your workspace? Is it sufficient for your needs?
- Would you like to see any changes or improvements made to the movement sensor system?

Stop 6: Offices (in both sides)

Plan:

- Walk through the offices (different sides of the building and different types)
- Ask the occupants about their experience using these spaces (focus on experience about open space landscape)
- Ask about any issues or concerns they may have had related to lighting, temperature, noise, or air quality
- Ask about any suggestions they have for improving these areas

  Sample questions:

- How do you feel about the layout of the open offices?
- How is the combination of occupants in the offices? 4
- Have you experienced any difficulties with noise levels/ distractions in the open offices? How have these been addressed? (Is it hard to focus?, is it better for collaboration?)
- How do you think about your privacy in open landscape?
- How do you feel about the lighting in the open offices? Is it sufficient for your work?

- How do you feel about the temperature and air quality in the open offices? Do you find them comfortable for working?
- Would you like to see any additional features in the open offices?

Stop 7: Shared Waiting Areas (informal sitting space by the staircase)

Plan:

- Walk through the shared waiting areas
- Ask the occupants about their experience using these spaces
- Ask about any issues or concerns they may have had related to lighting, temperature, noise, or air quality
- Ask about any suggestions they have for improving these areas

Sample questions:

- How often do you use the shared waiting areas, and for what purposes?
- Have you noticed any issues with the comfort or functionality of the shared waiting areas, such as inadequate seating or insufficient lighting?
- How do you feel about the acoustics in the shared waiting areas?
- Would you like to see any additional features in the shared waiting areas?

Stop 8: Staircase

Plan:

- Walk through the staircase and ask the occupants about their experience using it
- Ask about any issues or concerns they may have had
- Ask about any suggestions they have for improving the staircase

Sample questions:

- Can you tell me about your experience using the staircase? Do you use it often or do you prefer to use the elevator?
- Have you noticed any issues with the lighting in the staircase? Is it too bright or too dim? Are there any areas that are poorly lit?
- How does it look and how do you feel about it comparing it to your expectations from a staircase?

- Have you experienced any noise issues in the staircase, such as echoes or excessive noise from nearby equipment?
- Do you have any suggestions for improving the staircase, such as adding artwork or improving the lighting or ventilation?

Stop 9: Quit Boxes

Plan:

- Walk through the quit boxes and ask the occupants about their experience using these spaces.
- Ask about any issues or concerns they may have
- Ask about any suggestions they have for improving the quit boxes

Sample questions:

- How often do you use the quit boxes, and for what purposes?
- Have you experienced any issues with the comfort or functionality of the quit boxes, such as inadequate seating or insufficient lighting?
- How do you feel about the temperature and air quality in the quit boxes? Do you find them comfortable for taking breaks or making private phone calls?
- Have you noticed any difficulties with noise levels in the quit boxes? Is there any noise or distraction from nearby activities or spaces?or from these boxes to nearby spaces?
- Would you like to see any additional features in the quit boxes?

Stop 10: Lunch Room

Plan:

- Walk through the lunchroom and ask the occupants about their experience using the space
- Ask about any issues or concerns they may have had related to lighting, temperature, noise, or air quality
- Ask about any suggestions they have for improving the lunchroom

Sample questions:

- How frequently do you use the lunch room?
- How this room is being used?

- How does it work when others use the room regarding noise or any inconvenience?
- How would you rate the design and functionality of the lunch room?
- Have you experienced any issues with the lighting in the lunch room?
- How do you feel about the amount of natural light in the lunch room? Is it adequate or would you like more or less natural light?
- How do you feel about the temperature in the lunch room? Is it comfortable for you?
- Have you ever noticed any noise issues in the lunch room? If so, how were they resolved?
- How do you feel about the air quality in the lunch room?
- Do you feel that the lunch room adequately meets your needs as an occupant?
- Do you have any suggestions for improving the lunch room, such as additional features that would make it more comfortable or functional?

E - NSD CONSENT FORM

Are you interested in taking part in the research project of Value creation in early phases?

Purpose of the project
You are invited to participate in a research project where the main purpose is to find the relationship between early phase activities on value in use phase. The objective of this master's thesis is to fill the research gap between value assessment in occupancy phase of the buildings and its connection to the front-end.
Which institution is responsible for the research project?
NTNU is responsible for the project (data controller).
Why are you being asked to participate?
You are being asked to participate in a post-occupancy evaluation study for a master thesis project aimed at exploring ways to align the value-in-use phase with the early phases of building projects. The sample for the study includes owners, designers, contractors, managers, users and facility managers who have been involved in building projects.
What does participation involve for you?
If you choose to participate in this master thesis project, it will involve a post-occupancy evaluation method that employs conducting interviews with building owners, designers, contractors, managers and facility managers. These interviews will aim to gain a deeper understanding of a building's performance after being occupied and identify opportunities to enhance value and user satisfaction in future building projects.
The methods used for data collection will include interviews, surveys, and possibly observation. The scope of the study will cover a range of topics related to building performance, such as energy efficiency, comfort, indoor air quality, and maintenance. The type of information that will be collected will include opinions, experiences, and data related to the building's performance.
The information collected will be recorded electronically and/or on paper, depending on the participant's preference. If applicable, information may also be collected about the participant from other sources such as registers, records/journals, educational records, or other project participants.
It's essential to note that participation requirements may vary for different groups of participants, such as building owners, designers, contractors, and facility managers. In such cases, a separate information letter will be given to each group, outlining the participation requirements specific to that group.
Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data
We will only use your personal data for the purpose(s) specified here and we will process your personal data in accordance with data protection legislation (the GDPR). In connection with the institution responsible for the project, my supervisor, Ole Jonny Klakegg will have access to the personal data. However, measures will be taken to ensure that no unauthorized persons will be able to access the personal data, such as replacing names and contact details with a code and storing the list of names and codes separately from the rest of the collected data, storing the data on a research server, locking it away, or encrypting it. Also, participants will not be recognizable in publications.
What will happen to your personal data at the end of the research project?
The planned end date of the project is June 2023. At the end of the research project, all personal data and digital recordings will be destroyed, and the digital recordings will be deleted. If the collected data

will not be anonymised, the purpose of further storage/use of personal data will be verification, follow-up studies, and archiving for future research.

Your rights

So long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?

We will process your personal data based on your consent.

Based on an agreement with NTNU, The Data Protection Services of Sikt – Norwegian Agency for Shared Services in Education and Research has assessed that the processing of personal data in this project meets requirements in data protection legislation.

Where can I find out more?

If you have questions about the project, or want to exercise your rights, contact:

- NTNU via Ole Jonny Klakegg (supervisor): ole.jonny.klakegg@ntnu.no
- NTNU via Sara Hajizadeh (student): sarahaji@stud.ntnu.no
- Our Data Protection Officer: NTNU

If you have questions about how data protection has been assessed in this project by Sikt, contact:

- email: (personverntjenester@sikt.no) or by telephone: +47 73 98 40 40.

Yours sincerely,

Ole Jonny Klakegg (supervisor) Sara Hajizadeh (student)

Consent form

I have received and understood information about the project value creation in early phases and have been given the opportunity to ask questions. I give consent:

☐ to participate in the interview

I give consent for my personal data to be processed until the end of the project.

(Signed by participant, date)

NTNU

Norwegian University of
Science and Technology