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The Potential of Public Procurement to Achieve Low or Zero-emission Construction Sites

A case study from Norway

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Preface

The purpose of this master's thesis is to examine the potential of public purchasing as a tool to reduce greenhouse gas emissions at building construction sites. I hope this paper can be a small contribution to this. This thesis was conducted for TIØ4920 – Project Management Master's Thesis in the field of Project Management, specialization of Industrial Engineering, at the Department of Industrial Economics and Technology Management at the Norwegian University of Science and Technology (NTNU), Norway. It built upon a pilot study undertaken for the subject, TIØ5230 – Project Management specialization Project in Autumn 2017.

The thesis was supervised by Luitzen De Boer, Professor at the Department of the Industrial Economics and Technology Management, who has been very helpful throughout the process, which I appreciate.

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For their help with this thesis, I would like to thank Omsorgsbygg, and specially Flemming Idsøe, for providing me guidance and support throughout the empirical cycle. I would also like to thank everyone who took the time to participate in the interviews. Their willingness to help and level of reflection were essential to my thesis. I encourage fellow students to write their thesis about public procurement in the construction industry as it is both interesting and rewarding to learn about, especially when it promotes innovation and sustainable practices.

Finally, I must express my very profound gratitude to my lovely parents (Ahmed and Fatima), family members and friends for providing me with unfailing support and continuous encouragement throughout this journey. This accomplishment would not have been possible without them. Thank you.

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Abstract

Although the construction industry is one of biggest and long-standing industries, it constantly scores low on sustainable development and innovation. In contrast to private firms, public authorities have a great potential to reposition the construction business as an environmentally-friendly and innovative leader in today's ever-changing market. Such change emerges from the ability of public buyers to steer the market by promoting low-carbon innovations. The purpose of this study is to investigate the potential of the current public procurement toolbox to reduce greenhouse gas emissions resulting from the process of project execution (or at construction sites). In order to avoid clouded conclusions, the study distinguished between two levels of emission-reduction; low and zero-emission construction sites. Based on literature review and case study from a major Norwegian municipality, our study highlights several findings and implications. First, public buyers have at their disposal a variety of procedures and tools that have the capacity to exploit low-carbon solutions and reduce emissions at construction sites. Second, the case study unveiled four challenges that procurers face when they purchase projects to reduce emissions: lack of relevant environmental knowledge, demanding documentation, unavailable technology, and divergent views. Third, the toolbox of the EU public procurement, including interaction with suppliers, is found effective to achieve low-emission construction sites, but its role is limited in terms of achieving zero-emission construction sites. Moreover, we claim that public procurement is an effective tool as long as the needed low-carbon solutions are developed or available in the market. Finally, we conclude our study with several implications and recommendations for both practitioners and researchers.

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List of acronyms

CLT – Cross Laminated Timber

EC – European Commission

EPA – Environmental Protection Agency

EU – European Union

GDP – Gross Domestic Product

GHG – Greenhouse Gases

GPA – Agreement on Government Procurement

GPP – Green Public Procurement

GSS – Green Supplier Selection

IMP – Industrial Marketing and Purchasing Group

IPCC – Intergovernmental Panel on Climate Change

ISO - International Organization for Standardization

LCA – Life Cycle Assessment

LCC – Life Cycle Cost

MEAT – Most Economically Advantageous Tender

NGO – Non-Governmental Organization

NTNU – Norwegian University of Science and Technology

OECD – Organization for Economic Co-operation and Development

PMI – Project Management Institute

SME – Small and Medium-Sized Enterprise

TFEU – Treaty on Functioning of the European Union

WBS – Work Breakdown Structure

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1 Introduction

1.1 Background

According to the European Commission, buildings are responsible for 40% of energy consumption and 36% of CO2 emissions in the EU area (European Commission, 2018). Data from Intergovernmental Panel on Climate Change (IPCC), show that in 2010 the building sector accounted approximately for 32% of global final energy consumption, 19% of global energy-related CO2 emissions, and 51% of global electricity consumption (IPCC, 2014, P.677). The building sector falls under the construction industry, which has impacted the environment negatively since ever (Hill and Bowen, 1997, Martland, 2011, Tam et al., 2016, Tam and Le, 2014), in addition to being one of the primary contributors of greenhouse gas emissions globally (Hong et al., 2015). Moreover, the construction industry has been suffering for decades from low-innovation and short-term productivity (Blayse and Manley, 2004, Bygballe and Ingemansson, 2014, Dubois and Gadde, 2002a, Havenvid, 2015), which makes renewing the industry from sustainability perspective, a true challenge.

For obvious reasons, researchers around the globe conducted various studies on the construction industry to help it becomes sustainable (Hill and Bowen, 1997, Labuschagne et al., 2005, Martland, 2011, Waris et al., 2014). Not to mention the vital role of governments, policy makers, and international bodies in shaping new standards, legislation and rules to position the market with sustainability goals. Past studies have showed that environmental awareness in construction projects was more towards issues related to material selection, structure design, materials recycling rather than greenhouse gas emissions (Kim et al., 2011), and later, studies addressing the greenhouse gas emissions during construction processes are emerged (Peña–Mora et al., 2009, Waris et al., 2014).

Projects are powerful tools, whether used by businesses or governments, to perform works or create products. In contrast to private projects, public projects are heavily used by governmental authorities to create outputs targeting the broader aspects of social, environmental and economical returns. In other words, the motivation of the project is to improve the environment or fulfil needs for the society (Martland, 2011). Traditionally public projects are awarded through public procurement, which is highly relying on national regulations. EU member states spend on average around 14 % of their gross domestic product

(GDP). Over €1.8 trillion was spent in 2015, on purchasing goods, projects and services[1] (European Union, 2016). Such spending magnitude makes the public procurement, a powerful tool to influence and even shape the market. In Norway, the City of Oslo alone spends around 26 billion Norwegian kroner (over €2.6 billion) annually on procurement and investments, gives the city *''a great opportunity to influence businesses to become more sustainable''* (Oslo Municipality, 2017).

When public procurement is combined with sustainability concepts, and particularly environmental one, 'Green Public Procurement' emerges, and it's been proved that environmental benefits could be cultivated if the environmental requirements are added in public tenders (Baron, 2016, Parikka-Alhola, 2008, Testa et al., 2016, Igarashi et al., 2015, Weele, 2014, European Union, 2016, Europen Union, 2014). For years public procurement has been criticized for being market-driven by using competitive tendering and the lack of long-term relationships which are central to promote efficiency and innovation in business (Torvatn and de Boer, 2017). Considering the motivation of public projects and the powerful tools of public procurement, one could say that reducing emissions at construction sites is very conceivable. Hence, a need to investigate the ability of public purchasing to reduce emissions from the execution process has arisen. And ultimately, developing public procurement practices to reduce emissions in construction projects will not only serve the environment and economy but will also stimulate innovation in the construction industry.

1.2 Research Gap

With no doubt public procurement is an effective tool to influence the market, in which benefits like sustainable development and economic progress can be realized (European Commission, 2016). The European Commission has gone so far with developing green public procurement practices, through developing green criteria that facilitates the inclusion of green requirements in public tenders such as roads and office buildings. Literature also has many studies that discuss sustainable practices in construction projects (Hill and Bowen, 1997, Martland, 2011) and describe the various emissions developed during project life cycles (Hong et al., 2015, Ren et al., 2012, Yan et al., 2010). However, literature lacks the focus in the context of the role of public procurement to reduce emissions 'at construction sites'. Although previous studies addressed emissions from construction projects, little attention is

[1] These figures exclude utility companies; earlier estimates (2011) including utility procurement were of around 19% of EU GDP, accounting for more than EUR 2,3 trillion.

given to the construction phase. For example, it's unclear what low-carbon solutions should be used in order to reduce emissions at construction sites, which makes it difficult to distinguish between the different levels of emission-reduction; low and zero-emission construction sites. This ambiguity hinders procurers from producing effective tenders due to the absence of well-defined emission targets. It's becoming necessary to shed light on each project cycle separately especially the construction (execution) phase, as such focus will help to unfold new ways to improve sustainability in building and construction projects.

Including new challenges and requirements in purchasing and tendering processes allow the procurement toolbox to evolve organically and explore new solutions. Thus, understanding the current public procurement potentials with respect to reducing emissions at construction sites, can help public procurers to produce more effective tenders and stimulate market innovation in that area. In addition, this will allow both contractors and suppliers, operating in the construction business, to improve their proposals and include more innovative solutions in their offers to meet the expectations of both public procurers and sustainability goals.

1.3 Problem statement

The growing need to explore new tools and strategies, that stimulate effective reduction of greenhouse gas (GHG) emissions, stems from the adverse environmental effects caused by those emissions, and not to mention its role in global warming of the earth's climate (Brundtland, 1987). The construction industry, amongst other industries, is held responsible for large amount of emissions every year (Ahn and Lee, 2013, Anthonissen et al., 2015, Chang et al., 2011, Hong et al., 2015, Kim et al., 2011, Martland, 2011, Peña–Mora et al., 2009, Tam et al., 2016, Tam and Le, 2014). In spite of many studies have addressed emissions in construction projects, little is achieved in terms of reduction. And thus, existing tools must be exploited, and new solutions must be explored. Public procurement is an existing tool, which has a great potential due to the positive, strong influence it has on the market[2] by stimulating interaction with suppliers (Araujo et al., 1999, Torvatn and de Boer, 2017) and promoting low-carbon innovations (Baron, 2016, Testa et al., 2016).

The main purpose of this thesis, is to investigate the potential of public procurement setup to achieve low or zero-emission construction sites. Emissions at construction sites are emissions

[2] EU member states on average spend around 14 % of their gross domestic product (GDP), Over €1.8 trillion was spent in 2015, on purchasing goods, projects and services (European Union, 2016)

resulting from the process of project execution. Noteworthy, low-emission sites aim to reduce emissions at construction sites to a certain level, while zero-emission sites aim to eliminate emissions completely at construction sites. In order to achieve the study goals, first, an in-depth understanding of emission sources in construction projects is required, where only emissions resulting from execution processes in construction sites will be studied, see the study's boundary in Figure 6. Second, investigating a case study focusing on public projects with goals to reduce emissions at construction sites, is essential to understand how public procurement functions in this context. The case study used in this study only covers projects with low-emission construction sites targets as projects with zero-emission targets are still not exist. Moreover, looking into the potential of interaction in light of emission-reduction is vital, as it allows all sides of the equation (public buyers, contractors and suppliers) to come together and co-develop new, innovative solutions and products.

In order to give the study a clear focus, the following problem statement is formulated:

Can public procurement, and in particular interaction with suppliers, be an effective tool to achieve low or zero-emission construction sites.

The above problem statement is broken down into the following three research questions, to facilitate and guide the research process towards building up the required answers:

1. *What is the theoretical potential of the current public procurement toolbox, particularly interaction with suppliers, to achieve low or zero-emission construction sites?*

In order to answer this question properly, theories from public procurement, sustainable construction and innovation will be reviewed. Then the theoretical framework developed from the theoretical review chapter will be our point of departure to answer this question. Different procedures (i.e. restricted and open) and processes (i.e. formulation of criteria) of public procurement will be reviewed to understand the capacity of public procurement and its critical success factors when it comes to reducing emissions at construction sites. Literature regarding interaction among buyers and suppliers will also be discussed in the context of innovation and public procurement, to shed light on different interaction possibilities offered by different procedures. See Figure 1 in the following section.

2. *What challenges do public buyers face when procuring buildings to achieve low or zero-emission construction sites? And what role did interactions play?*

Primarily, the case study will be used to answer this question. Where empirical data of two projects, collected through documentation and interviews, will be analysed to reveal the challenges faced procurers when tendering buildings to achieve low-emission construction sites. In addition, interaction processes occurred in the two projects will be looked at with respect to those challenges, to shed light on the role interaction played during the procurement. Since the case study only covers projects with low-emission construction sites targets, we will focus on challenges related to achieving low-emission construction sites rather than zero-emission.

3. *What is the realized potential of public procurement toolbox and particularly interaction with suppliers, to achieve low or zero-emission construction sites?*

Both analysis and discussion will be utilized to answer this question. First, each project is analysed in light of the theoretical framework to understand the characteristics of the procurement process took place in each project. In addition, the analysis will help us to better draw the difference among 'low-emission' and 'zero-emission' construction sites. Afterwards, we will study the general potential of the whole purchasing process; pre-bidding, bidding, and post-bidding, in terms of innovation and interaction. And finally, each procedure will be discussed to understand its true potential to achieve low and zero-emission targets. See Figure 1.

1.4 Structure of the Study

The structure of this paper follows a traditional structure of theoretical and empirical study followed by analysis and discussion, as depicted below in Figure 1. Study's background with problem statement are described under this chapter. In chapter 2, the research methodology used to conduct this research is illustrated, including selection of the case and methodology evaluation. The theoretical study, presented in chapter 3, constitutes of four sections, starting with innovation and key influences. Then, literature addresses sustainable construction, and emission sources in construction projects are reviewed. Third section is dedicated for public procurement literature and buyer-supplier interface. The last section presents a theoretical framework, where set of theories and models are structured orderly within the framework. The framework will be used later during the analysis of each project.

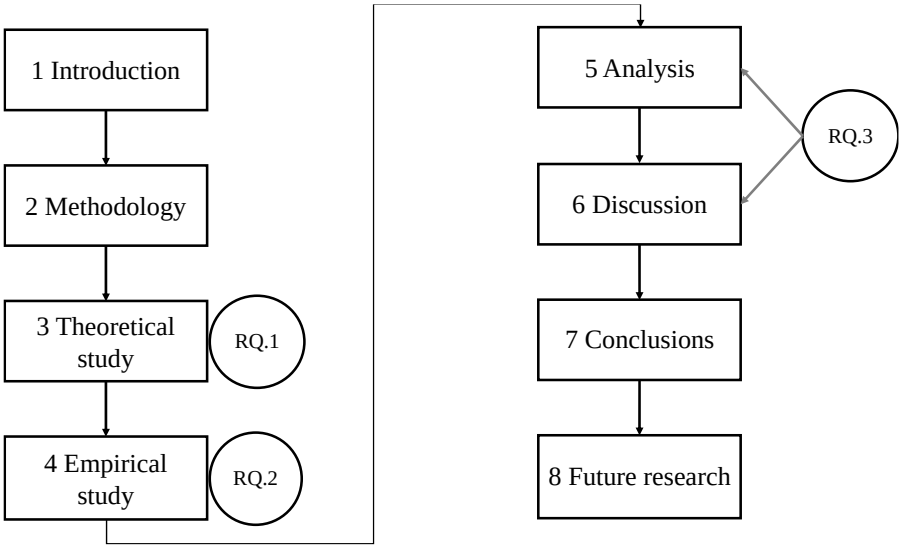

Figure 1 Structure of the study

In chapter 4, empirical data are presented based on the case study. The case looks at Omsorgsbygg (subsidiary of Oslo municipality and responsible for the municipal undertaking for social care buildings), where the focus is on the procurement of projects with high ambitious environmental goals towards reducing emissions at construction sites. More specifically, two projects from Omsorgsbygg portfolio are chosen to study their procurement processes.

Analysis of the case is organized under chapter 5; single-unit and cross-unit analysis. Analysis will form the basis to answer the third research question, and particularly the low-emission aspect of the question since both projects are characterized as low-emission construction sites. Afterwards in chapter 6, discussion will shed light on the potential of different procedures in relation to their interaction possibilities. Then, it will attempt to answer the zero-emission aspect of the third question. Chapter 7 summarizes the main conclusions and draw several implications for practitioners and policy makers. And finally, suggestions for further research are drawn under chapter 8.

1.5 Limitation of the Study

The study has several limitations related to methodology and the choice of the case study. First, the study employed embedded single-case design to perform the empirical study. In which Omsorgsbygg was the case, while the two projects treated as units. A multiple-case design could have been chosen instead of a single-case one. This could allow us to collect wide-range of data and may be leading to more analytical benefits and conclusions. However,

considering the study's time span and number of participants, the single-case design was favoured.

Second, the study used projects from only one country, Norway. We believe that inclusion of other projects from other European countries could have nurtured the study's results. This could have allowed us to compare procurement practices from different countries in the context of reducing emissions at construction sites, especially that public procurement tools are widely used across the EU countries. Moreover, each country has its own national environmental initiatives that supports the international agreements. For example, the City of Oslo has its own green transformation strategy which reflected on Omsorgsbygg environmental strategy. Therefore, it would be fruitful to explore cases from other countries besides Norway.

Lastly, the study did not cover the whole parties involved in the case. Even though the study used single-case design, there are many players involved in the procurement process of each project. Interviews are performed with persons from three different organizations. We think that more organizations could have been involved in the interviewing process such as machinery suppliers and other contractors. But it was a bit difficult to know all the involved parties from the beginning, since 4 out of 7 interviewees were in fact contacted because of snowballing effect. Nevertheless, the process of scheduling interviews takes long time especially when people are already busy with many other projects.

2 Methodology

The research methodology of a study needs to reflect the research objectives (Yin, 2014). This research is divided in two parts in order to answer the study's research questions: a literature review and an empirical case study. Research methodology is explained in this chapter. In which, first section describes how literature review is carried out. Followed by the empirical study section, where the choice of research design, data collection and data analysis are explained. Finally, methodology is evaluated, following prescription of Yin (2014).

Inductivism and deductivism are two theoretical approaches, used traditionally by researchers to conduct scientific researches. In a deductive approach, the researcher starts with existing theories and literature in relation to the subject, then he deduces a hypothesis (Bryman, 2012). The hypothesis is then followed by a research strategy showing how it will be tested; collection of data and analysis (Wilson, 2014). Conversely, an inductive approach employs a reversed approach, where theory is developed after analysis of collected data and observation (Bryman, 2012, Wilson, 2014). Initially, our study starts with a deductive approach where we examine first existing literature regarding innovation, sustainability in construction and public procurement. The theoretical study enabled us to build a good understanding and produce a theoretical framework. However, the study also contains inductive elements as it uses empirical data to further develop our understanding and reflect on theories.

A strategy that involves moving back and forth between data and theory is regarded as iterative (Bryman, 2012). Dubois and Gadde (2002b, P.555) propose a process, systematic combining, where theoretical framework, empirical fieldwork and case analysis evolve simultaneously, where they found that *"the researcher, by continuously going 'back-and-forth' from one type of research activity to another and between empirical observations and theory is able to expand his understanding of both theory and empirical phenomena".*

In this study, the potential of public procurement to reduce emissions at construction sites, is investigated in both literature and reality. However, the interdisciplinary nature of the topic, made it difficult to produce accurate theoretical framework without having initial interaction with the real world. Which falls in line with the claim of (Dubois and Gadde, 2002b) that " theory *cannot be understood without empirical observation and vice versa"*.

The *"continuous movement between an empirical world and a model world"* (Dubois and Gadde, 2002b), helps to better understand the issue of greenhouse emissions at construction sites, and provided further guidance to explore more theories under the public procurement section, which used later to draw more reliable results. For example, the literature did not distinguish clearly between 'low-emission' and 'zero-emission' construction sites, but we developed better understanding after the empirical cycle was started. Moreover, the role of interaction in the context of public procurement become more obvious after finishing the case study analysis, which enabled us to revise the theoretical framework and reflect new findings.

Researchers also distinguished between quantitative and qualitative methods when they choose to collect and analyse the data related to research topic (Bryman, 2012). Qualitative research follows the guidance and concepts of interpretive paradigm, in which its main objective is to build a detailed understanding of underlying processes, motivations, and reasons (Hennink et al., 2011). On the other hand, quantitative research is guided by assumptions derived from positivist paradigm, and its main objective is to quantify and measure data and then generalize results to a broader population (Hennink et al., 2011). Quantitative research strategy emphasizes quantification in the collection and analysis of data, while qualitative research strategy emphasizes words rather than quantification in the collection and analysis of data (Bryman, 2012, Hennink et al., 2011).

This study adopts qualitative research method for several reasons. First, qualitative methods are flexible and provide an in-depth understanding of new topics and complex issues (Bryman, 2012, Hennink et al., 2011). They may also include biases, which requires from researcher to stay aware of both their and study participants' subjectivity that might influence the research process, especially during data collection and interpretation (Bryman, 2012, Hennink et al., 2011). Second, qualitative research methods (i.e semi-structured interviews) allow to work close to data sources which enable them to follow events and patters that could help them to unfold unexpected findings over time (Bryman, 2012). In total, qualitative research is often employed to understand rather than explain, and thus it is regarded the most appropriate strategy for this study, which aims to understand the potential of public procurement as a tool to achieve low or zero-emission construction sites.

2.1 Literature Study

Literature study is a significant component of any research, as it is the starting point to gain insight into the current body of knowledge on a specific topic, and it also allows to develop an analytical framework based on existing concepts and theories (Bryman, 2012). Thus, a literature study has been conducted to get an overview of what is known in the academic and research field regarding this subject.

2.1.1 Search method

A narrative literature review, following the prescription of Bryman (2012), was undertaken to develop a theoretical background in light of the addressed problem statement. According to Bryman (2012), systematic reviews are comprehensive, less biased due to adopting explicit procedures, and often seen as an accompaniment to evidence-based approaches. Nevertheless, it's decided to perform a narrative review, even though, such an approach would reduce the reliability of the study. But it was more important to allow snowballing effect in the event of discovering new articles, which has been such a significant aspect of this literature study, as initial search scope was limited to some extent due to the little knowledge about the topic of "GHG emissions" at the beginning of the study.

Another reason to choose narrative review is the inter-disciplinary nature of the study, as it covers different topics at the same time: sustainability, construction projects, innovation and public procurement. Therefore, the study favoured narrative review method as narrative reviews *"tend to be less focused and more wide-ranging in scope than systematic reviews"* (Bryman, 2012, P.110). And by including combination of journal articles and scholarly books, that cover different topics, we were able to support the inter-disciplinary nature of the research study. Moreover, number of key governmental and organizational publications, is used to provide more insights on public procurement such as the handbook of green public procurement and EU directive 2014/24/EU on public procurement.

Bryman and Bell (2011), distinguished between a keyword search and journal search. The research theme of the potential of public procurement to achieve low or zero-emission construction sites has been built upon research from a broad range of subjects, such as innovation, public procurement and emissions from construction activities. As no single journal would be able to cover this research topic sufficiently, keyword search is favoured over a journal search.

Google Scholar and the online database available to NTNU (Oria) were used as points of departure for finding relevant journal articles and literature on the topics of innovation in construction industry, public procurement, sustainability and GHG emissions in the construction industry. Since Google Scholar was used most of the time and comprises of sources with different qualities, it's made sure only to rely on peer-reviewed journals and scholarly books. In addition, supplemental search engines such as Scopus and ScienceDirect were used, particularly in the event of searching for a specific article because of snowballing effect or when my professor refers to a specific article. Keywords were created based on selected subjects, namely 'innovation in construction', 'public procurement', 'purchasing', 'green public procurement', 'green supplier selection', 'public procurement for construction', 'buyer-supplier interface', 'sustainability in construction projects', 'sustainability in public projects', 'CO2 emissions in construction', 'emissions in construction projects', 'emissions at construction sites', and 'emissions from construction equipment'.

2.1.2 Review method

Literature review in this study was conducted as follows. First, search engines were filled with previous keywords, and outcome articles and other sources were downloaded and named accordingly. Thereafter, the abstracts were read carefully, and irrelevant articles were excluded. Finally, the remaining relevant sources were reviewed thoroughly and structured in a table sorted by author, title, journal and intended use. During literature review, the table was updated frequently either to include new articles or to exclude less relevant ones. In addition, the review process kept going in parallel to empirical study, to sort out what is thought as most relevant theory and literature to this study. The resulting table is presented in Appendix 1.

2.2 Empirical study

2.2.1 Selection of research design

Research design usually refers to the overall strategy selected to integrate the different components of a study. It provides a framework to guide the research process for the collection and analysis of data (Wilson, 2014). In his book, Case Study Research, (Yin, 2014) described five different types of research methods to conduct research: experiment; survey; archival analysis; history; and case study. In spite of there is no specific formula to choose a research design, the decision depends on the research questions to a large extent (Yin, 2014).

In the following, the choice of a case study as a research design will be rationalized, followed with an explanation of why a single-case is favoured over a multiple-case study.

Yin (2014) stated three conditions to assess the use of different methods and help researchers to select the most appropriate one: kind of research questions used; the extent of control over actual behavioural events; and the degree of focus on contemporary as opposed to historical events. Since the study focuses on contemporary events rather than historical ones and has no control over behavioural events, that leaves us with two options: case study or survey. By looking at the research questions of this study, it would be suggested to do a survey, a case study or both. However, it has been decided only to do a case study, for the following reasons.

First reason is obviously because of the time span of this thesis which is 5 months. One can argue that it's still possible to conduct both a survey and a case study in 5 months, but that would affect the research quality and results. Second, the answers to the 'what' questions can be found through the case study, and thus, performing a survey is not considered critical in this case. Third reason has to do with the available number of projects to conduct a proper survey, as projects with clear goals to reduce emissions at construction sites were not available couple of years ago, as the focus was more towards the project life time. Even though, if many projects with such goals are available, more time will be needed to find those projects and arrange the survey, which again can't be achieved within the study's time span. Lastly, our 'what' questions are *"justifiable rational for conducting an exploratory study"*, and therefore, any of the five methods can be used for such purpose, including case study (Yin, 2014, P.10).

Moreover, according to Yin, a case study research is *"empirical inquiry that investigates a contemporary phenomenon (the case) in depth and within its real-world context, especially when the boundaries between the phenomenon and context are not clearly evident" (Yin, 2014, p.16).* In other words, a case study design is preferred because theory can be developed by utilizing in-depth understanding of empirical phenomena and its contexts (Dubois and Gadde, 2002b). Overall, the case study approach is found to be appropriate as it will provide a general in-depth understanding of emission-reduction practices through publicly procured projects in the construction industry. Additionally, since the theme is focusing on the potential of public procurement to reduce emissions, it was necessary to employ a case study

with a number of projects to understand what it takes to achieve such reduction measures through public procurement procedures.

It's essential before starting with any data collection to decide on the nature of the case study, weather it is a single-case or multiple case. Explanation and arguments rationalizing the selection of single-case design are presented in the following. Yin stated that the single-case design is justifiable and favoured under certain conditions, in which it represents: a critical test of existing theory; an extreme or unusual circumstance; common case; it serves revelatory purpose; or it serves longitudinal purpose (Yin, 2014). A revelatory case takes place when a researcher has the chance to study and analyse *''a phenomenon previously inaccessible to social science inquiry'' (Yin, 2014 p.52).* We claim that the case in this research has a revelatory nature, as it investigates the potential of public procurement tools to achieve low or zero-emission construction sites, considering projects with strong focus on emissions at construction sites were not common or available years ago.

Furthermore, a multiple-case study may be preferred over a single-case one, because multiple-case studies provide more analytical benefits and direct replication, in addition to the analytic conclusions, which *"will be more powerful than those coming from a single case" (Yin, 2014).* However, Yin recommends using multiple cases whenever there are resources available, which agrees with Dubois and Gadde (2002b) argument, who claim that increasing the amount of cases, leads to more breadth, but less depth. And Hence, considering the resources (i.e number of research participants) and time span available to conduct this research, the single-case design is favoured.

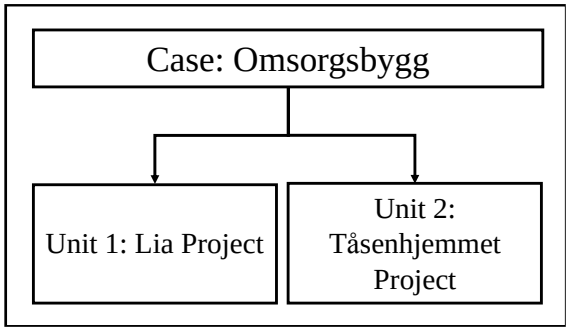

Figure 2 Demonstration of embedded single-case design, used in this study

Having settled on single-case design with multiple units of analysis, see Figure 2 above, it's also important to understand why Omsorgsbygg is selected as a case for this research. Cases are selected because they are unusually revelatory, represents extreme exemplars, or

opportunities for unusual research access (Yin, 2014). The Omsorgsbygg's case is considered suitable, in being regarded as a revelatory case. It is one of the first public entities to implement and enforce fossil-free construction sites as a minimum requirement in all of Oslo's public procurement actions, with extra-focus on utilizing new solutions. Hence, this case provides the opportunity to observe and analyse a phenomenon previously inaccessible to social science (Yin, 2014, p.200). This case provides the chance to investigate and study the methodology followed by Omsorgsbygg in preparation of several procurement actions, which targeted emission-reduction at construction sites. Moreover, in October 2016, Omsorgsbygg was awarded with the innovation in public procurement award by (DIFI) for their innovative procurement approach (Omsorgsbygg, 2016c), which makes it attractive for research purposes.

2.2.2 Data collection

Yin (2014) describes six sources of evidence which are commonly used in case study research: documentation, archival records, interviews, direct observations, participant-observation, and physical artifacts. A good case study research relies on multiple sources to gather information, as different sources work complementary to each other. In this research, only documentation and interviews will be employed. Noteworthy, documents are related directly to the case, in which some are provided by Omsorgsbygg, while others are accessed publicly through official governmental homepages.

First, collection and analysis of relevant texts and documents are used as one of the qualitative research methods in this study. J. Scott (1990) (as cited in Bryman, 2012), distinguished three different types of documents: official, private, and personal. The selection of documents in this research, is solely decided on their relevance and benefits to the case study. Documents includes Oslo municipality's environmental plans, Omsorgsbygg's environmental strategy, Oslo municipality's procurement, contract strategies, tender and procurement documents for two projects, environmental proposals and offers from contractors, and annual reports. Such documents are classified as official, and they are provided either by Omsorgsbygg official staff or accessed through public and governmental homepages like Oslo municipality, database for public procurement (www.doffin.no), and the agency for public management and egovernment (www.difi.no).

Analysis of documents provides a great deal of information and textual material of interest, that will help in understanding how current public purchasing toolbox is used to reduce

emissions at construction sites such as formulating the right requirements in tender documents. However, some documents are existed in multiple languages, and thus, more time was allocated for translation efforts to avoid building conclusions on false information, which can threaten the credibility of our research.

Second, qualitative research method and most important source, has been the interviews conducted throughout the study period. Selection of interviewees was mainly based on their involvement in the procurement process of the two projects, and as mentioned earlier 4 out of 7 interviewees were in fact contacted through snowballing from the first three interviews.

Hennink et al. (2011) defines in-depth interviews as *''one-to-one method of data collection that involves an interviewer and an interviewee discussing specific topics in depth''*. Thereafter, interview guides were prepared to prompt the data collection (Hennink et al., 2011). The guide starts with outlining the purpose of our study, before examining the sources of emissions at construction sites. Afterwards we move over to the procurement process and finish our interview with questions in relation to interactions. Our interview guides are attached in Appendix 2. We used two different guides to adapt with the different organizations involved in the study. Moreover, during some interviews our guide served more as guidelines for conversations, as we for instance realized that it was less appropriate to talk about the procurement process with a person involved in technical operations. We therefore adapted the conversations to the background of interviewees.

Table 1 List of interviews.

Date	**Organization**	**Employee's position**	**Location**	**Duration**
21-02-2018	Omsorgsbygg	Legal advisor	Skype	00:52:03
26-02-2018	Metier OEC (employed by Omsorgsbygg)	Project manager 2	Skype	01:12:25
02-03-2018	Omsorgsbygg	Technical manager	Oslo	00:54:17
02-03-2018	Omsorgsbygg	Project manager 1	Oslo	01:12:05
16-03-2018	The Main Contractor	Project manager	Trondheim	01:01:05
23-03-2018	The Main Contractor	Environmental leader	Skype	00:55:25
15-05-2018	National Programme for Supplier Development	Lead Climate Innovation	Skype	00:34:52

Although the role of public purchasing to reduce emissions at construction sites, was the main theme, other relevant topics were also covered in interviews to collect more information such as emissions sources and the role of interactions. Table 1 above shows an overview of interviews took place during the empirical research cycle; 4 from Omsorgsbygg, 2 from the main contractor, and 1 from the National Programme for Supplier Development. All interviews were recorded and transcribed. Noteworthy, since the last interview took place late in mid-May, it gave us enough time to build better understanding about the case. The interview also served to confirm information provided earlier, especially regarding interactions and future plans.

Our data collection process has followed the four principles proposed by Yin (2014) in order to maximize the benefits of our evidence. The four principles are as follows: use multiple sources of evidence, create a case study database, maintain a chain of evidence, and exercise care using data from electronic sources. These principles will help again to deal with construct validity and reliability.

First, according to Yin (2014, p.120), *"any case finding or conclusion is likely to be more convincing and accurate if it is based on several sources of information"*. Accordingly, data triangulation, as described by Patton (cited in,Yin, 2014), was established through the use of multiple sources such as documentation and interviews. Moreover, interview triangulation enabled us to cross-check information from different sources, since interviews are conducted with people from three different organizations; public buyer, suppliers, and third-party.

Second, established a detailed case study database through the use of two separate collections. First, we have created a case study database folder containing documents, interviews, recordings, and second, we have created another separate folder containing our written report. The folder structure makes the raw data available for independent inspection, which according to the principles of Yin increases the reliability of our study. Both folders were also uploaded in separate shared folders in google drive.

Third, we established a chain of evidence through the creation of explicit research methodology. By describing our methodology in detail, we aim to allow external observers to follow our chain of evidence from research questions, theoretical study, empirical study to conclusions.

Lastly, most of the documentation used in the case study were accessed through official websites or sent as electronic files from Omsorgsbygg officials. Moreover, several interviews

have been conducted using Skype program. Yin recommends several cautions when dealing with data from electronic sources. First, setting limits, such as time to spend on websites navigating for data. We spent a lot of time gathering procurement documents especially from official databases, but that was necessary as it's central to the research in hand. Second, we did cross-checking online material with other sources (i.e interviews) to avoid interpretive bias.

2.2.3 Data analysis

As pointed out by Yin (2014, P.133), *"the analysis of case study evidence is one of the least developed aspects of doing studies",* which makes analysing the case such a difficult task. However, in order to build theory from case studies, data must be analysed (Eisenhardt, 1989). Therefore, defining a general analytic strategy is considered an essential step to conduct a profound case study analysis, in which linking case data with concepts gives sense of direction in the analysis (Yin, 2014). Works of widely recognized authors, both Yin and Eisenhardt, are used to compose a transparent and explicit methodology to guide the case analysis; resulted analytic strategy and technique are inspired from their work.

Yin (2014) introduced four general analytic strategies to analyse the case study data: relying on theoretical propositions, working data from the ground up, developing case descriptions, and examining rival explanations. A first thought was to use a strategy that either relies on theoretical propositions or working data from the ground up. However, the research does not build upon propositions or predictions to use the first strategy. Besides working with data from the ground up alone can be difficult to recognize patterns and relationships. Since the goal is to have a systematic data analysis and the theoretical study has resulted in a theoretical framework. We found the developed framework capable to guide the analysis process, particularly single-unit analysis, through applying its content on each unit and driving data analysis. Consequently, our general strategy starts data analysis following the theoretical framework and then works with data to formulate comparisons, similarities, or patterns.

Usually after selecting a general strategy, it becomes important to apply some analytic techniques. Yin (2014) suggested five techniques to analyse the gathered data: pattern matching, explanation building, time-series analysis, logic models, and cross-synthesis. Due to the revelatory nature of case, this leaves us with pattern matching and cross-synthesis. It's very common to use pattern matching logic, where the empirical based pattern (our findings from the case study) is compared with a predicted one made before data collection (our

theoretical framework) (Yin, 2014). Moreover, the case study is a single-case one which contradicts with cross-case synthesis since it relies on multiple case studies. However, Yin (2014, P.167) mentioned a variation of the cross-case synthesis where a case study can extend to higher level, he describes this situation as *"the main case study may be about a broader or large case or unit of analysis, with multiple case studies serving as embedded units".* Thus, we decided to use both techniques; pattern matching logic and cross-synthesis.

All in all, we decided to use a twofold analytic technique: 'single-unit' analysis, where each project is analysed following the study's framework; and the variation of cross-case synthesis mentioned above, which we will refer to henceforth as 'cross-unit' analysis.

Detailed description of the case and its units are presented under empirical study, chapter 4. It allowed us to familiarise ourselves with each project as a stand-alone entity before diving into single and cross-unit analysis. They consisted of detailed descriptions of the case and its units through the use of documents and interview recordings. The main case (Omsorgsbygg) describes strategies and reasons behind procuring such projects, while the units of analysis (two projects) describe each project procurement in detail. Data for projects are organized in identical structure with separate sections to facilitate comparison, and data from interviews are gathered in separate section as it focuses on specific topics that concern both the main case and its units.

Single-unit analysis: data from chapter 4 about each project, will be analysed in light of concepts and theories from the theoretical framework. Our framework consists of three main stages; each stage builds upon the previous one. The first stage attempts to build an understanding for low and zero-emission construction sites, while the last two stages focus on the procurement process itself. This allows us to analyse emission-reduction goals and procurement process elements in each project separately. The single-unit analysis is found useful because it might unfold important insights about interaction practices used in each project. Patterns and differences recognized in single-unit analysis will help us to develop project identities, which will be the basis for the cross-unit analysis.

Cross-unit analysis: such variation is justified in the research's case study as it contains two projects treated as separate units of analysis. We preferred to call it 'cross-unit' analysis since we will be comparing the two projects against each other with respect to specific aspects. As argued by (Yin, 2014), following this technique will require separate data from the main case, in addition to cross-case data from the embedded units. Such cross-case searching tactics

"enhance the probability that the investigators will capture the novel findings which may exist in the data" (Eisenhardt, 1989). Moreover, comparing the two units with each other, will enable us to realize differences and similarities in procurement practices and interaction strategies implemented in both projects, especially that each project represents different level of ambitions when it comes to reducing emissions at construction sites.

2.3 Evaluation of methodology

We will evaluate the quality of our research methodology and design by following the four tests proposed by (Yin, 2014). In the following we will assess the extent to which each of those tests applies and fulfils criteria.

2.3.1 Validity

2.3.1.1 Construct validity

Construct validity is to correctly identify the operational measures that represents the concepts of the study (Yin, 2014). We have applied the three tactics proposed by Yin in order to increase the construct validity of the research.

Firstly, our study uses several operational measures identified as the tools of public procurement, particularly procedures and interaction with suppliers, through a theoretical study, an empirical study, analysis and discussion. In many places we referred to them as toolbox. One could say identifying the right measures in our study was straightforward to some extent because we are using the latest EU public procurement (EU directives), which are widely recognized and used in both academia and real life. The right application of those measures can be challenging sometimes in real life practices, and thus, our understanding of the measures might be criticized because of both subjective judgement and inconsistencies. However, in order to reduce subjective judgement and encourage converging lines of inquiry, multiple sources of evidence are used, as explained earlier in data collection. Moreover, we maintained a clear chain of evidence of our study, which also mentioned in data collection. Thus, allowing other investigators to check how the applied measures represent the right concepts.

And finally, we applied the last proposal of Yin, where we had shared our draft case report with key informants and participants to review our empirical data after the write-up. This procedure is used to corroborate essential findings and evidence presented in the case report.

2.3.1.2 Internal validity

Internal validity seeks to answer the question of whether a causal relationship, whereby certain conditions are believed to lead to other conditions, are distinguished from spurious relationships (Yin, 2014).

Internal validity is mainly a concern for explanatory case studies, in which an investigator tries to explain how and why. However, according to Yin (2014, p.47), *"this logic is inapplicable to descriptive and exploratory studies, which are not concerned with this kind of causal relationship".* Our case study is exploratory rather than explanatory as it investigates the ability of public procurement tools to achieve low or zero-emission construction sites, considering projects with strong focus on emissions at construction sites were not common or available years ago. Therefore, this point is found irrelevant to our case.

Additionally, internal validity for case study research concerns the problem of making inferences (Yin, 2014). As stated by Yin (2014, p.47), a case study *"involves an inference every time an event cannot be directly observed"*. Part of the information used in our empirical study comes from interviews, and often we collected personal thoughts. Subsequently, it's expected that some inferences will naturally happen. This affects the internal validity of our study has thus might reduce the quality of our methodology. However, in order to mitigate this issue, we had some key interviewees review our empirical data to check if wrong inferences were made. Moreover, we ensured to have more than one interviewee from the main involved organizations to avoid misleading inferences.

2.3.1.3 External validity

External validity deals with defining the domains to which the study's results can be generalized (Yin, 2014). In our case, the question is whether our findings can be generalized to other public organizations constructing other types of construction projects such as infrastructure, and to other countries than Norway. Unlike other research methods, such as survey and archival analysis, where it is possible to apply statistical generalization, case studies rely on analytic generalization (Yin, 2014). This means that we generalize our outcomes according to a theory on green public procurement in the construction industry. Therefore, it has been critical for us during literature review to build a strong theoretical foundation for both emissions from construction projects and green public procurement.

However, to achieve proper generalization, the study must be replicated to other contexts (other public organizations, construction projects, countries) to see if the theory holds. This is

why Yin repeatedly emphasized the role of multiple-case studies, as they provide more analytical benefits and direct replication. Thus, we recognize that external validity is reduced because our study relies on single-case study from one public organization, that builds social care buildings. We also recognize that a multiple-case study could have strengthened both the study analysis and theory building.

2.3.2 Reliability

Reliability means that the research process of the study, such as data collection procedures, can be repeated with the same results (Yin, 2014). We allowed replication by others by describing our research methodology thoroughly. Our literature search strategy of using specific keywords allow for replication. As mentioned earlier in section 2.1.1, we performed narrative review as it was necessary to allow snowballing effect in the event of discovering new articles and covering different topics at the same time. This is mainly because of the interdisciplinary nature of the study.

However, our choice to adopt narrative approach over more systematic one reduced the reliability of the study because it increases the chance of personal bias. We could have increased the transparent process of literature search and reduce personal bias by pursuing a more systematic review in article selection, and hence increased the possibility for repetition of our research process.

Moreover, we tried to increase the reliability of our study by implementing Yin recommended tactics; case study protocol and database. Interview guides are prepared as part of the study protocol, in which the two interview guides used are attached in appendix 2. The case study database is also developed, as mentioned earlier in data collection section.

2.3.3 Overall evaluation

Researchers criticize qualitative research as being too impressionistic and subjective, it's difficult to replicate, it lacks transparency in how the research was conducted, and it lacks the ability to generalize the finding to a larger population or other setting (Bryman, 2012).

These are certainly the main issues that we have struggled with while ensuring validity and reliability for our study. Concerning the issue of subjectivity, we have tried to reduce it through the use of multiple resources in data collection, although it is not always possible with the interviewees' personal views. The lack of transparency we have tried to mitigate it by documenting thoroughly the research process and data collection procedures. Then again,

the narrative approach in literature search and the nature of our interviews make the replication process difficult for others. Generalization to other settings could have been better if multiple-case design was adopted.

Overall, considering the given the time span and resources at our hand, we believe that we have managed quite well with the degree of validity and reliability of our study. We encourage readers not to jump to the end of this paper, but instead follow its course through literature review, empirical data, analysis, and discussion, and then to make up their own conclusion.

3 Theoretical study

In this chapter, relevant literature is studied, reviewed and synthesized to provide a theoretical background to enlighten the research questions. A lot is written about Innovation, sustainability and public procurement in literature, but a limited review, targeting the most relevant topics that address the problem statement, is made.

This chapter is divided into four sections. The first section of the theoretical background addresses a few characteristics of innovation in the construction industry and discusses the key influences on construction innovation. Next section discusses the role of sustainability in the construction industry; it summarizes various emissions from building construction sites. The third section reviews theory of public procurement and buyer-supplier interaction. Finally, a theoretical framework is produced in the last section based on relevant theories and models to show how theory will help to address the research problem statement, and more specifically the first research question.

3.1 Innovation

3.1.1 Innovation in construction

Construction industry has been described continuously as conservative when it comes to innovation (Bygballe and Ingemansson, 2014, Blayse and Manley, 2004), it also has unique setting and characteristics that favour short-term productivity (Dubois and Gadde, 2002a), for example, its relying on individual temporary projects. The project based character is however seen both as hindrance and driver of innovation (Havenvid, 2015). Hindering effect comes mainly from project organization setting, which does not favour learning as continuous process (Dubois and Gadde, 2002a), and on the other hand, the project is also viewed as creative arena where different actors come together to solve complex problems (Havenvid, 2015). Although the construction industry has following traditional ways for decades, it remains one of the most important industry in today's economy, and the more innovative it becomes, the greater its contribution to economic growth (Blayse and Manley, 2004).

There is no specific definition for innovation, as it can be understood variously by stakeholders. Some consider innovation happens when companies do new activities or existing activities differently (Bygballe and Ingemansson, 2014), and others defines it as *"carrying out of new combinations"* (Schumpeter, 1934, p. 65). Nevertheless, a comprehensive definition for innovation was put by Slaughter (1998) as follows: *''Innovation*

is the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change''.

Slaughter (1998) differentiated also between innovation and invention, in which *"an invention is a detailed design or model of a process or product that can clearly be distinguished as novel compared to existing arts".* Although an innovation itself could be considered as an invention, it does not need to be novel with respect to the existing arts, however an invention is not considered an innovation unless it can be put in use (Slaughter, 1998).

The Organization for Economic Cooperation and Development categorizes innovation as either technical or organizational (cited in Blayse and Manley, 2004). Technical innovation covers changes in a process or a product. In contrast, organizational innovation includes changes to the organizational structure and management techniques. However, both types can be viewed as related and interdependent, as organizational change and training can lead to technical innovation (Bygballe and Ingemansson, 2014). Furthermore, Slaughter (1998) classified innovation into five different types: 'incremental' (small changes based on current technology or knowledge), 'radical' (a breakthrough in technology), 'modular' (a small change in concept within a component only), 'architectural' (a change in links to other components or systems), or 'system' (multiple, integrated innovations that work together).

Another term yet to be defined is process innovation, it can be seen from single actor perspective as *''new activity links in which activities are coordinated in new ways across firm boundaries''* (Bygballe and Ingemansson, 2014). However, they argue that another understanding of innovation exists when a firm is interconnected within a network, in which any change , such as innovation, will affect both the individual firm and other actors, and the definition thus becomes *'' changes in activity links in terms of new types of production (or other) activities across firm boundaries''* (Bygballe and Ingemansson, 2014).

3.1.2 Key influences on construction innovation

The construction industry encompasses a broad range of key participants, such as governments, users, clients, suppliers, educational institutions, general and specialist contractors, and consultants, to mention a few. Blayse and Manley (2004) identified six primary key influences, which can stimulate or hinder construction innovation: clients and manufacturers; the structure of production; relationships between individuals and firms

within the industry and between the industry and external parties; procurement systems; regulations/standards; and the nature and quality of organizational resources.

First, clients are able to stimulate innovations in the construction industry in different ways. They can request new, novel requirements from contractors; put pressure on project players to improve performance; and demand higher standards (Blayse and Manley, 2004). Manufacturing firms are also considered as important sources for construction innovation because they operate in a more stable environment and their activities are not project-based, which allow them to build up knowledge bases and avoid learning continuities (Blayse and Manley, 2004).

Second, the nature of production in construction projects is characterized as one-off or temporary, as is associated with discontinuities in knowledge development and knowledge transfer within and among firms (Blayse and Manley, 2004, Dubois and Gadde, 2002a). This one-off nature of projects makes the application of innovation in different situations limited, and thus, reducing both values of innovation and incentives to innovate (Blayse and Manley, 2004).

Third, industry relationships have a major influence on construction innovation (Blayse and Manley, 2004, Dubois and Gadde, 2002a). *"The importance of relationships lies in their capacity to facilitate knowledge flows through interactions and transactions between individuals and firms" (Blayse and Manley, 2004).* An important term is yet to be mentioned is 'innovation brokers', innovation brokers act as information intermediaries, in which they connect construction firms and others, in which they introduce new technologies and competencies that construction firms might not be aware of. They, especially if they are involved in multi-industry, can maximize knowledge flows and growth to achieve innovations (Blayse and Manley, 2004). Examples of innovation brokers are construction research institutions, individual researchers, and professional institutions.

Fourth, procurement systems that prevent construction organization from performing non-traditional processes can damage innovation, while procurement methods that encourage firms integration improve innovation results (Blayse and Manley, 2004). The traditional lump-sum (fixed price) contract is the most conservative type and most injurious to innovation. According to Kumaraswamy and Dulaimi (2001) it involves high risk for contractors, adversarial relationships, poor integration across the supply chain, and the poorest innovation outcomes (cited in Blayse and Manley, 2004). If partnering is involved

alongside lump-sum contracts in straightforward projects, innovation can be improved. Complex projects with design-build, construction management, project management, or BOOT[3] style arrangement can have good innovation results, since *"these approaches integrate design and construction functions (and sometimes financing and operation), leading to improved design constructability and economy, through innovation"* (Blayse and Manley, 2004).

Fifth influence on construction innovation is regulations and standards. According to Dubois and Gadde (2002a), *"government regulations and industry standards make the system difficult to change, and this in turn hampers innovation".* However, when regulations and requirements become too strict for current technology, the industry players are forced to develop new technology to comply with those requirements, which may encourage demand for those improved technologies. Lastly, it is significant for construction firms, to have in place 'organizational resources', which include: culture of innovation; skills and capacity to successfully adopt innovations developed elsewhere; the presence of key individuals who champion innovation, processes that facilitate the codification of acquired knowledge, and an innovation strategy (Blayse and Manley, 2004).

3.1.3 Summary and highlights

The construction industry is different from other industries due to the temporary nature of its projects, and this is seen sometimes as hinderance to drive innovation within the industry. However, despite all criticism to the construction industry, it stays one of the major contributors in any nation's economy. Under the second section several key influences on construction innovation are summarized based on the work of Blayse and Manley (2004). These key influences will be used later in the theoretical framework and analysis in order to measure the required level of innovation.

3.2 Sustainable construction

3.2.1 Sustainable development

Different industries and businesses are becoming these days more aware of their negative impacts on environment and society, and many therefore have started taking responsible actions to integrate sustainability in their current business models. The construction industry

[3] BOOT refer to build, own, operate, and transfer.

is no exception to this. Although it realizes the importance of sustainability, organizations are still unable to attain sustainability due to the lack of experience and knowledge (Tam et al., 2016). Many definitions exist in literature for sustainability and sustainable development. However, most of these definitions agree that sustainability is based on three pillars i.e. social, environmental and economic considerations (Labuschagne et al., 2005, Martland, 2011, Griggs et al., 2013, Brundtland, 1987). In which environmental pillar tackles issues like pollution, climate change and the depletion of scarce resources. Economical pillar deals with people's livelihoods, employment, financial security and profitability. While the last pillar, social pillar, covers poverty reduction, improvement of working and living conditions, human rights and health. Economy, society and environment are also expressed as the three elements or the 3Ps of people, profit and planet. In his book, Christopher stated that for a business to become really sustainable, *''it must pay regard to the wider impact of the activities it undertakes if it seeks to remain viable and profitable''* (Christopher, 2011, p.242)

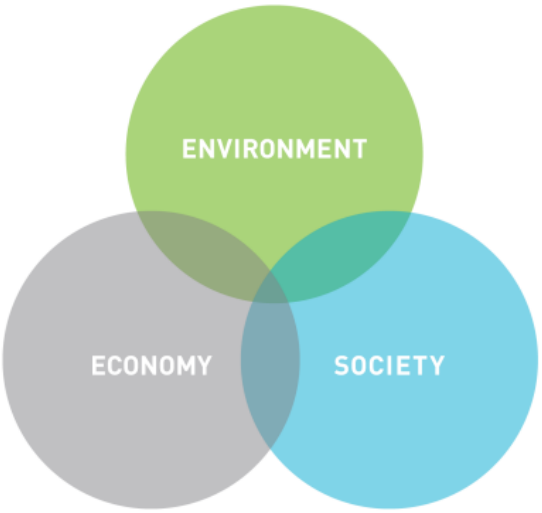

Figure 3 Three pillars of sustainability

According to the world commission on environment and development, sustainable development is defined as *''the development that meets the needs of the present without compromising the ability of future generations to meet their own needs''* (Brundtland, 1987). In 2013, Griggs et al. (2013) introduced a set of six sustainable development goals: thriving lives and livelihoods; sustainable food security; sustainable water security; universal clean energy; healthy and productive ecosystems; and governance for sustainable societies.

These goals build upon their new definition for sustainable development *''development that meets the needs of the present while safeguarding Earth's life-support system, on which the welfare of current and future generations depends''* (Griggs et al., 2013). Two years later, the

general assembly of the United Nations set 2030 agenda for sustainable development with 17 goals. One of the goals is to ensure sustainable consumption and production patterns, including promoting public procurement practices that are sustainable, in accordance with national policies.

3.2.2 Sustainable construction

The construction industry, among others, has many negative impacts on environment such as air pollution, water usage, land usage, energy consumption, usage of natural resources, and waste generation, just to name a few (Tam et al., 2016, Tam and Le, 2014, Martland, 2011). Furthermore, the construction industry plays an important role in global warming as it's a major contributor of greenhouse gas emissions globally (Hong et al., 2015). Others addressed also the need to consider environmental issues when evaluating any construction project (Martland, 2011); environmental issue ranges from local level like 'not in my backyard' to international level concerning the future of the planet.

This growing need to address the industry impacts on environment lead for new terms to emerge in literature like 'sustainable construction', which was first proposed to describe the responsibility of the construction industry towards sustainability (Hill and Bowen, 1997). In the first international conference of sustainable construction in Florida, USA, Kibert (1994) proposed that sustainable construction means *''creating a healthy built environment using resource-efficient, ecologically based principles'' (Cited in Hill and Bowen, 1997).*

Later, principles of sustainable construction were described by Hill and Bowen (1997): social, economic, biophysical and technical principles of sustainable construction. They identified social principles as following: improving the quality of human life; increasing human health through providing safe working environment; development of human resources; fair distribution of social costs of construction or fair compensation for people who are affected negatively by construction operations; fair distribution of the social benefits of construction; and finally seeking intergenerational equity so social costs are not passed to future generations. Economic principles of sustainable construction can be achieved, as explained by Hill and Bowen (1997), through ensuring financial affordability for targeted users; employment creation; using full-cost accounting and real-cost pricing to reflect social and biophysical costs; selecting responsible suppliers and contractors who can demonstrate environmental performance; and introduce policies and practices to ensure competitiveness in the marketplace.

The third term is called Biophysical, it covers aspects like atmosphere, land, underground resources and marine environment (Hill and Bowen, 1997). It's principles of sustainable construction require the following: extracting resources, and producing substances which are foreign to nature at slower rates than their redeposit into the earth; reduce the use of materials, energy, water, and land in construction projects; maximize recyclability and reuse; minimize global and local air and water pollution resultant from construction operations; minimize damage to historical, cultural, and scenic landscapes; and prioritize the usage of renewable resources over non-renewable one. Finally, they used the term ''Technical'' to describe the performance and quality aspect of construction operations. Technical principles of sustainable construction are: construct durable, reliable and functional structures; pursue quality in construction; and promote sustainable construction by using serviceability (Hill and Bowen, 1997).

Other researchers like Tam et al. went further and developed a sustainable checklist for construction projects to achieve sustainability in various stages of projects, the checklist is also built around the three pillars of sustainability: economic, environmental and social. According to Tam et al. (2016), sustainable checklist aims to achieve cost effectiveness by minimizing cost and maximizing profits, besides improving environmental performance through the reducing of pollution (including pollution to water, land and air), efficient use of resources and employing recycling and reusing.

Tam et al. (2016) have provided detailed checklist which is divided into five stages covering the whole project life cycle. The following are summary for each stage:

- Feasibility stage, in which clear objectives are defined, new policies are introduced, environmental impact studies are conducted, and local communities are involved.
- Planning stage involves making the project economically-viable, reusing existing land, and using products which are friendly to the environment.
- Design stage, where the project is designed with flexibility, minimum waste generation, efficient use of open-space, safe working environment, and efficient use of resources (including energy, water, and material).
- Construction process involves using local products and workforce, hiring experienced staff, provide necessary training, encouraging environmentally-friendly atmosphere, involving personnel in processes, ensuring energy consumption, and using waste and water management plans.

- Finished product stage, in which maintenance is minimized to minimize costs, maximize returns, explaining sustainability features, seeking feedback, and using recyclability approaches.

3.2.3 Characteristics of public projects

Projects are organizational tools used to perform work or create product. Project Management Body of Knowledge (PMBoK®) defined a project as *''a temporary endeavour undertaken to create a unique product or service"* (PMI, 2013b). However, projects need to pass different stages before reaching their end, Pinto described the stages of project life cycle: conceptualization, planning, execution and termination (Pinto, 2013, p.12), see Figure 1 below.

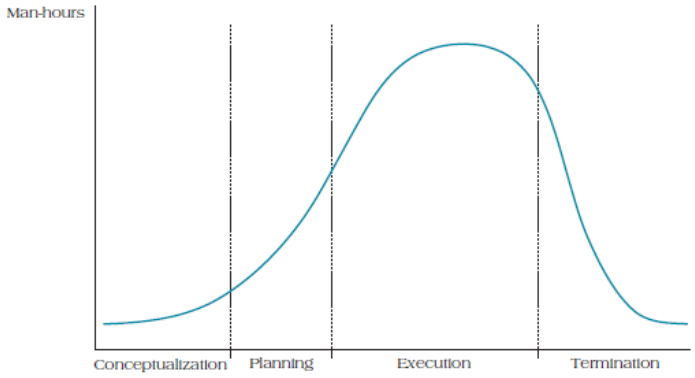

Figure 4 Project Life Cycle Stages (Pinto, 2013, p.12)

According to Pinto (2013), projects commenced in conceptualization stage, where projects' objectives and specifications are born. Followed by the planning stage, in which detailed description of specifications and plans are prepared. For example, WBS[4] is prepared during this stage. During execution, the actual work is performed, and thus, major amount of manhours and money are consumed rapidly during this stage, as illustrated below in figure 4. Last stage in project life cycle is termination, it happens when the project is completed and delivered to the client, the project releases all resources in this stage gradually until the project is closed and its organization is dissolved.

Moreover, usually at the outset of the project, there a lot of room to influence the final project results without impacting cost, while it decreases as the project progresses towards completion (PMI, 2013a). Figure 5 illustrates how the cost of making changes increases largely as the project approaches its completion.

[4] Work breakdown structure

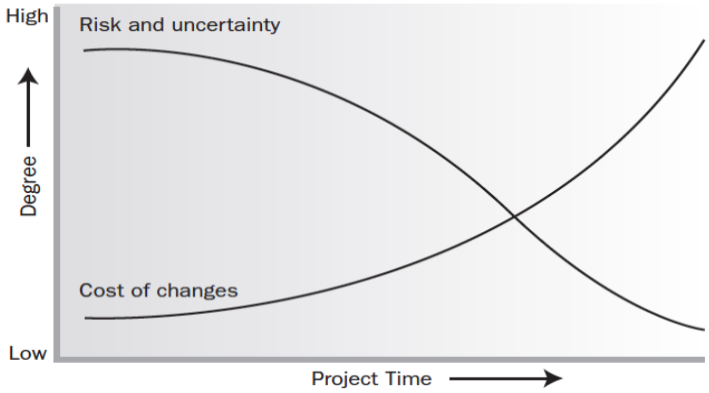

Figure 5 Project's risk and cost of changes with time (PMI, 2013a)

Private and public projects are very different, although both have a lot in common in terms of life cycle, execution plans and project management techniques. Since public projects are targeting the broader aspects of social, environmental and economical returns, this naturally makes them more complex. Private projects on the other hand are directly related to private sector perspective. The private sector is the part of a country's economic system that is managed and controlled by individuals or companies, instead of the government. The private sector's main motivation in undertaking projects is to achieve financial returns to its owners (Martland, 2011). The shareholder perspective drives private companies, where those companies are considered instruments to create financial returns on the behalf of those who invest risk-taking capital. Thus, companies belong to their owners and should act in accordance with owners' interests which are achieving profitability and return on investment (De Wit and Meyer, 2014).

However, in contrast to private projects which measure success in financial rewards (Martland, 2011), public projects measure success in societal needs and sustainability. The motivation of the project is to improve the environment or fulfil needs for the society. For public projects, the evaluation process for a successful project will be much longer than a private project (Martland, 2011). Thus, public projects might be a better starting point than private ones to promote sustainability like emission-reduction in construction projects. In any public project, three dimensions should be studied to evaluate the project in hand: economical, environmental and social impacts.

The public sector has more focus on the economic goals or benefits rather than the financial goals. In which, the purpose of the project is to facilitate a potential to expand the economic benefits in a region, both during and after the project is finished (Martland, 2011). For example, during the project, it will provide jobs by creating new opportunities for other

businesses like material suppliers. Second dimension of public projects, inspired by sustainability, is their environmental impact, either directly or indirectly. Among other industries, the construction consumes a lot resources that make an impact on the environment at some point (Martland, 2011). Martland stated in his book:

''Whether the benefits of the project are worth the environmental costs will always be a relevant question, especially when those receiving the benefits are not those who bear the costs''(2011, P.102).

In other words, projects need to be studied and evaluated carefully to assess expected benefits against environmental impacts. The last dimension in the evaluation process is the social impacts. Martland defined also users of the project, who are usually related to social impacts as:

'' People who live near the project, people who are displaced or competitively disadvantaged because of the project, or people who are hurt or whose lives are hindered due to the construction or operation of the project'' (2011, p.112).

Negative social impacts can be poor quality of life (i.e dust and noise), deaths and injury during construction, illnesses resulting during normal operation (i.e asthma from air pollution) , disruption of neighbourhoods (i.e loss of property) , loss of privacy and so on (Martland, 2011). However, social impacts can be positive such as poverty alleviation through job creation, economic growth, and human training and development.

Freeman and Reed (1983) proposed two definitions for stakeholders: narrow and wide sense of stakeholder. The former refers to any individual or group that the organization depends on to survive such as employees, customers, suppliers, key government agencies...etc. On the other hand, 'wide sense of stakeholder' covers any individual or group that can affect the organization's operations or who is affected by its operations such as public interest groups, protest groups, government agencies, trade associations, competitors, unions, employees, customers ...etc. By following (Freeman and Reed, 1983) definitions, private projects' stakeholders can be classified under the narrow sense of stakeholder, while public projects have wider sense of stakeholders. This adds more complexity to project processes like planning and execution due to the wide range of requirements (i.e. sustainability goals) that public projects must consider.

3.2.4 Emissions in construction projects

3.2.4.1 Sources of emissions in construction

In this section, several studies will be reviewed to understand various sources of emissions in construction and building projects. According to Kim et al. (2011), past studies, addressed environmental impacts in construction projects, focused on issues related to material selection, design, and materials recycling rather than greenhouse gas emissions. While previous efforts were focused on increasing the environmental performance during the operation or use phase, lately, efforts that targeting environmental impacts during the construction phase like air pollution, have emerged (Peña–Mora et al., 2009, Waris et al., 2014).

The three main greenhouse gases (GHG) that result from construction activities are carbon dioxide (CO2), nitrous oxide (N2O) and methane (CH4) (European Commission, 2017, Yan et al., 2010). There are also other gases but these three GHGs account for 98.9% of the entire GHG emissions (Matin et al. 2004 cited in Kim et al., 2011). However, to make it possible to compare and combine the relative effect of different gases, the emissions of individual GHG are usually converted into CO2 equivalents and then aggregated (European Commission, 2017). To serve the context of the study and to avoid any confusion, this study will use either 'GHG emissions' or just 'emissions' to refer for all types of GHGs (CO2 and CO2 equivalents).

A quantification study of building project made by Hong et al. (2015), followed the guidance of ISO 14064 on direct and indirect emissions to explore GHG emissions during the construction phase of a building project in China. In their research, they identified sources, then quantified all carbon impacts of all activities during the construction period of the building:

- Direct emissions: ISO 14064-2006 guidance of greenhouse gases defines direct greenhouse gas emission as *''GHG emission from greenhouse gas sources owned or controlled by the organization''* (ISO, 2006). According to the (Hong et al., 2015), several sources of emission fall under this category. First, fuel used in construction equipment and vehicles including mobile and off-road combustion such as excavator, bulldozer, piling machine and light vehicles used on the construction site. Second, onsite electricity use, in which GHG emissions are calculated from electricity production. A complete Life Cycle Assessment (LCA) analysis of electricity production covers

different phases of production from fuel extraction phase to operations phase. Last source is assembly and miscellaneous works, which include chemicals use, welding processes, waterproof paint, pipe binders, holes reservation, and thermal insulation.

- Indirect emissions: ISO 14064-2006 guidance of greenhouse gases defines indirect greenhouse gas emission as *''GHG emission from the generation of imported electricity, heat or steam consumed by the organization''* (ISO, 2006), it also recognises emissions arise from greenhouse gas sources that are under other organizations. Following this definition, several sources are identified as following: manufacture and transportation of building materials, transportation of construction equipment and offsite construction related staff activities (Hong et al., 2015).

In another study by Yan et al. (2010), greenhouse gas sources were categorized as following:

- Manufacture and transportation of building materials. It includes embodied (GHG) emissions of building materials, which are emissions due to energy consumed during the manufacturing process of these materials. In addition to, emissions from transportation for building materials, which are emissions due to fuel and energy consumed during transportation of these materials to construction sites.
- Energy consumption of construction equipment, in which covers emissions from fuel combustion of construction equipment and electricity used for construction equipment.
- Energy consumption for processing resources, emissions due to the electricity used in processing operations of water and sewage.
- Disposal of construction waste, where emissions due to fuel combustion during the transportation of waste from construction sites to disposal sites.

Moreover, a study from the UK, made by Ren et al. (2012), shows CO2 emissions during the construction of a hotel project. They identified six main sources of emissions: management team travelling to and from construction site; operations including staff travelling to and from site, material transit on site and construction vehicles used in operation; visitors travelling to site to observe the construction process; plant, machinery usage on construction site; utilities, mainly usage of electricity; and deliveries such as material transportation from market to construction site.

Noteworthy, above studies, except Ren et al. (2012), cover emissions occur in all phases of a construction project; material manufacturing, transportation, construction process, equipment uses, and disposal. However, the scope of this study will only focus on emissions that result

during execution process or at construction sites. A visualization of the study's scope, showing what emissions are included, is illustrated in Figure 6, in which the study's scope lies within the blue dashed circle.

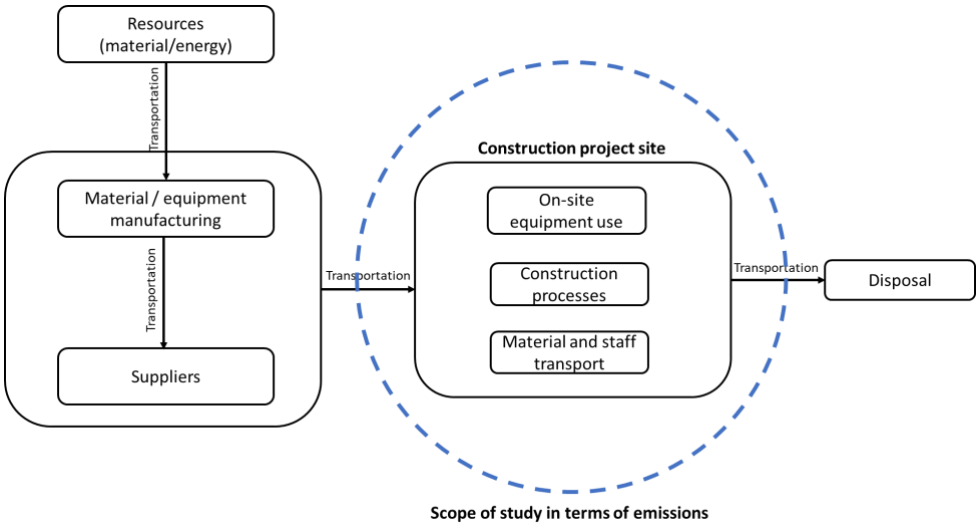

Figure 6 System boundary for emissions in construction projects

3.2.4.2 Emissions from construction machinery

The rise of various, automated heavy construction equipment have occurred in the last two centuries (Gransberg et al., 2006). Construction equipment constitutes an important part in any construction activity, whether activities were involving demolition an existing structure or building a new one. Construction of projects requires heavy equipment to support, assist and help in many work activities (Gransberg et al., 2006). In other words, Equipment and machinery are required to support human resources, in both light and heavy works, and to increase the productivity in various construction operations. Equipment and machinery used in construction include, but not limited to, construction Equipment, construction Vehicles, earth moving machinery, lifting appliances & conveyors, scaffolding & formworks, and site installation (Gransberg et al., 2006). Table 2 below shows list of construction equipment categorized based on purpose and use in five main categories.

Regardless if the onsite equipment is running on electricity or fossil fuels, they will produce direct GHG emissions. Since the fuel combustion ones like bulldozer will generate gases to the atmosphere, while electric compacter contributes in GHG emissions due to the electricity production (Hong et al., 2015), which highlight the need for renewable electricity sources.

Table 2 List of construction equipment (Basic Civil Engineering, 2015, Gransberg et al., 2006)

Earth Moving equipment	**Construction vehicles**	**Material handling equipment**	**Construction equipment**	**Tunnelling equipment**
Excavators	Tippers	Crane	Concrete Mixture	Road Headers
Graders	Dumber	Conveyors	Compactors	Tunnel Boring Machines (TBM)
Loaders	Trailers	Hoists	Pavers	
Skid loader	Tankers	Forklifts	Road Rollers	
Crawler loaders			Compressors	
Backhoe				
Bulldozers				
Trenchers				
Scrapers				

Construction equipment, machineries and vehicles have a high impact on environment than passenger vehicles (Waris et al., 2014). According to the United States Environmental Protection Agency (EPA), the US construction industry has around two million equipment, machineries and vehicles which are powered by fossil fuels, which are responsible for large amount of discharge of CO2, hydrocarbons and particulate matter (Waris et al., 2014).

A research ,based on a case study from China, conducted by Yan et al. (2010), found that almost 98.6–99.2% of the total GHG emissions in building construction come from manufacturing and transportation of building materials plus energy consumption of construction equipment: 81.6–86.7% are from production of building materials; 6.1–8.4% are from the transportation for building materials; and 6.4–8.6% are due to the energy consumption of construction equipment.

The Korean Institute of Construction Technology (2010) stated that gas emissions from onsite construction equipment responsible for 6.8% of the overall emissions produced in Korea in 2009 (cited in Waris et al., 2014). However, results can vary dependent on the type of project. For example, earthmoving equipment like excavators produce highest percentage of GHG emissions (up to 90 %) among all construction activities (Kim et al., 2011). Besides that factors like equipment type, fuel used, and its efficiency affect rates of emissions (Waris et al., 2014). Due to the low percentage of GHG emissions from onsite equipment compared to material production and transportation, onsite equipment emissions were neglected in previous studies (Kim et al., 2011).

3.2.4.3 Selection of onsite equipment

In any construction project, there are several sources of GHG emissions as mentioned earlier, however, emissions occur in construction sites are mainly due to energy consumption of construction equipment like use of diesel vehicles (Waris et al., 2014).

Several studies discussed criteria for the selection of sustainable construction equipment for onsite operations, in which emphasizing dimensions like efficiency, productivity, and sustainability in addition to the conventional triangle of cost, time, and quality (Waris et al., 2014, Gransberg et al., 2006). Waris et al. (2014) described six factors based on the three aspects of sustainability: life cycle cost, performance, system capability, operational convenience, environmental impact and social benefits.

- Life cycle cost: LCC factor assessment describes the cost of elements which are important to calculate the cost of construction equipment, as it comprises both ownership cost and operational cost.
- Performance: performance measurement indicators are used to monitor and control the use of equipment.
- System capability: this factor describes the equipment design which is important in measuring productivity and operation capability for earthmoving vehicles.
- Operational convenience: this factor describes items such as easy maintenance, meeting job requirements, access to spare parts, compliance with site conditions, adaptability of equipment to road conditions.
- Environmental impact: The construction equipment which are power-driven by diesel have major impact on environment due to gas emissions, and so it's vital to incorporate the environmental issues in the selection of equipment construction. The Environmental impact factor covers criteria such as:
  ''Oil and lube leakage control, use of biodegradable lubricants and hydraulic oil, quantity of particulate matter, fossil fuel consumption, use of sustainable fuels, greenhouse gas emissions, energy saving, noise control, vibration control and environmental statuary compliance'' Waris et al. (2014).
- Social benefits: the sixth factor concerns with equipment operators needs and safety, where they work in safe working environment and develop their skills and career path.

3.2.5 Emissions at construction sites

Based on the studies from previous sections and the study's system boundary, a summary showing sources of GHG emissions at construction sites is produced, see Table 3 below. The table shows the three main sources of emissions at construction sites and their site-related activities, then activities are sorted based on locations and project stage. The following paragraphs describe each activity in detail to draw a comprehensive picture of emissions at construction sites.

Table 3 Main sources of emissions at construction sites

Main Source	Activity	Environmental aspect	Environmental impact	Emission location	Project stage
Transportation	Material delivery	fuel and energy consumed during transportation	Air pollution	Inter-project: to construction site	All stages except conceptualization
	Waste transport			Inter-project: from construction site	Execution/termination
	Staff travel	fuel and energy consumed during use of light vehicle transport		Intra/inter-project: to, from or at construction site	All stages except conceptualization
Production and execution methods	Construction operations	fuel and energy consumed during construction operations		Intra-project: at construction site	Execution/termination
Equipment use	Construction machinery	fuel and energy consumed during use of construction equipment			

The first activity, as illustrated in above table, concerns the delivery of both permanent and consumable materials to construction sites. Permanent materials are materials used to produce project deliverables and will be permanent parts of the project such as steel reinforcement, paint, concrete and insulation. while consumables are material used during construction to execute the main construction activities like formwork woods, screws, welding rods, and office supplies. Second activity is waste disposal, where waste is transported from construction sites to proper disposal sites, and obviously such activities will result in emissions due to fuel consumed in transportation. Wastes are produced in projects because of

construction activities and operations, such as solid waste, chemical waste and liquid waste. Packaging materials like woods and paper boxes are good examples of solid waste.

Third activity is staff travel, it describes the use of light vehicle transport by both management and construction staff during project life cycles. Light vehicles consume fossil fuels and produce intra-project and inter-project emissions. Travels can be from home to construction site, vice versa and within construction site itself. Although emissions from light duty vehicle are way less than heavy duty vehicles and construction equipment, they produce substantial amount due to the intensity of use over the project period.

Next activity is execution methods, which is purely dependent on how construction activities are performed. In general, execution method is how the contractor is going to produce work packages that together forms the project deliverables. Execution methods are translated into the work plan; however, it depends on several factors such as: the contracting firm's own techniques, client's requirement, project situation, project type and use of machinery. For example, using prefabricated concrete elements can reduce heating and drying activities at site, but they will increase the utilization of heavy equipment (i.e. cranes) during installation.

Last activity is mainly concerning the use of construction equipment and vehicles during construction operations, that produce intra-project emissions, full list is described previously in Table 2. Emissions from construction equipment and vehicles were neglected before because their smaller contribution compared to emissions from material production (Kim et al., 2011). However, construction equipment produces the largest source of emissions at construction sites after exclusion of emissions from material production (Yan et al., 2010).

3.2.6 Summary and highlights

Every business should stay aware of sustainable development and sustainability concepts to understand the wider impact of the activities it undertakes. The construction industry, like other industries, has the potential to become sustainable. Hill and Bowen (1997) described four principles that enable construction firms to achieve sustainability: social, economic, biophysical and technical. The characteristics of both public and private projects are compared against each other, to show why public projects are considered a better starting point than private ones to promote sustainable practices like emission-reduction in construction projects. Moreover, different types of GHG emissions - occur because of construction projects - are described based on several studies. However, as illustrated earlier in Figure 6, only emissions occur during project execution or in project construction sites,

will be investigated in this study. Finally, sources of GHG emissions at construction sites are summarized in Table 3 to align with the study's context.

3.3 Public procurement

Purchasing is defined as *" the management of the company's external resources in such a way that the supply of all goods, services, capabilities and knowledge which are necessary for running, maintaining and managing the company's primary and support activities is secured at the most favourable conditions"* (Weele, 2014, P.8)

Two terms are often used interchangeably: 'public procurement' and 'public purchasing'. Although procurement is a wider term than purchasing according to (Weele, 2014, p.8), see Figure 7 below, both terms will be used interchangeably in this study to describe the process of procurement by public authorities.

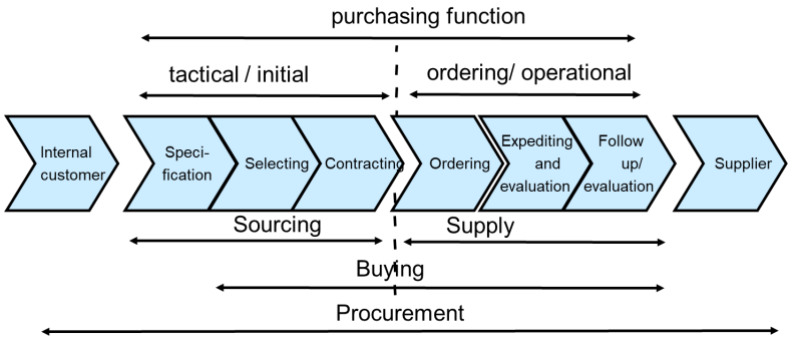

Figure 7 Purchasing process model, (Weele, 2014, p.8)

3.3.1 Public procurement in the EU

OECD defines public procurement as *'' the purchase by governments and state-owned enterprises of goods, services and works''* (OECD, 2015). Another definition is set by Torvatn and de Boer (2017) as *'' any acquisition made by a public organization and agency where public money is spent to acquire goods and/or services from non-public suppliers''.* Procurement within governmental agencies and authorities includes a lot of money. EU member states on average spend around 14 % of their gross domestic product (GDP), over €1.8 trillion was spent in 2015 on purchasing goods, projects and services[5] (European Union, 2016). Governmental procurement differs from procurement by private organizations in that it serves political strategies and goals, and due to the political dimension in public procurement, governments must study many considerations to spend tax payers as wisely as

[5] These figures exclude utility companies; earlier estimates (2011) including utility procurement were of around 19% of EU GDP, accounting for more than EUR 2,3 trillion.

possible (Weele, 2014). The objective of public procurement is to find and procure products and services with good value for money (European Union, 2016), while avoiding waste, fraud and corruption, and risks in different stages of the procurement process (Baron, 2016). In other words, public procurement to match supply with demand, while at the same time taking value for money consideration into account (European Union, 2016).

Public procurement law is built based on the international – agreement on government procurement (GPA), - European law - Treaty on functioning of the European union (TFEU) – and national laws (Weele, 2014). The law plays an important role in forming and controlling public contracts, in which it describes matters like dealing with suppliers and award criteria (Weele, 2014). Public authorities need to consider complex legislation before making purchasing decisions. Four principles must be followed when dealing with suppliers: non-discrimination, equal treatment, transparency, and proportionality (Europen Union, 2014). Poor handling and acknowledgement of public procurement laws causes procedural mistakes, which lead to delays in project execution and excessive claims from suppliers (Weele, 2014).

Value for money is a key consideration in public procurement, public authorities are obligated to get the best value for taxpayers' money for everything they procure (European Union, 2016). And thus, Identifying the most economically advantageous tender does not necessarily mean going only for the cheapest offer. It means finding a solution, which meets the requirements are identified, including environmental ones, in the most cost-effective way (European Union, 2016).

According to the European commission, public procurement strategy aims *'' to improve EU public procurement practices in a collaborative manner by working with public authorities and other stakeholders''*. The Commission introduced six policy priorities for public procurement, published on the commission's homepage (European Commission, 2016):

- Ensuring wider uptake of innovative, green, and social procurement
- Professionalizing public buyers
- Increasing access to procurement markets
- Improving transparency, integrity and data
- Boosting the digital transformation of procurement
- Cooperating to procure together

The latest EU directives on public procurement are: Directive 2014/24/EU on public procurement; and directive 2014/25/EU on procurement by entities operating in the water,

energy, transport and postal services sectors. Translation of these directives into the national legislation of the members states becomes mandatory since 14 April 2016. The recent EU directives on public procurement made existing public procurement rules more simple and flexible to benefit public purchasers and businesses, particularly small and medium-sized enterprises (SMEs). They aim to increase the efficiency of public spending to ensure the best possible procurement outcomes in terms of value for money, open the EU's public procurement market through simpler procedures, facilitate the participation of and help public purchasers to implement environmental polices (European Commission, 2016).

European commission defined the basic principles in public procurement: non-discrimination, which means that its prohibited to discriminate suppliers on ground of nationality; equal treatment, this principle specifies equal treatment of all tenderers during all tender stages of the purchasing process, ranging from formulation of specification, conditions and selection criteria, to the stage of evaluation of offers and award; transparency, in which tender opportunities must be advertised widely enough to ensure competition; and proportionality, which means that the requirements must be both appropriate and necessary to achieve the contract (European Commission, 2016, European Union, 2016).

The above directives on public procurement include the following procedures: open procedure; restricted procedure; competitive procedure with negotiation, competitive dialogue; and innovation partnership (Europen Union, 2014). Following illustration in Figure 8, provides clear comparison between those procedures. Noteworthy, those procedures provides a number of stages where environmental considerations can be incorporated: subject matter and technical specifications; selection and exclusion criteria or supplier's qualification stage (e.g. compliance with environmental laws, technical and professional ability); award criteria; and contract performance clauses (European Union, 2016). Moreover, before launching a procurement procedure, contracting authorities are allowed to conduct market consultations, such as dialogue conferences, where they can inform market participants of their procurement plans and requirements and seek their feedback and advice.

The open procedure is a single stage competitive bidding procedure, which starts with a call for bids, followed by the reception of tenders. Then, suppliers are evaluated on either lowest price or a set of criteria (economically most favourable).

The restricted procedure is a two-stage bidding procedure. First, a call for competition invites interested suppliers to submit an expression of interest. Interested suppliers may be evaluated

and shortlisted on one or more screening criteria, leading to a minimum set of 5 qualified suppliers that are invited to submit a bid. Then, bids are evaluated on either lowest price or a set of multiple criteria (economically most favourable).

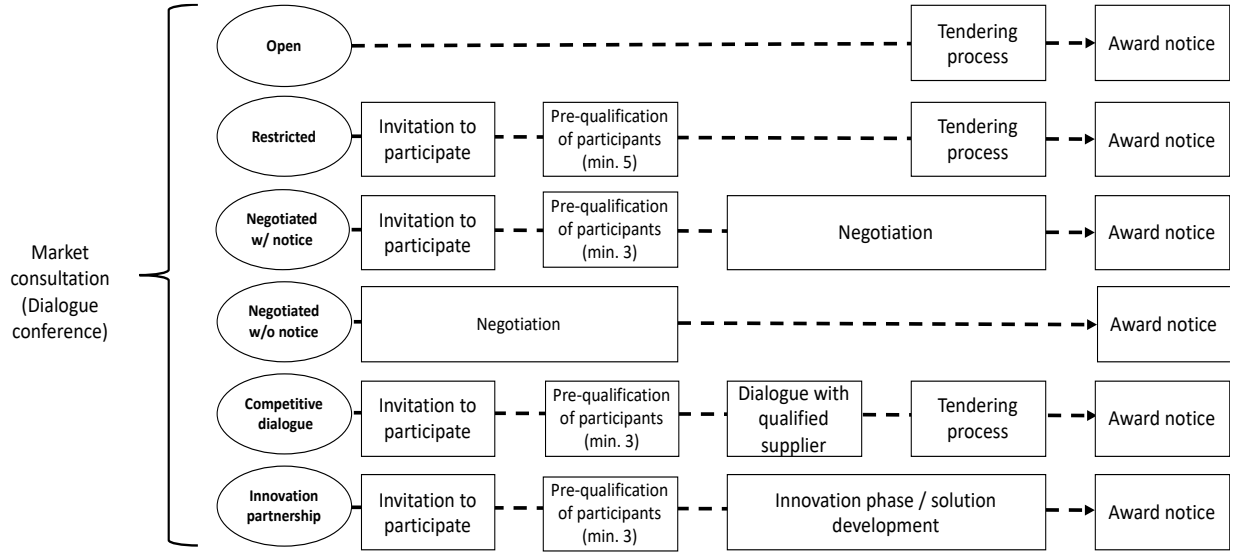

Figure 8 Procurement procedures in the EU/EEA

The negotiated procedure is a procedure featuring direct purchasing to be used in exceptional situations where the open or restricted procedures cannot be used, like lack of time in case of emergency situations. The procedure takes two forms, one with notice, and one without. The negotiated procedure with notice starts with invitation to participate, and a shortlisting of minimum three suppliers. It is then followed by a negotiation stage, where the contracting authority negotiates directly with suppliers, until signing the contract. As such, there is not necessarily a tender process as with the other procedures. The negotiated procedure without notice is similar to this, only that prior announcement and shortlisting are not necessary.

Competitive dialogue was added to the previous EU directive 2004/18, as there was a need for a procedure that was more flexible than the restricted procedure and more transparent than the negotiated procedure. It addresses the need for specific interaction with the supplier when specifications are not clear. Following an invitation to participate, interested suppliers may express their interest and at least three should be qualified for the next stage, where parallel dialogues is taken place among the purchaser and the qualified suppliers. Each supplier suggests a technical solution for the purchaser during dialogue. Based on these dialogues, the purchaser decides on one final solution to be used as specification in a final competitive bidding step, open only to the qualified suppliers.

Innovation Partnership is a new procedure added for the new EU directive 2014/24/EU, which replaced EU directive 2004/18. EU homepage describe the innovation partnership as a procedure *''allows for the combination of development and purchase elements tailored to public requirements, with specific rules in place to ensure equal treatment and transparency''.* The innovation partnership process constitutes of three phases: first, competitive phase where the most suitable suppliers are selected on the basis of their skills and abilities; second, the suppliers or supplier chosen will then develop the innovative solution together with the contracting authority. If more than one supplier was chosen, this phase may gradually reduce the number of suppliers, depending on whether they meet predetermined criteria; last phase, a final supplier is chosen who will provide the solution developed.

Furthermore, another term to know is Pre-Commercial Procurement (PCP). It is an approach to public procurement of research and development (R&D) services, where it takes place prior to the 'regular procurement' where the EU procedures for public procurement apply. Although it is an important tool to stimulate innovation, our study will not focus on it as it's is not part of the EU directives on public procurement.

3.3.2 Green public procurement

The most recognized definition of green public procurement (GPP) is the one provided by the European Commission:
"A process whereby public authority seeks to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured" (European Union, 2016).

The term green supplier selection (GSS) is emerged after the inclusion of environmental criteria within the supplier selection process (Igarashi et al., 2013). GSS process is an important part of the GPP process, and it is a core procurement activity in both the private and public sectors (Igarashi et al., 2015). They also stated that *''GPP includes more than GSS, but it should be noted that GPP is typically used in a narrow definition, focussing on nearly the same meaning as GSS in the public sector''.* And therefore, GSS and GPP mean nearly the same meaning in public sectors, which means models fall under GSS can be also employed for the use of public authorities in public procurement.

GPP empowers the purchasers to make better decisions and prioritize environmental needs (Igarashi et al., 2015). GPP process usually includes specific criteria related to suppliers' competencies and capabilities, in addition to criteria related to environmental performance. And then purchasers choose the most appropriate supplier for the job. Even though adding specific criteria looks very helpful for purchasers, but it adds more complexity to the process as purchasers need to collect more information about their potential bidders and invest more time in the selection process (Igarashi et al., 2015).

After the procurement goals and needs are translated into specifications, the purchasers will start researching the market looking for potential suppliers (Weele, 2014). Purchasing process consists usually of number of separate activities (Igarashi et al., 2013, Weele, 2014). Weele (2014, p.28) broke down the purchasing process (see Figure 9) into six main steps: define specification, select supplier (includes tendering), contract agreement, ordering, expediting, and evaluation.

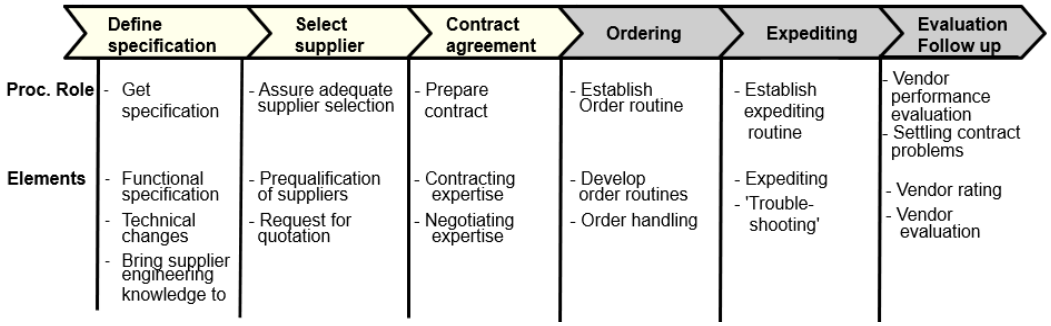

Figure 9 Purchasing process (Weele, 2014, p.28)

Igarashi et al. (2013) described the process in six steps, as illustrated in Figure 10. First, it starts with identification of the needs which are translated later into specifications. Second, measurement criteria for potential suppliers are set in place. Third, call or invitation for tender is communicated through a proper channel to suppliers. Then, reviewing of submitted information and qualifications takes place to select suppliers, this step however can take place in the shape of several rounds, where final choice of suppliers is selected from shortlisted, qualified number of suppliers. And lastly, an evaluation of suppliers' performance is maintained, recording such information is useful to improve the future supplier selections.

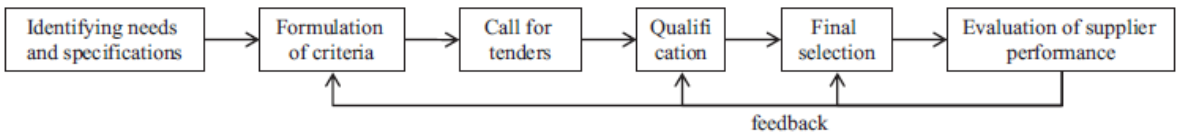

Figure 10 Supplier selection process (Igarashi et al., 2013, Igarashi et al., 2015, Weele, 2014)

Environmental requirements and criteria can be included at different stages of the supplier selection process: the specification stage, the qualification stage, the final selection stage and in the contract performance clause with the chosen supplier (Igarashi et al., 2015, European Union, 2016). In which criteria of each of the previous stages will be different by nature as each one of them is designed for different purposes. However, its crucially important that all criteria are aligned together within the same procurement strategy (Igarashi et al., 2013), and towards the same subject matter of the contract (European Union, 2016, Europen Union, 2014). Furthermore, Parikka-Alhola (2008) mentioned that environmental criteria and environmental impacts should be related, in which the criteria have strong influence to reduce those impacts.

Criteria can be also categorized under two groups: organization-related and product-related criteria, where the former is suitable in qualifying and selection, while the latter is suitable in the final stage after evaluation the bids of qualified supplies like the award stage (Igarashi et al., 2013, Parikka-Alhola, 2008).

At any case, the criteria mentioned in the call for tenders should be formulated properly and clearly, so suppliers can understand the environmental requirements and prepare their bidding documents accordingly (Parikka-Alhola, 2008). Selection criteria, also named qualification criteria in other resources (Igarashi et al., 2013), is to assess the suitability of suppliers to carry out the job (European Union, 2016). European Union (2016) mentioned that the most relevant selection criteria for GPP are related to technical and professional ability including: human and technical resources, experience and references, educational and professional qualifications of staff, Environmental management systems and schemes (e.g. EMAS, ISO 14001), supply chain management/tracking systems, and conformity assessment certificates.

In the Award stage, authorities use pre-determined, advertised in advance, award criteria to evaluate the quality of submitted tenders and compare costs (European Union, 2016). According to Directive 2014/24/EU on public procurement, most economically advantageous tender (MEAT) must be used as a basis to award contracts, where the most economically advantageous tender is assessed on the basis of the best price-quality ratio. Moreover, most economically advantageous tender should always include a price or cost element, and it could also be carried out on the basis of either price or cost effectiveness only (Europen Union, 2014).

Award criteria are weighted and scored to select the best performing tender. Table 4 illustrates weighting of environmental criteria from different studies found in literature. European Union (2016) does not set a maximum limit for environmental weighting, however, there are several considerations must be considered in weighting such as how significant the environmental criteria for the contract.

Table 4 Environmental criteria weighting factor from past studies

Studies	**Project type**	**Country**	**Weight of environmental consideration in award criteria**
(Uttam and Roos, 2015)	Works	Sweden	10 %
(Varnäs et al., 2009)	Works	Sweden	Max 10%
(Palmujoki et al., 2010)	Product, service, and works	Sweden/Finland	5-10% (Finland) 5-30% (Sweden)
(European Union, 2016)	-	-	No maximum
(Anthonissen et al., 2015)	Works	Belgium	50%
(Igarashi et al., 2015)	Product	Norway	5% to 20%.

According to European Union (2016), a GPP policy to be most effective, it should include the following: clear targets, priorities and timeframes; indicate the scope of the purchasing activities covered; indicate who is responsible for implementing the policy; and include a mechanism for appropriately monitoring performance. Moreover, feedback and input from internal users, suppliers, and management are essential to ensure successful application. Market consultation is also recommended by (European Union, 2016) to produce effective GPP, in which market dialogue between authorities and suppliers takes place before tender, such dialogue can be useful particularly when introducing ambitious environmental goals or seeks information about the availability of innovative solutions in the market.

Public authorities need to choose small range of products or services when they want to introduce GPP practices, as starting with pilot projects will help in the spread of GPP by demonstrating success at smaller scale first (European Union, 2016). However, several factors should be considered when prioritizing which products are most suitable for GPP: environmental impacts, products with highest impacts in environment; budgetary importance, where products represent large amount of the authority spend; and products with high potential to influence the market (European Union, 2016).

Another important step in GPP application is identifying the environmental criteria. EU has developed several GPP criteria for number of products and service groups, in which they are ready to be inserted into the tender documents. Product and service groups include: cleaning

products and services; copying and graphic paper; combined heat and power (CHP); office buildings; electrical and electronic equipment in the health care sector; food and catering services; furniture; gardening products and services; imaging equipment; road Design, Construction and Maintenance. Etc. Noteworthy, EU state that the term 'GPP criteria' includes specifications, selection criteria, award criteria, and contract performance clauses.

GSS strategies

Igarashi et al. (2015) studied number of procurement projects to find out to what degree the environmental criteria are presented in different stages of the selection process. Based on that, they introduced four strategies, illustrated in Figure 11 below, to face the increased complexity arises from inclusion of environmental criteria, in which purchasers such public authorities can have more vision over the selection process.

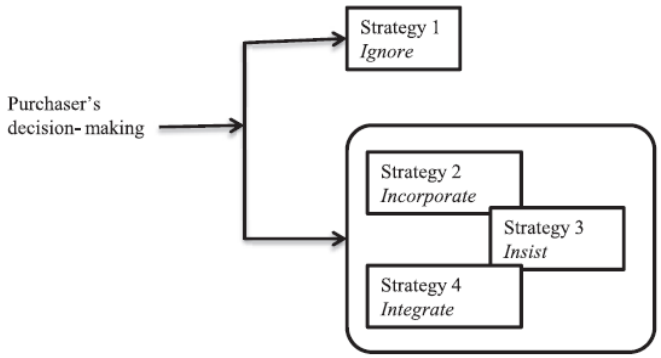

Figure 11 Strategies for dealing with green supplier selection (Igarashi et al., 2015)

The first strategy is to ignore the green dimension, in other words the environmental criteria is completely absent in the specification, qualification and award criteria stages. Which means that only traditional criteria will be considered during the process. Second strategy is when environmental criteria is incorporated under the existing criteria, where environmental criteria are not mentioned as independent criteria, instead its added under the other main categories like cost or quality. Such approach can minimize the effort in preparing tenders documents, however this strategy might not address the environmental requirements clearly to suppliers.

Third strategy is addressing environmental criteria as independent, mandatory criteria in all stages, except award stage. This strategy deals with environmental criteria as real qualifiers, however green performance is not traded off for performance from other criteria since green criteria are absent from the final award stage. Last strategy is called Trading off

environmental performance for other criteria (integration of environmental criteria), in which one or more independent, explicit criteria are included in the award criteria. Application of environmental criteria in the final award stage enable them to be traded off for the other criteria like price or quality, and thus leads to ‘’value integration’’.

Two sub-strategies lie under strategy number four: one sub-strategy allocates small weight, for example, 5-10% to environmental award criteria despite the product’s good environmental performance, and thus allows little value integration. In this case, the relevance of environmental award criteria for making a difference between two suppliers is questionable. The other sub-strategy is to allocate more weight, for example, 15-20%, to the environmental criteria. In summary, if the purchasers to not ignore the environmental criteria, this leaves them with strategies 2,3, and 4.

Conceptual model of GSS

Igarashi et al. (2013) suggested a conceptual model of GSS, see Figure 12 below, built upon four key dimensions of GSS process: aligning supplier selection with an organization's overall green Strategy; the role of decision-making tools and models in GSS; GSS as a series of interrelated decisions and information processing activities; and the wider supply chain context in which GSS takes place.

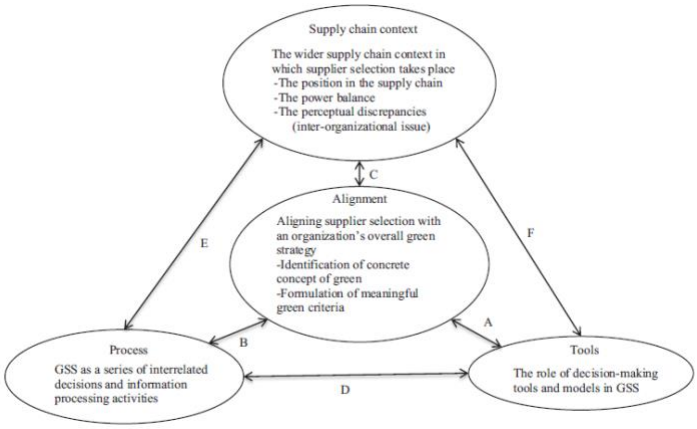

Figure 12 Conceptual model of GSS (Igarashi et al., 2013)

The first-dimension concerns the development of meaningful understanding of what “green” means with respect to the organization’s overall strategy. Without such understanding, the organization will be left with endless list of environmental criteria that might complicate the decision process when it comes to supplier selection, and consequentially degrading the value of green procurement. The environmental criteria to be effective, they cannot be chosen

randomly without relation to the organizations long-term goals, for example stimulate product innovation or cost efficiency.

After developing what ‘’green’’ stands for in supplier selection with regards to the organization’s overall strategy, comes second-dimension which deals with the role of decision-making tools and models, as different supplier selection situations will require different decision-making tools and models. The third-dimension highlights GSS as a series of interrelated decisions and information processing activities, it also address the fragmented nature of supplier selection process and how more coherent GSS can be achieved.

As previously mentioned, environmental criteria can be included in different stages of the supplier selection process, which means different stages might require different criteria, but after all and as Igarashi et al. (2013) said *‘’It seems important to make sure that the various green criteria applied in the different phases, taken together, constitute a coherent set aligned with the overall green strategy’’*.

The fourth and last dimension deals with GSS as part of wider supply chain context, as most organizations are both suppliers and customers, and therefore addressing environmental requirements through supplier selection can occur in the wider supply chain context of each organization.

3.3.3 Benefits and challenges of green public procurement

GPP plays an important role in stimulating the demand for environmentally friendly products and services in the market, and therefore, there is an emerging need to uncover the factors behind successful inclusion of environmental criteria in public tenders (Testa et al., 2016). According to Parikka-Alhola (2008), potential environmental benefits could be obtained if the environmental criteria are included systematically in public tenders.

A study by PricewaterhouseCoopers (2009) mentioned that *‘’public purchasers have the possibility to substantially reduce CO2 emissions through GPP’’*, such result is drawn based on their study of the adoption of GPP practices in seven European countries (Austria, Denmark, Germany, Great Britain, Sweden, Finland, and the Netherlands), where it estimates an average reduction of CO2 emissions of 25% in 2006-2007 when purchasing green for the ten product groups, which are analysed.

Furthermore, including green criteria in public tenders and implementation of green public procurement policies, can stimulate innovation capabilities of firms (Testa et al., 2016), since

they strongly influence the investment on both technological and organizational levels (Testa et al., 2011). Such development and investment make GPP '' *a vehicle for economic growth; it is estimated that in 2020 the sales of eco-industries will reach EUR 2,2 trillion"* (OECD, 2013).

On the on the hand, with all evident benefits of using GPP, public authorities have come across several obstacles while using GPP practices (Testa et al., 2012). A study by Bouwer et al. (2006) showed 3 major obstacles encountered by public authorities:

- Economic: green products perceived as more expensive products when compared to those not environmentally friendly
- Political: lack of organizational resources (including time and money) and of promotion policies for GPP
- Cognitive: a lack of information tools, lack of training, and lack of competence in establishing environmental criteria

A survey for Italian public authorities by (Testa et al., 2012), shows also that several problems emerged among public authorities who adopted GPP practices: lack of information about the real environmental impacts of the products; difficulty in finding suppliers; difficulty in the preparation of call for tenders and purchasing; and lack of guidelines by higher-order authorities. Another survey by OECD, found that the most repeated barriers by interviewed national representatives were lack of training for public purchasers and lack of information on both financial aspects and environmental benefits (cited in Testa et al., 2012). However, some of barriers were dealt with and tackled by promoting the use of internet tools on GPP, for example Buying green: a handbook on green public procurement, released by EC (Testa et al., 2012).

Additionally, (Uyarra et al., 2014) conducted a survey of suppliers to public sector organizations in the UK, in which several barriers to innovation are reported by suppliers: the lack of interaction with procuring organizations; the use of over-specified tenders as opposed to outcome based specifications; low competences of procurers; and a poor management of risk during the procurement process.

3.3.4 Buyer-supplier interactions

Attention to the supply side in companies has grown significantly during the two last decades of the 1900s (Gadde and Snehota, 2000). IMP approach views relationships as invaluable for organizations (Snehota and Hakansson, 1995), due to the benefits that can be obtained, such

as efficiency, effectiveness and innovation, when organizations relate to other actors in its environment (Torvatn and de Boer, 2017).

Such benefits made interaction with suppliers become popular in recent years (Gadde and Snehota, 2000, Araujo et al., 1999, Torvatn and de Boer, 2017). However, although such interaction can provide pleasant results, but it also comes at a price. Gadde and Snehota (2000) presented a model showing the economic consequences of supplier relationships, see Table 5. It allows to study the dimensions in supplier relationships that are important for choices of supply strategy, in which variance of relationships benefits and costs is dependent on the degree of involvement.

Usually high-involvement relationships cost more than low-involvement relationships due to coordination, adaptation and interaction efforts (Gadde and Snehota, 2000). However, it's also possible that direct procurement and transaction costs to decrease while relationship and supply handling costs increase under high-involvement conditions. In general, when developing a supply strategy, the choice for level of involvement must be justified with driving costs down, creating benefits or both (Gadde and Snehota, 2000). For example, high involvement might impose higher costs on the buyer such as relationship and supply handling costs, but such costs could be justified if the relationship led to a new solution or innovative product that have a potential to disrupt the market.

Table 5 Model of economic consequences of supplier relationships (Gadde and Snehota, 2000)

Relationship costs	**Relationship benefits**
Direct procurement costs (DPC)	Cost benefits (CB)
Direct transaction costs (DTC)	Revenue benefits (RB)
Relationship handling costs (RHC)	
Supply handling costs (SHC)	

Addressing economic consequences alone is not enough to design a prosper supply strategy as there are other dimensions should be taken into account such as the degree of innovativity offered by a supplier during the relationship. Araujo et al. (1999) defined four different types of supplier interfaces from customer-based perspective and their related consequences, see Table 6; each interface builds upon how resources of the supplier are activated. In other words, interfaces provide the customer with different ways to access the resources of their suppliers to achieve innovativity and productivity objectives. Noteworthy, purchasing firms or authorities need to have a variety of interfaces to achieve those objectives (Araujo et al., 1999).

Table 6 Consequences of Different Types of supply interfaces

Interface Category	Customer Benefits Productivity	Customer Costs Productivity	Customer Benefits Innovativity	Customer Costs Innovativity
Standardized	economies of scale and learning curve	Standardization may create costs elsewhere	None	No direct costs
Specified	economies of scale and scope	Supplier's resources may become locked-in	Minimal, supplier can only propose alternatives	Suppliers resources are used rather than developed
Translation	Supplier can propose efficient solutions that improve both sides	Benefits may not be shared with buyer	Supplier can propose solutions	Poor knowledge of user context hinders radical innovation
Interactive	Open-end interface allows full consideration of costs for both sides	Costs from how to make best use of existing resources	Knowledge of user context enables supplier to develop wide range of solutions	Joint development and learning need investments
Source: adapted from (Araujo et al., 1999)				

The new public procurement directives reform in the EU offers now wide range of interaction opportunities that public purchasers can take advantage of for purposes like innovation and new product development, except that little has been done towards strategic, long-term relationship (Torvatn and de Boer, 2017).

In their study, Torvatn and de Boer (2017) looked over various criticisms of EU public procurement directives prior to the reform. First, public purchasers quite often tend to use competitive tendering instead of more relationship-based solutions, as a result standardized supplier interface (Araujo et al., 1999) are very common among public purchasers. Second, although using of mixed methods, such as negotiation or competitive dialogue, can offer good solutions when the purchase is more complex than buying standardized products, it does not however, solve the problem. As Howden-Chapman and Ashton (2000) mention (cited in Torvatn and de Boer, 2017), the use of mixed methods tends to increase bureaucracy and challenges the knowledge and skill of public purchasers.

Another point of criticism is that using of competitive tendering by public buyers raise the chance of working against support of local business activity such as municipalities' policy to grow unmatured, local business. Since larger, regional suppliers are more likely to win bids than smaller, local suppliers due to their capabilities in economies of scale and efficient production.

In their conceptual study, Torvatn and de Boer (2017) positioned different public procedures against the model of buyer-supplier interfaces, developed by (Araujo et al., 1999), in which each procedure's potential towards innovation is identified. Table 7 shows how a

standardized or specified interface is dominant when open or restricted procedure is followed. Moreover, relying only on standardized or specified interfaces will restrict innovation opportunities through public procurement that uses open or restricted procedures (Torvatn and de Boer, 2017).

Table 7 Positioning the different EU public procurement procedures against Araujo et al. (1999)

Procedure	**Typical (dominant) interface**	**Innovation potential**
Open, restricted	Standardized, specified (interactive if the tender is preceded by a dialogue process)	The development towards creating dialogue with suppliers prior to an open or restricted tender improves the innovation potential
Negotiation, competitive dialogue	Translation, interactive	The interactive nature of competitive dialog improves the innovation potential
Innovation partnership	Interactive	The interactive nature of innovation partnership improves the innovation potential
Source: (Torvatn and de Boer, 2017)		

A good example of supplier interaction prior to the formal start of competitive bidding procedures, mentioned by Torvatn and de Boer, is the national program for supplier development in Norway, which intends to create more interaction among suppliers and public procurers within the existing framework of public procurement. This interaction enables both purchasers and suppliers to learn more about each other; purchasers learn more about the possibilities on the supplier market and at the same time, suppliers learn more about customer demand and needs. And as a result, *''purchasers may be able to write more realistic and inspiring, innovation-driven specifications''* (Torvatn and de Boer, 2017). Other procedures, again in Table 7, like competitive dialogue and innovative partnership have interactive nature, which improves the innovative potential through public procurement.

Torvatn and de Boer (2017) concluded that the new EU directives for public procurement made the room of interaction among suppliers and public purchasers larger, and they also increased the innovation potential offered by public procurement procedures.

3.3.5 Demands on public procurement

In this section several demands on public procurement will be presented based on a study, public procurement in perspective, made by Telgen et al. (2007). In which they combined existing literature and then grouped them to gain clarity and oversight of demands on public procurement. According to their study, public procurement complexity stems from greater and highly varied demands than those imposed on private purchasing. Telgen et al. (2007) outline that public procurement needs further development to face these challenging demands and deal with complexity. A summary of these demands is presented below in Table 8.

Table 8 Demands on public procurement (Telgen et al., 2007)

External demands	transparency integrity accountability exemplary behaviour
Internal demands	serving many goals simultaneously political goals many stakeholders
Demands originating from the context	budget driven budgets are open mutually dependent budget situations cultural setting
Demands on the process	strict limits difficult to have long-term relationships cooperation
Multiple roles for the public organization	large buyers reciprocity both a player and decision maker

First, external demands on public procurement. Transparency is required by public procurement, to ensure equal opportunities for all supplier and have transparent procurement process, besides that the public sector is expected to perform with integrity, in order to avoid improper, wasteful or corrupt practices. Furthermore, the public entities are held accountable for the effectiveness, efficiency, legal and ethical manner of their public procurements and are expected also to set an example by exemplary behaviour.

Second, public procurement must serve multiple goals at the same time, which includes internal goals (i.e economic and managerial goals) and general, public goals (i.e good sewage system). On top of that, public entities are expected to consider political goals. In addition, there are several stakeholders (i.e citizens, users, and officials), that may have different goals and conflicting interests in which public procurement is expected to account for.

Third, public procurement is budget driven; the organization can only spend what is in the budget. In addition, budgets are open and accessible to both public and suppliers, thus influencing the relations among purchasers and suppliers considerably. In the public sector there are usually many layers of government that function in mutually dependent budget situations, and consequently such arrangements may cause sub-optimization. Additionally, the unique cultural setting of public organizations, makes employees concerned about public interests, which can cause risk aversion and a tedious decision-making process.

Fourth, according to Murray, public procurement is controlled by strict limits because of legal rules and organizational procedures (as cited in, Telgen et al., 2007), and these rules come sometimes from different levels (international, national, local). As a result, these rules

and regulations hinder establishing and engaging in long-term relationships with suppliers. Moreover, from a competition point of view, cooperating with other public entities is virtually not restricted.

Lastly, the public organizations play multiple roles. While they are buying goods and services for their organizations, they primarily buying for the citizens. Additionally, public entities have complicated relationship with suppliers because of reciprocity when they are buying from supplies that are buying from the same public entities. Besides, the public sector is both a player and decision maker on the rules of the game, as one hand it determines the rules and regulations, while one the other hand it controls and audits the application of these rules.

3.3.6 Summary and highlights

Under this section, several concepts from literature are retrieved are described, such as public procurement, green public procurement (GPP), green supplier selection (GSS) and GPP criteria. The origins of public procurement in the EU area are also explained, where different public procurement procedures are described and compared. Then, GPP process and its main ingredients are explained afterwards, in which two models from (Weele, 2014) and (Igarashi et al., 2013) are used to describe the steps in any procurement process. Followed by GSS strategies from Igarashi et al. (2015), which will be used later to find out to what degree the environmental criteria are presented in different stages of the selection process. The conceptual model for GSS process by (Igarashi et al., 2013) is also reviewed, in which couple of key dimensions in this model will be used later in analysis.

Benefits and challenges of green public procurement are then depicted from several sources to highlight the potential benefits that could be obtained if the environmental criteria are included systematically in public tenders. Moreover, interaction with suppliers, with respect to public procurement process, shows how different interfaces, provided by (Araujo et al., 1999), can affect the productivity and innovativity of both purchasers and suppliers. Innovation potential of different public procedures is described according to study by (Torvatn and de Boer, 2017), refer to Table 7. Finally, demands on public procurement are described based on (Telgen et al., 2007) to understand its complexity.

3.4 Theoretical Framework

The review of the literature in previous sections, is used to develop the theoretical background required to facilitate answering the study's problem statement. The review

covered different topics in innovation, public procurement, and sustainability in construction. An illustration of theories retrieved from literature, is shown below in Figure 13. We believe that the synthesis of different perspectives provides a novel and worthless evaluation of the potential of public procurement to reduce emissions at construction sites.

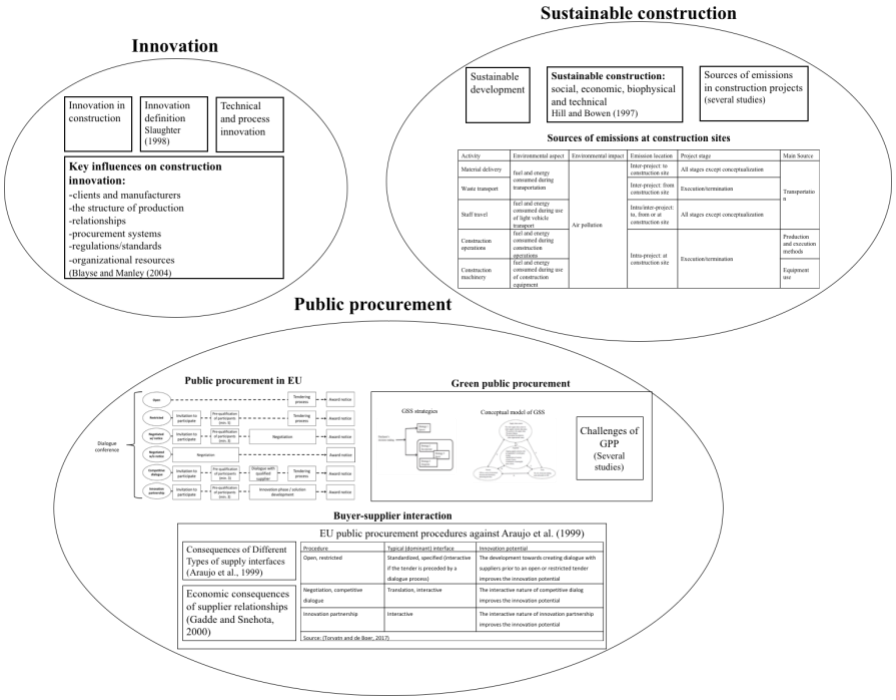

Figure 13 Illustration showing most important literature covered in our study

In the following, theories and concepts presented in the above illustration, will be structured to form the research's theoretical framework and guide the paper towards its goals, see Figure 14. The purpose of the framework is to show explicitly how different literature and previous research efforts will be applied to approach the research's problem statement.

The theoretical framework, shown in Figure 14, is divided into three stages to address the research problem statement, and more specifically to answer the first research question and then later to drive the single-unit analysis for each project. Firstly, the framework attempts to build an understanding of both low-emission and zero-emission construction sites. Principles of sustainable construction, as described by Hill and Bowen (1997), are reviewed to draw clear picture of how sustainable projects look like. Then, several studies such as (Hong et al., 2015, Ren et al., 2012, Yan et al., 2010), are reviewed to narrow down the wide sustainability goals in construction towards reducing greenhouse gas emissions and make it compatible with the study's context. Afterwards, only sources of emissions at construction sites are summarized in Table 3 and in accordance with the study's boundary as illustrated in Figure 6.

The resulted sources can act as point of departure for public procurers to formulate their requirements and criteria.

In the second stage, the framework investigates the ability of current public procurement toolbox to address those requirements and criteria. After defining those requirements or 'demand', initial interaction with the market suppliers and contractors in the shape of market dialogue can take place to understand the capability of the market and availability of solutions. Dialogue can influence the demand and cause some changes to requirements and criteria to match the current supply capabilities. Later, public procurers are left with several public procedures to choose from, in which different GSS strategies from Igarashi et al. (2015), can be applied to serve the procurement goals. Both procedure and amount of interaction used in the process will be positioned against buyer-supplier interfaces following the work of Araujo et al. (1999) and Torvatn and de Boer (2017).

The conceptual model of GSS by Igarashi et al. (2013) is centred in the middle as it provides guidance to public buyers from defining the demand till choosing the most qualified supplier. For example, alignment dimension describes how the defined demand relates to the public authority's overall green strategy. General challenges, drawn from studies for (Bouwer et al., 2006, Testa et al., 2012, Uyarra et al., 2014), facing public procurers are also placed in the centre. Later in the analysis part, challenges faced procurers during procuring projects with emission-reduction targets will be discussed in light of those general ones.

However, the previous investigation of public procurement capacity to reduce emissions at construction sites assumes limited interaction, which means limited innovation possibilities during the process. In order to fully understand to what extent public procurement can contribute in this context, it's found important to focus more in the next stage on innovation.

Therefore, key influence on construction innovation described by Blayse and Manley (2004), are incorporated in the last stage of the framework to explore more innovation possibilities within the current public procurement toolbox. Such iteration helps to examine the interaction prospects in broader context; such as different interaction possibilities among firms or the role of 'innovation brokers' who act as information intermediaries. This might influence again requirements and demand; such refinement might lead to new solutions or concerns. In any case, procurers are required to act accordingly to manage the procurement process towards achieving its goals. And finally, extended interaction and innovative possibilities will enable procurers to choose more effective procedure and GSS strategy that reduce emissions

at construction sites. The conceptual model of GSS by Igarashi et al. (2013) is centred again in the middle of third stage, where it plays the same role described in the second stage. The same applies also for the general challenges facing public procurers in public tenders.

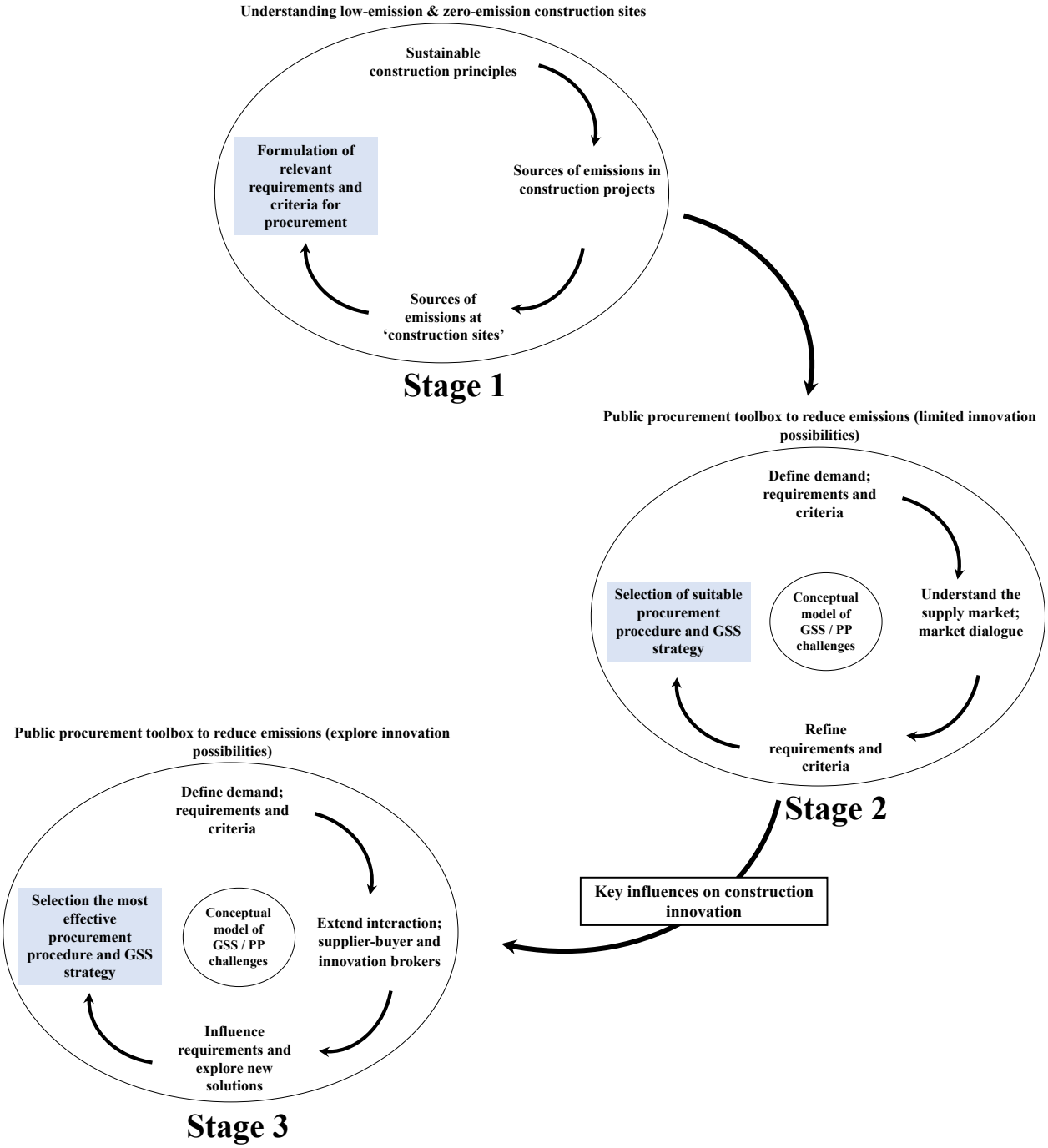

Figure 14 Theoretical framework of the study

As mentioned earlier, the above framework will be used largely to answer the first research questions and to drive the analysis. Noteworthy, the theoretical framework is revised during the empirical cycle of the case study, which led to incorporation of important aspects,

particularly related to interaction and innovation, the new, revised theoretical framework is presented in the discussion chapter. Following Dubois and Gadde (2002b) recommendation, looking into real world observation was necessary to develop better theoretical perspective and understand how public procurement tools function in such context, especially when the focus is to reduce emissions during the construction phase of projects.

4 Empirical study

As stated earlier in the methodology chapter, a case study research design is employed for the purpose of this research. The case study builds upon data gathered from documents and in-depth interviews. Documents are either provided by Omsorgsbygg's officials or accessed through the homepages of the following organizations: Oslo municipality, Omsorgsbygg, and Norwegian Agency for Public Management and e-Government (DIFI)[6]. While interviews are conducted with 7 employees; 4 from Omsorgsbygg and 2 from the main contractor, and 1 from the National Programme for Supplier development. This chapter constitutes of several sections, starting with introducing various information and facts about the case, then walking through data gathered from both documents and interviews of two projects, which are selected from Omsorgsbygg's portfolio, and finally closing with summary and highlights.

4.1 Introduction

In 2016, the City of Oslo announced a green transformation strategy, which aims to reduce greenhouse gas emissions, improve air quality, and enhance public transport. Therefore, several initiatives are launched in order to reduce greenhouse gas emissions in the city. Around 854,000 tones of CO2eq are released annually from construction sites in Norway (Statistics Norway as cited in DIFI, 2018), in which building construction sites are responsible for 340,000 tones of CO2eq. Moreover, it has been found that construction machinery is also responsible for 30% of transport emissions. This triggers the need to reduce emissions from construction projects during the construction phase. Oslo municipality in cooperation with other public organizations like DIFI, has formulated general requirements that will help its subsidiaries to address these new requirements in their upcoming new projects. Omsorgsbygg is one of the biggest subsidiaries of Oslo municipality, owning more than 900,000 m2 of public buildings in Oslo. Omsorgsbygg, among other organizations, took the lead to run several pilot projects adopting new requirement in parallel with the City of Oslo new vision. The case will focus only on two projects from Omsorgsbygg portfolio to address the research problem statement.

[6] Tender documents are accessed through www.doffin.no

4.2 Strategy

4.2.1 The City of Oslo

Oslo, the capital of Norway, is a hub of banking, shipping and trade in the country. It has a population of nearly 670,000 inhabitants. The vision for Oslo is a green, inclusive and smart city. Recently the City of Oslo was awarded the title of European Green Capital 2019 (City of Oslo, 2018). As a member of the UN Global Compact, a voluntary initiative based on universal sustainability principles, the City of Oslo is committed to the 'Ten Principles' concerning human rights, labour, environment and anti-corruption.

In December 2015, a new global climate agreement was adopted at the Climate Change Conference in Paris. The parties agreed to limit global warming to a maximum of two degrees and promised to try to keep the temperature increase under 1.5 degrees.

Besides combating the climate change, the City of Oslo saw an opportunity to upgrade the city and make it better (Oslo Municipality, 2016). To make this happen a wide cooperation, between the municipality, residents, business community, organisations, and other public enterprises, is required. It's believed that the green transformation will not only reduce greenhouse gas emissions, but it will also make the air cleaner and produce better public transport. Such change will increase the quality of life and thrive business community (Oslo Municipality, 2016)

''Being a city rich in resources, in a country with abundant access to renewable energy, gives Oslo a unique position, with the potential for developing innovative solutions and be a leading city internationally'' (Oslo Municipality, 2016)

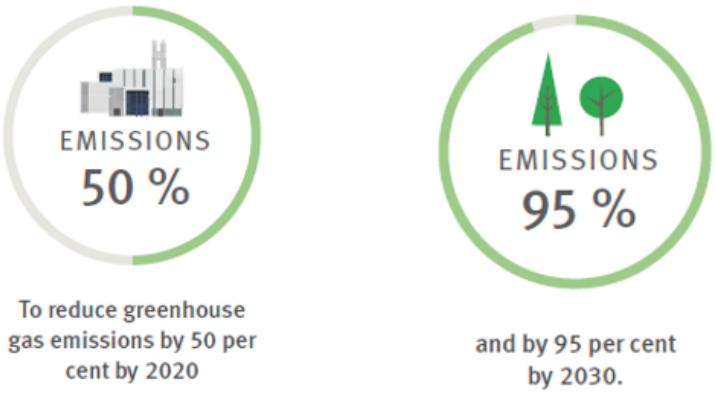

Figure 15 Emission targets for City of Oslo. Adapted from (Oslo Municipality, 2016)

Therefore, the city has developed and adopted the Oslo Climate and Energy Strategy, which is in accordance with the Paris Agreement. The target is to reduce the city's CO2 emission levels by 50% by 2020 and 95% by 2030, compared to the 1990 levels, see Figure 15.

The strategy follows a multidisciplinary and cross-sectoral approach to achieve the green shift. It involves five sectors: transport, energy, buildings, resource utilisation and cross-sectoral energy issues. The city translates the strategy into 16 initiatives, that describes how implement the green transformation in those five sectors will be undertaken. The City of Oslo plans to use the business community as spearhead in its green shift strategy, as interaction with the business community could stimulate economic growth and technological innovations (Oslo Municipality, 2016).

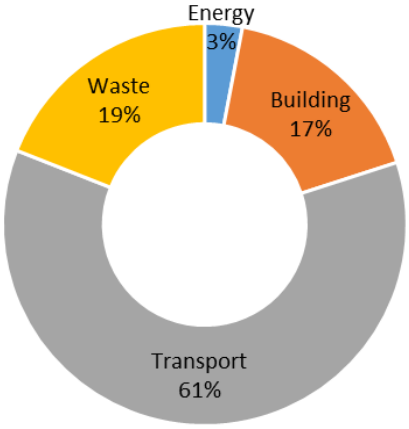

Figure 16 Sources of greenhouse gas emissions in Oslo[7]. Adapted from (Oslo Municipality, 2016)

A total of 19% of the city's emissions come from the treatment of sewage and waste, and around 17% of the emissions come from the use of fossil heating oil in buildings. While emissions from transport accounts for 61%; of which around half are attributable to transport of people, and half to both goods transport and construction activities (Oslo Municipality, 2016). The construction machinery is responsible alone for 30% from the transport emissions (Oslo Municipality, 2016).

Sustainable public procurement

The City spends approximately 2 billion euro per year on procurement, which accounts to around 5 % of the national public procurement budget (City of Oslo, 2016). With such magnitude of buying power, a difference could be made. The City of Oslo was the first city worldwide to adopt a climate budget following the Paris Agreement. It aims to become a

[7] Source: Statistics Norway combined with The City of Oslo's own numbers, 2013.

world leader in using public procurement as a strategic tool to achieve climate targets. The City of Oslo adopted the new procurement strategy in October 2017. The strategy states that *"The City of Oslo's procurements shall be innovative, cost-efficient, and contribute to building confidence in the City of Oslo as a public buyer"* (Oslo Municipality, 2017).

The City of Oslo plans to focus on the following areas, in the coming years, as part of its efforts to achieve sustainable procurement: developing more sustainable mobility solutions; reducing greenhouse gas emissions caused by deliveries of goods and services; reducing greenhouse gas emissions from public buildings; reducing greenhouse gas emissions from construction sites; reducing energy consumption; reducing and recycling of waste; encouraging more sustainable consumption and re-use; increasing the share of organic food and beverages to 50%; and increasing the share of innovative procurement and encouraging development of climate neutral technology and solutions (City of Oslo, 2016).

4.2.2 Omsorgsbygg

Omsorgsbygg is a public building owner in Oslo and aims to be a frontrunner in developing green energy efficient buildings. It owns about 900,000 m2 of buildings in Oslo. It is also a subsidiary operates under Oslo municipality, which is responsible for the municipal undertaking for social care buildings. Omsorgsbygg mission is to own, manage and develop municipal building, besides achieving high quality care services, for children, young people and society (Omsorgsbygg, 2016a).

''Better buildings, better life'', Omsorgsbygg vision (Omsorgsbygg, 2016a).

After Omsorgsbygg went through some changes in 2015, the demand for more social care buildings has been increased, which open new opportunities for Omsorgsbygg. Omsorgsbygg stated in the annual report of 2016 four main strategic objectives. First, buildings must lead to development, construction of both environmental-friendly and energy efficient building. Omsorgsbygg will develop the necessary expertise and knowledge through establishing collaborative agreements with other organizations in order to achieve this goal. Second, Omsorgsbygg to deliver buildings within agreed time, cost and quality. Therefore, Omsorgsbygg will maintain high level of competences at their disposal, such as quality and management systems and tools, to fulfil their customer and end-user's expectations. Third, customer satisfaction is another important strategic goal that Omsorgsbygg will make sure to achieve in their projects.

Lastly, Omsorgsbygg to be an attractive and competitive workplace for its employees, as having flexible work environment and providing necessary training will develop its core competencies and help the organization to thrive and achieve its objectives (Omsorgsbygg, 2016a).

Omsorgsbygg's Environmental strategy

Omsorgsbygg underlines the significance of creating environmentally-friendly solutions across its value chain, which is stated in its environmental strategy as:

"Omsorgsbygg shall become a leader in development, construction and management of environmentally-friendly and energy-efficient buildings'' (Omsorgsbygg, 2016b).

Omsorgsbygg supports Oslo Municipality's strategic objective to reduce greenhouse gas emissions levels by 50% by 2020 and 95% by 2030 (Omsorgsbygg, 2016b, Oslo Municipality, 2016). Omsorgsbygg believes that high, environmental ambition level should be reflected on all phases of a construction project. Moreover, it wants its buildings to apply good innovative solutions and processes in all phases to achieve environmental goals. In their strategic vision, Omsorgsbygg stated that emission-reduction from construction sites must be translated into requirements to stimulate new solutions. To achieve the above, Omsorgsbygg started applying new tools and requirements, such as all new and existing buildings must score minimum ''very good'' on BREEAM-NOR (environmental classification tool), and carrying out pilot projects with fossil-free objectives (Omsorgsbygg, 2016b).

4.3 Zero-emission construction sites

According to Norway's Agency for Public Management and e-Government (DIFI), a zero-emission construction site requires future-oriented and climate-friendly solutions. DIFI defines a zero-emission construction site when *''all processes at the construction site are zero-emission''*.

Three processes are identified, that could transform a traditional building construction site into an zero-emission one (DIFI, 2018). First, zero-emission solutions for construction machinery, through using for example electric machinery or hydrogen-powered machinery. Second, zero-emission solutions for building heating and drying, such as electricity or district heating. Third, zero-emission solutions for transportation within, to and from construction site. This may include transport of building materials, construction machinery, waste or personnel. However, no construction sites have been completely zero-emission until now.

While on the other hand, a fossil-free construction site requires avoiding any usage of fossil fuels on site. For example, fossil-free solutions for construction machinery, heating and drying, and transport.

According to study conducted by DNV GL, early use of electricity and district heating in construction processes can reduce almost all CO2 emissions from Norwegian building sites (DNV.GL, 2017). In total, 340,000 tonnes of CO2 are emitted from Norwegian building sites annually, that includes all project execution phase starting from excavation to interior works and finishing.

Their study shows that emissions like CO2eq can be reduced by almost 99% and NOx by 96% through utilizing both Zero-emission and fossil-free solutions during the building execution phase (DNV.GL, 2017). Table 9 below shows alternative solutions that can reduce emissions at building sites. However, few solutions are available today, such as biodiesel and some small electric machines. While others are under development such as electric heavy-machineries and hydrogen-driven machines.

Table 9 Zero-emission and fossil-free solutions. Adapted from (DNV.GL, 2017)

Heating and drying	**Construction machinery**	**Transport**
District heating	Biodiesel	Biodiesel
Electricity	Electricity	Electricity
Biodiesel	Hydrogen	Hydrogen

Usually building and construction activities are mainly powered by fossil fuel like diesel, and only minor tasks in small projects can be handled with battery-electric solutions, as existing electric machinery is small and needs more development to handle bigger tasks.

4.4 Omsorgsbygg's projects

2016 was the year when Omsorgsbygg started transforming its building sites into fossil-free one. As an effort to combat the climate change and support agreement signed in Paris in 2015. However, the long-term goal is to achieve zero-emission construction sites and pursue Oslo municipality goals. Since the construction machinery is responsible for about 30% of emissions from the transport sector, the construction industry represents a great potential to achieve major cuts in emissions.

For years, Omsorgsbygg's buildings were focused to reduce energy use and emissions from materials. And although Omsorgsbygg apply strict requirements when it comes to environmental considerations, the construction sites were not considered as areas of concern

before. However, Omsorgsbygg has realized that this an important milestone and quite a challenge, that must be achieved to move forward. Not to mention, the large emissions from construction process of these buildings that affects both population and local environment.

For the above reasons, Omsorgsbygg analysed current challenges and market, which unfolded several major issues (Omsorgsbygg, 2016c). First, public procurement procedures do not demand the use of state-of-the-art solutions which reduce (diesel) emissions generated at construction sites. Second, tackling emissions produced at construction sites is not addressed systematically in public tenders as price is usually the only competitive factor when it comes to choosing solutions and machinery for construction works. And finally, new solutions need to be developed in order to have zero-emission construction sites.

By end of 2015, Omsorgsbygg cooperated with Bellona organization, to help Omsorgsbygg shift towards fossil-free and eventually zero-emission construction sites, Bellona is an independent non-profit organization that aims to meet and fight the challenges of climate change. Later, Omsorgsbygg in cooperation with The National Programme for Supplier Development [8], held conferences with the market to obtain feedback on the kind of solutions the market could deliver today to reduce emissions at construction sites, and develop more environmental-friendly solutions to achieve zero-emission construction sites in the near future (Omsorgsbygg, 2016c).

Following the results obtained from market dialogue conferences, Omsorgsbygg initiated several procurement actions. Two projects are selected from Omsorgsbygg's portfolio for the purpose of this case study. These two were procured as a result of the new procurement approach; one involved demolition and construction of a new kindergarten, while the other one involves demolition and reestablishment of a nursing home.

4.4.1 Lia kindergarten

4.4.1.1 Description of the project

Omsorgsbygg, the Municipal Undertaking for social care buildings, shall develop and construct a new kindergarten in Harald Sohlbergs vei 19. The new nursery consists of 10 departments. The project includes demolishing the existing building, engineering and constructing the new building. In addition, the nursery shall have a special department for

[8] See section 4.5.8 to learn more about its goals.

children with disabilities, and the project includes also development of outdoor area. Following Table 10, shows major project milestones and actual status for each one.

Table 10 Status of Lia design and construction phase

Milestones	Expected / finish date	Status
Contract award	25-Oct-2016	Finished
Initial design stage	02-May-2017	Finished
Detailed design [9]	NA	Ongoing
Demolition of existing building	17-Oct-2016	Finished
Construction	27-Oct-2017	Finished

The general aim of the project is to develop and construct a new nursery that: satisfies standard requirement and specification for kindergartens; has 10 departments, including constructing an outdoor area and a special department for children with disabilities; produces more energy than it uses throughout the year, a so-called plus building; and shall be environmentally certified in BREEAM-NOR, minimum ‘’very good’’.

Reducing emission at construction site

According to the environmental follow-up plan attached in the competition documents, contractors needs to follow the minimum requirements to reduce emissions at construction sites. First, the building construction site must be fossil free, where machines that can be powered by electricity must be powered by electricity through grid connection or battery, otherwise all diesel-powered machines should use the 2nd generation of bio-fuel that comes from a certified sustainable source in accordance with the EU renewable energy directive. Second, reducing emissions from heating and drying operations. Drying operation must be controlled, and solutions that add moisture to the building must be avoided.

4.4.1.2 Main phases of the project

After the procurement process is done, the project is divided into three main phases:

I. Preliminary project: pre-project start immediately after the contract is signed.

[9] The detailed design has been ongoing even after the construction is finished because of remaining acoustical works.

II. Detailed engineering design, construction, commissioning and start-up: this phase is started immediately after submitted the preliminary project. This phase includes, among other things, search process, detailed design, and construction.

III. Trial operation, hand-over and claims period

4.4.1.3 Contract strategy

As mentioned in the contract strategy; which describes the plan to procure the project, the purpose of the procurement is to contract a contractor to carry out a preliminary project, demolition, detailed design and construction. See the summary of the tendering process in Table 11 below.

Table 11 Summary of Lia's tendering process

Project name and number	Lia barnehage / 11680058
Contracting authority	Omsorgsbygg Oslo KF
Object of the contract	Open tender competition for the procurement of turnkey contract for engineering design services for and the construction of Lia nursery.
Type of contract	Design and execution
Scope	The new nursery consists of 10 departments, including a special department for children with disabilities
Reducing emissions at construction site	Minimum environmental requirement
BREEAM-NOR	minimum 'very good'
Plus building	Plus, or passive
Estimated value excluding VAT	60 mil nok
Conditions for participation	Personal situation of economic operators, economic and financial ability, and technical capacity
Technical capacity requirements	Tenderers must have the capacity to carry out the assignment; tenderers shall have experience from assignments of an equivalent nature; and tenderers shall have a well-functioning quality assurance system that is relevant for the execution of this assignment.
Procurement procedure	Open procedure
Award criteria	The most economically advantageous tender Quality criterion - Name: Suggested solutions / Weighting: 40% Quality criterion - Name: execution plan / Weighting: 10% Price - Weighting: 50%
Awarded	Yes
Total value of the contract excluding VAT	Lowest offer 49 mil nok and highest offer 59 mil nok

Within the environment section in contract strategy, several requirements were mentioned: following the new Omsorgsbygg's environmental strategy; BREEAM-NOR classification with minimum 'very good'; and plus-building or passive-building requirement. Noteworthy, the project is fossil-free building site, in which construction activities must use electricity or bio-fuel.

Due to time pressure, it is decided to conduct an open tender competition. To ensure well qualified suppliers, suitable qualification requirements are prepared. The contract model for Lia project is a total contract, the decision is justified and backed with the following reasons.

First, Omsorgsbygg has carried out many projects with similar scope as a total contract model, where most of them are completed within time limits. Second, since the project is expected to be completed by end of 2017 and due to extensive rules and requirements for public procurement, selecting a total contractor will save time. In addition, the municipality has spent a lot of resources developing detailed, standardized specifications, which makes it possible to use a total contract. Lastly, contractors are familiar with this contract model and have a better knowledge of the market, and thus they can obtain less expensive prices than what a municipal builder can.

4.4.1.4 Qualification requirements

Omsorgsbygg performed a qualification of suppliers based on the following requirements. First, companies to submit documentation of company registration certificate. Second, Tenderers must have the financial capacity to implement the assignment/contract.

Lastly, suppliers must show that they are technically capable for this assignment. Tenderers must have the capacity to carry out the assignment with experience from assignments of an equivalent nature, complexity and extent: experience as a turnkey contractor in major projects and the construction of buildings with high environmental ambitions. Tenderers shall have a well-functioning quality assurance system that is relevant for the execution of this assignment. They shall provide a certificate for the company's quality assurance system issued by independent bodies which certify that the tenderer fulfils certain quality assurance standards, for example ISO 9001.

4.4.1.5 Award criteria

Table 12 below shows the set of award criteria used to evaluate the proposals received from suppliers who participated in the competition.

Table 12 Award criteria from Lia kindergarten competition. (source: WWW.DOFFIN.NO)

Criteria	**Weight (%)**	**Documentation requirement**
Quality criterion (Suggested solutions): • Planning solution • Outdoor area • Technical solutions • Aesthetics and material selection	40%	• Description, presentation, sketches and drawings of the offered solution. • Simulation of energy consumption that shows specific net energy needs • Description of strategies and principles for lighting, heating, ventilation and energy production
Quality criterion (execution plan): A.	10%	• How the project is going to be implemented in the different phases (methods, routines, etc.) • Progress plan showing activities for the entire project phases and milestones
Price	50%	• Price form is provided to be filled

4.4.1.6 Contractor´s proposal

The contractor, who won the contract, has proposed several environmental plans for this project, including several ways to reduce emissions at the building construction site. The contractor emphasized the importance of having an environmental management system, to ensure efficient operations throughout the project. Moreover, good environmental management system reduces risk and ensures reliable and continuous improvement of environmental performance. The contractor will also develop the environmental competences of both employees and subcontractors as it's the responsibility of all involved parties to follow up on the project´s environmental performance.

The contractor will follow the minimum requirements, in which the building construction site will be fossil-free construction site. The contractor will cooperate with the machines' suppliers to find the suitable bio-fuel solutions. Furthermore, in this project the contractor will work together with suppliers to find construction machinery that are powered with electricity or batteries, such machines will be used only if they are suitable for the work and already available in the market. Heating of the building will be done through fluid-borne system which runs on electricity or bio-fuel, besides that the project will try to minimize the moisture in the building to avoid the need for excessive drying.

4.4.2 Tåsenhjemmet project

4.4.2.1 Description of the project

Omsorgsbygg shall develop and construct a new nursing home in Oslo, Tåsen, Pastor Fangens vei 26. The project includes demolition of an existing nursing home, preliminary project, detailed engineering design services for and the construction of a new nursing home. This project is part of Oslo municipality's overall plan to rehabilitate and renew 2,500 nursing home before 2025. Following Table 13, shows major project milestones and actual status for each one.

Table 13 Status of Tåsenhjemmet design and construction phase

Milestones	**Expected finish date**	**Status**
Contract award	End of October 2017	Finished
Initial design stage	2nd quarter 2018	Ongoing
Detailed design	4th quarter 2018	Not started
Demolition of existing building	1st quarter 2019	Not started
Construction	4th quarter 2020	Not started

The new nursing home shall house 125 resident rooms and a day centre. The building shall have a maximum of four floors and approx. 14 500 m² gross area. The general aim of the project is to develop and construct a new nursing home that: has single rooms, which are suitable for elderly persons with compound medical diagnoses, including cognitive decline; produces more energy than it uses throughout the year, a so-called plus building; shall be environmentally certified in BREEAM-NOR, minimum ''outstanding''; is constructed with wooden supporting constructions; reduces emissions from the construction site as much as possible; and is a Futurebuilt project [10].

To ensure good solutions, satisfied users and best utilization of competence, Omsorgsbygg decided to have a preliminary project with the contractor following an interaction contract model. This phase shall try to optimize the project as regards function, quality and cost. By the end of the interaction phase, the parties will agree on the progress plan and a fixed price for the execution phase. The execution phase will be carried out as an ordinary turnkey

[10] Futurebuilt is a ten-year programme (2010-2020) with a vision of developing carbon neutral urban areas and high-quality architecture. The aim is to complete 50 pilot projects with the lowest possible greenhouse gas emissions.

contract. The demolition of the existing nursing home will be carried out as a part of the same turnkey contract.

4.4.2.2 Main phases of the project

The procurement process and project implementation can be divided into five phases:

I. Prequalification: Suppliers to submit a request for participation in the competition. Then, Omsorgsbygg performs a prequalification of suppliers.
II. Limited tender competition: the prequalified suppliers will be invited to participate in a restricted tender competition. See the summary of the tendering process in Table 14.
III. Interaction and optimization (Preliminary project and initial design): the winner of the tender competition will optimize the project and develop a preliminary project together with Omsorgsbygg. The pre-project phase will end up with a description, a fixed price and implementation plan.
IV. Construction and implementation
V. Hand-over and trial operation

4.4.2.3 Contract strategy

As mentioned in the contract strategy; which describes the plan to procure the project, the purpose of the procurement is to contract a contractor to carry out a preliminary project according to the order from Sykehjemsetaten (SYE). Then, the preliminary project provides the basis for a possible implementation (demolition, detailed design and construction).

Within the environment section in contract strategy, several requirements were mentioned: following the new Omsorgsbygg's environmental strategy; BREEAM-NOR classification with 'outstanding'; plus-building requirement; wood as construction material; and reduce emissions at the construction site.

Due to the project size and ambitious targets, it is decided to conduct a limited tender competition. To ensure well qualified suppliers, suitable qualification requirements are prepared. Based on assessments of the various contract models, as well as evaluation after dialogue conference, it has been decided that the contract model for the Tåsenhjemmet will be an interaction contract in the preliminary project phase, which will be continued to the total contract during the implementation phase. The model has many similarities with total contract, but it has a special feature that an incentive agreement is agreed upon, where both parties have full access to all project conditions. The interaction model is characterized by a

total contractor being brought earlier into the project than in more traditional implementation models. The main contractor, architects, technical consultants and technical contractors are assembled into a group headed by the main contractor. Omsorgsbygg and the main contractor will be developing the project so that the project can be delivered as soon as possible, and the project can be influenced to the greatest extent possible.

Table 14 Summary of Tåsenhjemmet's tendering process

Project name and number	Tåsenhjemmet / 11680048
Contracting authority	Omsorgsbygg Oslo KF
Object of the contract	Restricted tender competition for the procurement of an interaction contractor for the demolition, preliminary project and construction of Tåsenhjemmet
Type of contract	Design and execution
Scope	The new nursing home shall house 125 residents rooms and a day centre. The building shall have a maximum of four floors and approx. 14 500 m²gross.
Reducing emissions at construction site	As much as possible
BREEAM-NOR	minimum 'excellent', aiming for 'outstanding'
Plus building	yes
Futurebuilt project	yes
Estimated value excluding VAT	300-350 mil nok
Conditions for participation	Personal situation of economic operators, economic and financial ability, and technical capacity
Technical capacity requirements	Tenderers must have the capacity to carry out the assignment; tenderers shall have experience from assignments of an equivalent nature, complexity and extent; tenderers shall have an environmental management system.; and tenderers shall have a well-functioning quality assurance system that is relevant for the execution of this assignment.
Procurement procedure	Restricted procedure
Number of participants	5
Objective criteria for choosing 5 participants	The contracting authority will invite the 5 tenderers who best fulfil the requirement specifications out of the received requests for participation in the contest, to submit a tender.
Number of offers submitted	3
Award criteria	The most economically advantageous tender Quality criterion - Name: Suggested solutions / Weighting: 40% Quality criterion - Name: Assignment comprehension / Weighting: 35% Price - Weighting: 25%
Awarded	Yes
Total value of the contract excluding VAT	360 mil nok

4.4.2.4 Qualification requirements

Omsorgsbygg performed a qualification of suppliers based on the following qualification requirements. First, companies to submit documentation of company registration certificate. Second, Tenderers must have the financial capacity to implement the assignment/contract.

Lastly, suppliers must show that they are technically capable for this assignment. Tenderers must have the capacity to carry out the assignment with experience from assignments of an equivalent nature, complexity and extent: non-residential building; engineering design services for and/or the construction of buildings with high environmental ambitions; and collaboration partnering. Tenderers must also have an environmental management system through an account of the company's environmental management system or a certificate issued by independent bodies, for example ISO 14001. Tenderers shall have a well-functioning quality assurance system that is relevant for the execution of this assignment. They shall provide a certificate for the company's quality assurance system issued by independent bodies which certify that the tenderer fulfils certain quality assurance standards.

4.4.2.5 Award Criteria

Table 15 shows the set of award criteria used to evaluate the proposals received from 3 suppliers who participated in the competition, in which 2 of the short-listed suppliers withdrew before the competition due to insufficient capacity.

Table 15 Award criteria from Tåsenhjemmet competition. (source: WWW.DOFFIN.NO)

Criteria	**Weight (%)**	**Documentation requirement**
Quality criterion (Suggested solutions): • Urban environment • Energy use	40%	Supplier's description of solutions: A. Building and functional plans, including: B. How energy consumption in combination with indoor climate and wood use is thought to be solved.
Quality criterion (Assignment comprehension): B. Reduction of environmental impacts during construction phase C. Implementation plan	35%	Supplier's description and explaining how to resolve the following: A. Measures to: • Utilize the use of wood to reduce construction time and how to handle moisture during the construction period. • Reduce transport to and from construction site • Reduce greenhouse gas emissions and local emissions from construction site B. Implementation plan: • Description of the project organization and persons' documented experience (i.e. CV) • Implementation plan for all phases of the project
Price	25%	Price form to be filled by the prequalified suppliers

4.4.2.6 Contractor´s proposal

The winner contractor has provided several solutions according to the requirements mentioned under the award criteria as part of their offer in the second stage of the competition. However, only solutions related to reduction of emissions at construction sites will be presented to be in line with the context of the study. See first point under assignment comprehension in Table 15.

Reduce greenhouse gas emissions and local emissions from construction site

The contractor confirmed in their proposal that they will perform the project as a fossil-free building site. Although replacing diesel with bio-diesel reduces greenhouse gas emissions, but biodiesel still provides local emissions from construction sites. Therefore, the contractor expressed their ambitions to propose more solutions, not just fossil-free, but also zero-emission solutions. This means that they will use some electrical equipment and machines.

Firstly, electric solutions to be used in the project. Electric tower cranes will be used instead of diesel-powered mobile cranes, and an electric wheel loader will be used for internal logistics, which replaces diesel-powered truck. The machine is an electric 4-ton wheel loader. Together with electric lifts, this means that the internal logistics can become one step closer towards zero-emission. The contractor mentioned that more electric machines to be used once more machines become available in the market. In addition to the above, vehicles must run on biodiesel, idle driving in the site is banned, and modern engine technology is required such as Euroclass 5 and 6.

Second, to reduce the climate impact from the construction phase, the site will follow an environmentally friendly plan. Where, barracks will have solar cells, heat pumps, and have charging possibilities for electric cars. Third, reducing emissions from drying and heating operations. Reducing energy demand can reduce the need for drying and heating significantly, such thing can be done through good planning. Another step to do, is selection energy-efficient and environmental-friendly energy sources. A good and zero-emission solution can be to utilize the energy from heat pumps or through electric sources.

Lastly, GHG emissions can be also reduced through tackling transport from and to the construction site. The contractor will request vehicles with more environmental-friendly technology like electric vehicles. They will also coordinate with suppliers that deliveries to be carried out using vehicles running on biodiesel, in addition to using modern machines, for example with Euro class VI.

Building with woods

The use of prefabricated wood elements, such as cross laminated timber (CLT) [11], will facilitate the installation process and shorten the construction time for the building. The contractor has provided several reasons, explaining why building with woods is favoured in this project: improved control and quality as elements come prefabricated directly from a factory, such as dimensions and focal points; laminated and big wood elements can be installed once arriving at the building site; lower self-weight than other building materials, wood elements require less crane capacity; prefabricated wood elements reduce the amount of waste on the site; and besides the significant reduction in construction time, general costs for operations will be reduced accordingly.

Reduce transport to and from construction site

The contractor suggested several solutions that will help to reduce the transport intensity in the project. First, earthworks account for a large proportion of transport activity to and from a construction site. In order to minimize the amount of earthwork needed, the contractor will place the new building on the footprint of the existing nursing home, and access and exits zones are planned with the existing terrain which also minimizes the need for further excavation and road works. Furthermore, materials resulting from demolition will be used in the new outdoor layout.

Second, using prefabricated construction material will reduce waste and consequently require less transport. BIM tool will be utilized in cooperation with suppliers to ensure few errors and less waste. Third, material suppliers will cooperate with the contractor to reduce the transport intensity through using larger vehicles, less deliveries, and optimized material packaging. Moreover, a large storage area will be used to store the construction materials; it allows for greater deliveries, easier transport possibilities, safe and dry storage, and flexibility in logistics planning at the construction site.

Lastly, the contractor also suggested several solutions to reduce transport intensity within the construction site, such as walking and cycling routes, bicycle parking, public transport, and electric cars' parking with charging possibilities.

[11] Cross-laminated Timber (CLT) is a massive wood construction product consisting of bonded single-layer panels arranged at right angles to one another.

4.5 Interviews

4.5.1 High ambitions

According to project manager 2, expressing the environmental requirements in the procurement process is extremely important, as companies in Norway and other western Europeans countries are very contract oriented. So, it becomes crucial when targeting high environmental demands to approach contractors who are only interested to be part of such new, innovative and demanding projects. Project manager 1 believes that, high environmental targets help *"to label the project and make it more interesting and attractive for contractors".* Besides using more certifications help to maintain the ambitions high during the project life time, he added.

Project manager 1 stated that contractors are sometimes sceptic about new solutions, such as using grid-connected equipment (through a cable connecting it to the grid), as they believe it will complicate logistics and restrict machinery's movement. He also said that *"there is a lot of potential to use grid-connected equipment and that is already available",* Omsorgsbygg is developing in cooperating with other organizations a new 50 tons excavator to use in Tåsenhjemmet project with a cable to show contractors that its possible, he added. Although, *"contractors are comfortable to do things the way they had to do things"*, there is a shift right now, project manager 1 argues. The contractors started to see these new challenges as opportunities because they help to improve themselves and take the lead in the market. According to the contractor's project manager, *"the industry is changing now, and we want to be part of this change",* and thus, a lot of money is being used in order to be in a position where we can give such projects more focus than others.

Both project manager and environmental leader from the contractor organization in Tåsenhjemmet confirmed that what makes Tåsenhjemmet project a high ambitious one is the combinations of different environmental ambitions; BREEAM, plus building, Futurebuilt, building with woods and low-emission requirement. The contractor's project manager said that while other requirements may support the goal of reducing emissions at construction sites, others like Plus house may result in more emissions during the construction phase because more materials will be used (i.e roof materials). Furthermore, raising the environmental ambition towards zero-emission sites, requires using electric machinery, which are not available at the moment in the market. *"If not, suddenly new machines become*

available in the market, its next to impossible to raise ambitions from low-emission to zero-emission construction sites", the contractor's environmental leader said.

Building with woods (CLT)

According to project manager 1, it was their first time to build a large building with massive wood (CLT), so it was a true challenge for them. *"We were unsure how to do that, so we contacted timber consultants around Norway, and they provided us with insights and how we should make descriptions in the requirements and tender documents regarding wood"*, project manager 1 said. The main challenge was how to describe requirements concerning building with woods in the procurement documents. Another issue is how to exploit the quality of the woods to reduce emissions at construction sites, especially for emissions coming from drying and heating activities.

According to project manager 2, the use of woods will reduce the need for heating and drying significantly. Furthermore, the wooden elements will come pre-fabricated, which reduces the work needed at site but raises the amount of logistics at site. As Omsorgsbygg wants to minimize the elements movement at site to minimize machinery emissions. The contractor's project manager in Tåsenhjemmet expressed his deep concerns about logistics. As there is a large amount of massive wood elements that need to be installed just-in-time or in very short time. *"Logistics is very important in this project, and if we fail in that it's going to be a catastrophe",* he added

Users' experience

High environmental goals and technology should not affect the users' experience, technical manager in Omsorgsbygg said. His concern is connected with the building users, as people who are going to live, and work there later are not technical people, and therefore it's important to make users' experience as simple as possible. So, the purpose is to make something, the users can easily understand and use, especially when using new technologies to achieve environmental goals. *"Make it simple and stupid"*, the technical manager stated.

Changing requirements

In Tåsenhjemmet, Omsorgsbygg raised the BREEAM ambition from excellent to outstanding, and from the contractor's point of view it's always difficult to re-estimate extra cost and re-evaluate possible impacts for both design and construction phases, the contractor's environmental leader said. *"We could have done a better job in the procurement*

phase in identifying possible solutions for both choices (excellent and outstanding), if Omsorgsbygg mentioned that clearly in the requirements", he added.

4.5.2 Documentation

According to project manager 1, documentation was such a difficult task in Tåsenhjemmet project, preparing procurement documents took a lot of time due to new environmental requirements. For example, making and formulating the award criteria was the most difficult part, he added. Project manager 1 emphasized the importance of documentation in such procurement as it's the key to *"understand the competences and know-hows of contractors", where* documentation should be well-prepared and clear to the contractors, so they can show the public organization what they are capable of. For example, *"some contractors have different approach and new ideas that could be much better than someone was doing traditional nursing homes''*, project manager 1 added.

Good example of documentation difficulty is preparing the description of the initial design phase (preliminary project phase). It's important to plan this phase properly so that contractors and design team are more prepared for what should be done in this phase, project manager 1 said. Because *"we have seen in many projects that usually there is a gap between what the building owner thinks he ordered and what the contractor thinks he bided for"*, he added.

According to project manager 2, *"thinking out of the box does not always comply with standards''*. In other words, building a project according to the Norwegian standards hinder the utilization of new technology and new thinking, because they are not always complied with those standards. *"It seems like engineers and contractors are more used to build according to Norwegian standards than to think innovatively",* take for instance the ventilation systems, there is a lot of standards to comply with, but now new material and technology (i.e. building with woods) became available and that do not always comply with standards, he said. Contractor's project manager mentioned that some information during the procurement process was not enough for them to make detailed proposal, because there are no standards behind them. Such as some requirements related to building with woods; there is no standard for that. *"Documentation was very important in Tåsenhjemmet project since there were no previous standards"*, he added.

4.5.3 Knowledge and competence

According to project manager 1, over the last few year Omsorgsbygg has built a lot of competences with those kinds of procurements. *"Tåsenhjemmet project gave us a lot of knowledge and experience in how we can challenge the legal framework and see the possibilities instead of constraints"*, he said. Omsorgsbygg emphasized the important role of public procurers to take risk and push the limits by doing more untraditional projects with untraditional requirements. An example of knowledge gap, made by the legal advisor at Omsorgsbygg, is that the project team from Omsorgsbygg was not familiar with interaction contract model, which was one of the reasons why total contract model is selected instead of the interaction in previous projects.

While in Tåsenhjemmet project, they had first to learn and educate themselves about it, Project manager 1 said. *"We talked with the National Programme for Supplier Development, and they helped us with that"*, he added.

In addition, the legal advisor at Omsorgsbygg mentioned that the expert knowledge about the environment is very significant to achieve success in such type of procurements. She mentioned an example of that when Omsorgsbygg started to hire experts with BREEAM, in order to fill the gap in this topic. In Tåsenhjemmet and Lia projects, Omsorgsbygg managed to get the environmental knowledge needed to get the documentation done and then launch competitions.

4.5.4 Procurement procedure

According to project manager 1, using open procedures is suitable when you have a project that neither is large nor resource demanding to make a bid. In the case of Tåsenhjemmet, bidders have spent around 1 million (nok) to make their bids. The open procedure was not selected, because *"we were afraid we won't receive many bids, as the resources to make the bid were so high",* besides more bidders will reduce their chance of winning, project manager 1 said. Whereas in a restricted competition, each bidder has 20% chance to win the bid. Project manager 1 mentioned also setting a maximum price in Tåsenhjemmet, which was used in the competition by the suppliers to prepare their offers accordingly. The price then will be adjusted during the preliminary project phase; optimizing the project. Moreover, Omsorgsbygg chose to pay the contractor on hourly basis during the preliminary phase (initial design). Project manager 1 believes it was a good call as it encouraged the contractor

for innovation and enable Omsorgsbygg to push further and heighten the environmental goals.

Omsorgsbygg's legal advisor said that *"we could have done the same results with open competition"*. However, restricted method is chosen over an open one for Tåsenhjemmet project, because it is such a large project, it costs a lot of money to make the offers for such ambitious project, and it's a lot of work to process those offers, she added. Because of the innovative characteristics of Tåsenhjemmet project, the procurement took a lot time to set up the project description and requirements, project manager 2 said. Two suppliers withdrew from the competition, and fortunately remaining 3 submitted good proposals. However, it would be very challenging if Omsorgsbygg was left with only 2 poor proposals, he added.

The contractor's project manager said that generally having an open procedure in projects would affect them negatively, as open procedure allows more competition. However, unlike other projects, Tåsenhjemmet was different as only few contractors have the required competencies to do such an ambitious project. And thus, it was not an issue if it was an open or restricted procedure, he added.

Procurement Time

Omsorgsbygg spent a lot of time in preparing Tåsenhjemmet procurement files, and that may be because of its environmental, innovative characteristics, project manager 2 said. "*First dialogue conference was early 2016 and then 2.5 later years the project is awarded, this is quite long time",* project manager 2 added. Projects like Tåsenhjemmet demand a lot more resources in the planning phase, and this is due to several reasons as mentioned by project manager 1: building with woods require finishing the design early in order to plan the deliveries; and reduction of emission at construction sites requires that logistics to be planned properly. Such projects are consuming more time and resources not only from Omsorgsbygg, but also from the contractors as well. As contractors need to prepare a lot of documentation during procurement, and then later during construction they have to follow-up with their subcontractors to meet project's requirements. *"It's more complex that we thought it's going to be"*, project manager 1 said. It's true that the procurement process takes a lot of time, but *"what decide a good or bad project, is the procurement process"*, project manager 1 said. It's a process that too often get little focus, and probably it should be given a bit more time, especially when trying to do something new, he added.

4.5.5 Interactions and collaborations

Dialogue conferences

In the first dialogue conference in March 2016, Omsorgsbygg purposely invited machinery suppliers and equipment rental firms, even though normally contractors are the ones whom Omsorgsbygg does dialogue with, Project manager 1 said. Omsorgsbygg thought it was good idea to invite suppliers in the first dialogue conference. Such direction allows Omsorgsbygg to collect feedback directly from machines' suppliers. The market dialogue unfolded that bio-fuel solutions capable of reducing emissions are already available in the market today, while others, like fully electric ones, are not available and still require development (Oslo Municipality, Omsorgsbygg, 2016c).

Later in May 2017, Omsorgsbygg had another dialogue conference where they teamed up with other public builders. The purpose was to develop zero-emission solutions for their construction sites. According to project manager 1, *"it's a whole new role for Omsorgsbygg, as we normally just own and build buildings"*. However, to help the market move faster, Omsorgsbygg had to participate in technology development projects in accordance with the National Programme for Supplier Development. See section 4.5.8 for further information.

The tendering process of Lia project was preceded only by the first market dialogue. While Tåsenhjemmet's tendering process used feedback from both the first and second market dialogues.

Workshop

In Tåsenhjemmet project, a workshop was held just before launching the competition and right after the 5 vendors were selected. *"That was very different from a normal competition" ... "and it certainly was very new working method for them"*, legal advisor said. Omsorgsbygg paid for this event and invited experts to help the qualified 5 contractors in several topics. Each contractor showed up with their teams (5-10 people per each team), and contractors were asking questions while experts walking in the room and answering their questions. *"It helped to understand what the building owner wants"*, the contractor's project manager said.

The purpose of this workshop is to provide the short-listed suppliers with the best possible professional expertise for delivering a successful tender with focus on engineering and construction of the building with wood. The workshop is managed by Omsorgsbygg and

includes topics such as massive use of woods in large projects, sound and acoustics, fire, life and maintenance, and environment.

Interaction contract model

Using interaction model during Tåsenhjemmet enabled Omsorgsbygg to push more towards innovation as it opens up more opportunities among the buyer and suppliers. *"We even engaged the start-up community through an incubator for start-ups; we had events for them and invited them to come with their solutions that could be implemented in Tåsenhjemmet project",* as stated by project manager 1. Omsorgsbygg were able to test out 50 tons grid-connected excavator because of such process, he added. The contractor in Tåsenhjemmet had done many projects through the interaction method. As the contractor's project manager mentioned, such process drives innovation because it enables them to develop their solutions and discuss them with the owner in an open, transparent and trustful environment.

4.5.6 Intra-logistics

Intra-logistics in Tåsenhjemmet project was mentioned several times by project managers from both Omsorgsbygg and the contractor. Having an organized logistics scheme at the construction site will not only reduce the construction time, but it will also reduce emissions both from transport and construction machinery, Project manager 1 said. Project manager 2 also emphasized the significance of optimizing the deliveries volumes to reduce transport intensity. Project manager 1 added that BIM software (Building Information Modelling), will be utilized to manage intra-logistics at construction site, as it will help *"to see where and when should we place different building elements, so they don't be placed randomly and in the way of each other"*. And then by using BIM model, according to project manager 2, contractors need to make sure that the intra-logistics are handled more efficiently. In which *"we want to make sure that when they arrive at the construction site they go where they should be installed immediately"*, project manager 2 added.

The contractor also highlighted the issue with intra-logistics, according to an environmental specialist from the contractor in Tåsenhjemmet, a storing area is proposed to store small scattered material, and smaller deliveries should be consolidated in larger, well-planned deliveries. Another solution to reduce the emissions coming from intra-logistics is replacing the mobile cranes with tower cranes (electric), he added. The specialist pointed out that usually *"massive woods (CLT) contractors prefer mobile cranes over tower ones, and if we had no demands regarding emissions we would have used the mobile ones."*

4.5.7 Future of zero-emission construction sites

According to Omsorgsbygg, achieving zero-emission construction site is likely to happen within the next couple of years. Although such project will be a small one like kindergarten, but this will pave the road for other larger projects to follow. The project will be able to achieve zero-emission construction site by using electric (both grid connected and battery) and hydrogen-driven machinery. Such machinery will include both light and heavy-duty machinery like compacters, lifts, dumper and excavator. In that scenario, the transport to and from construction site will be excluded as it will take longer time to achieve, *''I guess zero-emission transport to and from site will not happen before 2022 but it will happen after all''* as stated by one of Omsorgsbygg's project managers.

While the contractor has more conservative view on when zero-emission construction sites will be achieved. The contractor said that such goal might be achieved by 2025 as it will take longer time and cost more money to convert all types of machines, especially the heavy machines, to electric or hybrid ones. An important factor to consider while development of electric machines, is performance as contractors expects good performance similar to what bio-fuel or diesel machines offer. Moreover, according to the contractor's project manager, it's important to have more projects like Tåsenhjemmet in the future, as this helps the procurement methods to evolve and adapt with new solutions that become available in the market.

4.5.8 The National Programme for Supplier Development

In order to understand the role played by the programme in Omsorgsbygg case, we had an interview with a lead climate innovation, who led several interaction processes for public builders, including Omsorgsbygg, and in relation to both the fossil-free and zero-emission construction sites. Therefore, all the information presented in this section are taken from the interview with her.

The National Programme for Supplier Development aims to accelerate innovations and development of new solutions through the strategic use of public procurement, while at the same time contributing to new market opportunities for these innovations. The programme is a joint collaboration of three entities, representing both the public and private sectors: DIFI (Agency for Public Management and eGovernment); Norwegian Association of Local and Regional Authorities (KS); and Confederation of Norwegian Enterprise (NHO), which provides the link to the private sector actors. Currently, the programme is hosted by NHO.

The programme is involved with Omsorgsbygg in several processes and one of them is construction sites. The programme helped Omsorgsbygg with setting up market dialogues and initiating several development projects. Omsorgsbygg first communicated their future goals to the programme. In the case of Omsorgsbygg, their interest was clear, to reduce emission at construction sites. The programme started searching for other public buyers who might have same interests as Omsorgsbygg. Then the programme invited everyone to a start-up meeting. Participants have the choice to express their interest if they want to be part of this process or not. According to the programme, having all public buyers to agree on single formulation to present it to the market was really challenging, as some actors were interested in bio-gas, others were happy with fossil-free, and others were determined to achieve zero-emission construction sites.

Then the programme arranged market dialogues with contractors and suppliers based on requirements of public builders. In Omsorgsbygg case, the fossil-free and zero-emission construction sites were covered in two different market dialogues. After that, market dialogues were succeeded with tendering process and development projects. The first market dialogue in March 2016 led to tendering processes, while the second market dialogue in May 2017 led to both tendering process and development projects.

Development projects

As mentioned before, the second market dialogue focused on zero-emission construction sites. *"Omsorgsbygg was very eager to raise the bar even more and said we want to electrify the heavy-duty machines"*, but the supplier at that time said you are only one public buyer (one customer). The suppliers cannot shift their machinery based on one customer only because Omsorgsbygg alone does not represent big market for them. Afterwards, the programme gathered 8 additional public buyers who have similar interests and targets, since achieving zero-emission construction sites can't be accomplished without development of new technology.

The programme started looking for funding schemes like Pilot E. Pilot E is a funding scheme focusing on energy and low emission carbon society. It is a collaborative funding mechanism between innovation Norway, Nova, and Research Council of Norway. These projects are not pre-commercial procurements, but rather they are development projects which have received funding. Pilot E directed their funding in 2017 for zero-emission construction sites following the prior market dialogue.

Currently, there are 4 specific pilot E projects which are under development. These development projects are focusing on developing zero-emission machinery; running on hydrogen and on electricity.

The construction sites have wide-range of machinery, and four different development projects will not be enough to cover the different machinery in a construction site. However, it's just the beginning, and some of the solutions will be available after one year. It's significant that public buyers keep pushing for such solutions as requirements in their tenders once they become available, as supplier will feel more confident to invest in new technology knowing that there is a continuous demand for such solutions.

From the above, the contribution of the programme in Omsorgsbygg case can be summarized in the following. First, setting up market dialogues with contractors and suppliers. Second, sending early signal to the market about the buyers' demand. Third, creating purchasing power through gathering public buyers together to encourage suppliers to develop new solutions. And finally, the programme arranged the funding mechanisms needed to start development projects.

4.6 Summary and highlights

In this chapter, various empirical data from two projects and interviews are presented in order to learn about emission-reduction criteria, procurement process, interaction possibilities, and solutions proposed by contractors. The strategic objectives of both Oslo municipality and Omsorgsbygg include several facts and numbers about the greenhouse gas emission in Norway, and especially the construction industry.

Then description of fossil-free and zero-emission construction sites is presented following (DIFI) definitions. Subsequently, data from the two projects and their procurement processes are presented in a way that allows us to identify differences and similarities. Lia used open procedure, while Tåsenhjemmet used restricted procedure and has higher environmental demands than Lia. Lastly, data acquired from interviews are structured under 8 topics to serve the purpose of analysis and discussion.

5 Analysis

As described previously under methodology, this chapter is dedicated for analysing the case study. First, single-unit analysis is performed for each project following the three stages of the theoretical framework presented earlier in the theoretical study chapter. Second, cross-unit analysis is performed among the two projects following the resulted project identities.

5.1 Single-unit analysis

Empirical data including project description and procurement features, will be analysed against theories and concepts mentioned in the theoretical framework. In the first stage, project's environmental goals will be reviewed to understand how ambitious the project is with respect to reducing emissions at construction sites. In the second and third stages, features of the procurement process are analysed to explain why certain choices are made this way during the procurement process such as the choice of the procurement procedure or collaboration. The second and third stages differs in the level of interaction exercised during the procurement process, in which the third stage aims towards more innovation possibilities through extended interaction. After the first stage, project analysis continues through second stage, and if extended interaction is spotted then analysis will continue to the third stage where more innovative outcomes are expected from the procurement.

5.1.1 Lia

5.1.1.1 Understanding low-emission & zero-emission; stage 1

With reference to the theoretical framework in Figure 14, we start looking into the first stage; understanding low-emission and zero-emission construction sites. In this stage, we start with the principles of sustainable construction described by Hill and Bowen (1997): social, economic, biophysical and technical principles of sustainable construction. See Figure 17.

Since Lia project is a public project, this makes it complex by nature as it targets the broader aspects of social, environmental and economical returns. Those three aspects could have been used to evaluate Lia project, but sustainable construction principles are found more suitable as they focus on the construction industry.

The purpose of Lia is to build a kindergarten with different departments, including one for children with disabilities. The project obviously improves the quality of human life and fulfil society needs, and thus it achieves some aspects of the social principle.

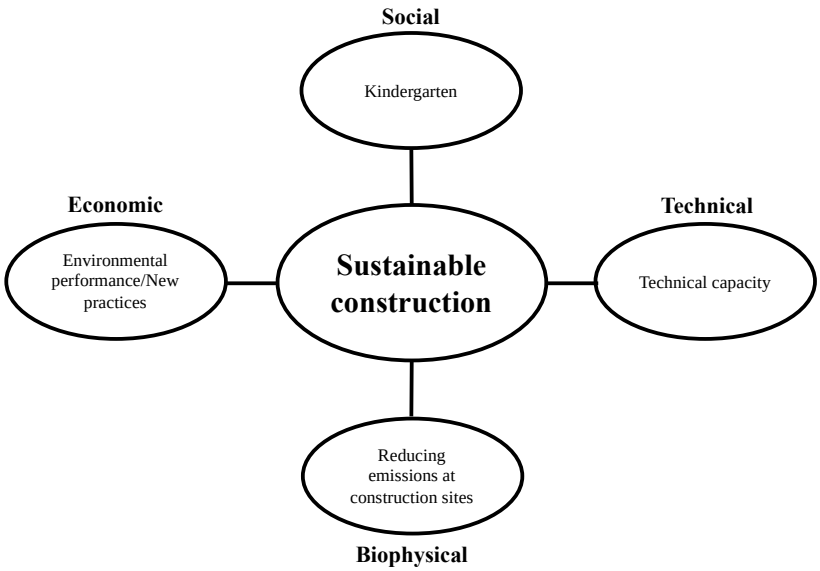

Figure 17 Sustainable construction principles (Hill and Bowen, 1997)

As Lia depends on tax payers' money, this imposes several requirements tied to the economic principle. In contrast to private projects which aim to achieve financial returns, Lia's economic returns can be measured through: using full-cost accounting; job creation; selecting responsible contractors who can demonstrate environmental performance and introduce policies and practices to ensure competitiveness in the marketplace. The data does not show how many jobs are created or how full-cost accounting has been done in Lia, but following the procurement data, it's obvious that Omsorgsbygg used several measures to choose a contractor based on environmental performance. In addition, reducing emission at construction sites can be seen as new practices that are introduced into Omsorgsbygg's projects. However, it's difficult to decide at this stage the extent of economic returns in Lia as the evaluation process for a successful public project will be much longer than a private project (Martland, 2011).

The third principle, biophysical principle, concerns aspects like atmosphere, land, underground resources and marine environment (Hill and Bowen, 1997). For example, to minimize global and local air pollution resultant from construction operations. Although Lia does not include reducing emissions at construction sites explicitly in the project goals, the project site still considered as low-emission construction site. This is mainly because Lia is following the minimum requirements defined in the follow-up environmental plan such as fossil-free policy and reducing emissions from heating and drying.

Finally, the technical principle describes the performance and quality aspect of construction operations. Omsorgsbygg has done a huge number of similar projects in the past, which

means Omsorgsbygg has good technical capacity in this area. However, Lia will not be analysed against the technical principle as it's beyond the scope of the study.

The biophysical principle is the point of departure to understand the low and zero-emission construction sites. The data presented earlier in Table 3 provides a good understanding for the various sources of emissions found at construction sites, but it does not tell what sources and solutions should be targeted to achieve different level of reduction; low-emission or zero-emission construction sites. In the following, we propose a classification for low and zero-emission construction sites based on case study and Table 3.

Omsorgsbygg defined what a low-emission construction site means and what requirements should be considered to achieve such sites. Omsorgsbygg, in cooperation with Bellona organization, found three main areas that could be targeted to reduce emissions at construction sites: construction machinery; heating and drying operation; and transport from and to construction site. However, a better definition was presented later by (DIFI) to describe the low-emission construction sites, see section 4.3. In which, they distinguished among fossil-free and zero-emission construction sites. Zero-emission construction site requires *''all processes at the construction site are zero-emission'' (DIFI),* while on the other hand, fossil-free requires avoiding the use of fossil fuels in any construction operation.

In order to classify Omsorgsbygg's projects, we needed more comprehensive classification. Therefore, we used DIFI definitions in addition to Table 3, from the theory chapter, to construct Table 16. This new classification will allow us to categorize the case projects precisely, as it is critical to understand project's level of ambition before choosing an effective procurement approach. This new table not only shows the two main categories of low and zero-emission, but also breaks them down into one more level. Low-emission classes covers fossil-free (C1) and low-emission (C2), while zero-emission classes follow the same definition of zero-emission presented earlier from (DIFI) and covers two levels; near zero-emission (C3) and zero-emission (C4). Table 16 allows us to characterize projects accurately under four different classes based on implemented solutions to reduce emissions.

Table 16 Low and zero-emission construction sites classification

Main Source	Activity	Low-emission classes		Zero-emission classes	
		C1; Fossil-free	**C2; Low-emission**	**C3; Near Zero-emission**	**C4; Zero-emission**
Transportation	Material delivery	Fossil fuel	Fossil fuel	Fossil-free (biodiesel)	Electric
	Waste transport	Fossil fuel	Fossil fuel	Fossil-free (biodiesel)	Electric
	Staff travel	Fossil fuel	Electric	Electric	Electric
Production and execution methods	Construction operations	-Fossil-free (biodiesel)	-Use alternative building method -Fossil-free (biodiesel) -Some operations use electricity	-Site operations use electricity - Use alternative building method	-Site operations use electricity - Use alternative building method
Equipment use	Construction machinery (incl. intra-logistics)	Fossil-free (biodiesel)	-Some electric machinery -Fossil-free (biodiesel)	All machinery uses electric or hydrogen	All machinery uses electric or hydrogen

Obviously, Lia project rests in the low-emission category, and more specifically to fossil-free (C1), see Figure 18 below. It follows fossil-free policy at construction site and focuses on reducing emissions from heating and drying. And it does not adopt new alternative methods in building that might have potential to reduce emissions. Moreover, deliveries are not transported through vehicles running on biodiesel. In conclusion, Lia does fall under low-emission category but at basic level because many solutions are not implemented in the project. In other words, Lia belongs to the low level of low-emission spectrum.

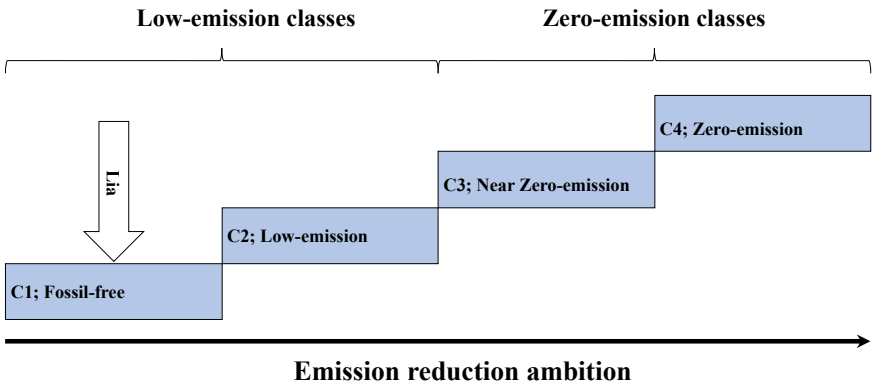

Figure 18 Lia's emission-reduction ambition

5.1.1.2 Public procurement toolbox; stage 2

Following the second stage of the theoretical framework, Lia project's procurement process is investigated to track how the public procurement toolbox is utilized to target emissions at construction sites.

Define and refine demands

Lia project goals were explicitly focused on environmental impacts during the project lifetime, while reducing emission at construction sites was missing from project goals. However, that does not mean that Lia project is not targeting emissions at construction sites, instead those requirements were covered implicitly.

Following the supplier selection process described previously by Igarashi et al. (2013), any procurement process usually starts with identifying needs and specifications. In the case of Lia Project, the step of identifying the needs and specifications evolved significantly after obtaining feedback from the first dialogue conference in March 2016. They were able to develop and refine their demands based on the available solutions in the market; fossil-free solutions. This feedback forms also the backbone for all subsequent procurement actions under Oslo Municipality where fossil-free became policy since the beginning of 2017.

The choice of Procurement procedure

The open procedure, see Figure 8 in section 3.3.1, is one of the EU public procedures to select suppliers, where it starts with a call for bids, followed by the reception of tenders. Then, suppliers are evaluated on either lowest price or a set of criteria (economically most favourable). Lia is such a small project, and its goals are not very ambitious regarding reducing emissions at construction sites. Omsorgsbygg found the open procedure quite suitable for Lia goals. Moreover, Omsorgsbygg was not concerned about having few participants in the bidding, on the contrary, they were confident they will have more due to the limited efforts needed to prepare the bids. See main features of Lia's procurement process in Table 17.

Environmental requirements and criteria can be included at different stages of the supplier selection process: the specification stage, the qualification stage, the final selection stage and in the contract performance clause with the chosen supplier (Igarashi et al., 2015, European Union, 2016). Reducing emissions at construction sites was mentioned in Lia project under environmental follow-up plan as part of the documentation provided in the tendering process.

This document can be considered as part of the project environmental specification. Yet, reducing emissions was missing from qualification requirements and award criteria.

Table 17 The main features of Lia's procurement process

Project	**Lia**
Low-emission requirements	Fossil-free minimum requirements
Procedure	Open
Supplier qualification Requirement [12]	Technical capacity: buildings with high environmental ambitions; environmental management system; and quality assurance system
Award criteria	Reducing emissions is missing from award criteria. Quality/price ration is 50%/50%
Market dialogue	Dialogue conference
Contract type	Design and build
Contract model	Total contract model
Winning proposal to reduce emissions	Basic and focuses mainly on fossil-free solutions

With reference to GSS strategies described by Igarashi et al. (2015), incorporate strategy is found to be implemented in Lia project, as emission-reduction criteria were absent from the award criteria, but it's incorporated under the existing criteria, where criteria like planning, execution and technical solutions are mentioned. Instead of mentioning it as independent criteria, its added under the quality category. The targeted emissions occur during the construction cycle, and therefore, they are part of both planning and construction phases. Additionally, contractors are expected to follow the minimum requirements mentioned in the environmental follow-up plan document. Although such approach can minimize the effort in preparing the tender documents, it might not address the emissions requirements clearly to suppliers (Igarashi et al., 2015). Since Lia was one of the first projects to lower construction emissions within Omsorgsbygg's portfolio, strategies like 'insist' or 'incorporate' are found effective when introducing new requirements to the market (Igarashi et al., 2015).

Challenges and difficulties

Omsorgsbygg did not report any challenges during the procurement process for Lia project. This sounds rational because the ambition of reducing emissions was limited mainly to implementation of fossil-free solutions. However, Omsorgsbygg pointed out during one of the interviews that fossil-free solutions were not proposed in the dialogue from contractors themselves. According to Omsorgsbygg, usually they approach contractors to perform market dialogues, but they purposely invited machinery's suppliers in the dialogue conference. The

[12] Other qualifications like company registration certificate and financial capacity are not mentioned in the comparison since they are identical in both procurements

decision to involve machinery suppliers paid off as such direction allows Omsorgsbygg to learn about availability of bio-fuel solutions.

Strategy

According to the conceptual model of GSS developed by Igarashi et al. (2013), the environmental criteria to be effective, they cannot be chosen randomly without relation to the organizations long-term goals. Aligning supplier selection process with Omsorgsbygg environmental strategy, helped Omsorgsbygg to produce effective criteria towards targeting greenhouse gas emissions.

After the City of Oslo adopted their Climate and Energy Strategy, which is in accordance with the Paris Agreement, Omsorgsbygg shaped in 2016 their own environmental strategy that supports reducing the city's CO2 emission. Omsorgsbygg wanted to focus on the construction phase, especially when construction machinery alone counts for 30% of the transport emissions. In which they decided to translate reducing emissions at construction sites into meaningful requirements to stimulate new solutions.

5.1.1.3 Public procurement toolbox; stage 3

The third stage of the theoretical frameworks builds upon the key influences on construction innovation mentioned earlier by Blayse and Manley (2004). We take a closer look on the Lia's procurement process to spot if one or more key influences were used during the process to drive innovation. Third stage means that the used public procurement toolbox in Lia allows for more innovation and interaction possibilities. If the analysis reveals that key influences are truly used to drive innovation, then Lia will be characterized as encouraging extra innovation. Otherwise, the procurement process will be labelled with limited innovation possibilities, and thus, Lia belongs to the second stage rather than the third one.

Key influences on construction innovation

Blayse and Manley (2004) identified six primary key influences, which can stimulate or hinder construction innovation: clients and manufacturers; the structure of production; relationships between individuals and firms within the industry and between the industry and external parties; procurement systems; regulations/standards; and the nature and quality of organizational resources.

Table 18 Key influences in Lia project

Key influences	Lia
Clients and manufacturers	Omsorgsbygg did not ask for novel requirements, instead they ask for minimum requirements; fossil-free to reduce emissions
Structure of production	One-off nature of projects reduces both values of innovation and incentives to innovate
Relationships; interactions among individuals and firms	One market dialogue preceded the tendering process and early collaboration with Bellona
Procurement systems	Design and build improve design constructability
Regulations/standards	Rules of public procurement hinder establishing long-term relationships with suppliers (Telgen et al., 2007).
Nature and quality of organizational resources	Omsorgsbygg supports innovation

Following the analysis results in the above table, we notice that some aspects (3 out of 6) drive for innovation, but their influence on the procurement of Lia project is still limited. Especially when a major key influence; interaction, was not applied after the call for tenders, and it was limited to only early interaction. Therefore, the second stage of the theoretical framework is found suitable enough for analysing Lia procurement process.

Limited innovation possibilities

As illustrated in Table 7, open procedure provides standardized or specified interface with suppliers (Torvatn and de Boer, 2017), where it provides the buyer with either none or minimal (supplier can only propose alternatives) innovativity benefits (Araujo et al., 1999). However, in the case of Lia, the tender was preceded by a dialogue conference which guided Omsorgsbygg to develop fossil-free requirements and ask suppliers to only use construction machineries that run on bio-diesel.

Thus, the interface prior to the bidding process in Lia is considered interactive because the tender was preceded by a market dialogue, while the interface during the bidding process itself is still considered as specified. Preceding the bidding process with dialogue improved the innovation potential of the procurement (Torvatn and de Boer, 2017). Obviously, the procurement lacks for interaction after the call for tenders, but considering the goals and requirements of Lia, the amount of interaction (one market dialogue) is found to be enough as it enabled Omsorgsbygg to implement fossil-free solutions which meet the project minimum environmental requirements. Yet, the interaction itself was not enough to encourage extra innovation. Therefore, it's concluded that Lia has limited innovation possibilities. The interface during Lia procurement will be discussed further in the next chapter to see if the interface was really interactive or takes different form.

5.1.1.4 Project identity and key findings

Based on the previous analysis, we spotted three characteristics we believe they shape Lia's identity: first, the project ranks low on low-emission spectrum (C1 fossil-free); second, the project has low interaction level because Omsorgsbygg interacted with suppliers only once during the whole process; and lastly, innovation is perceived as limited since the project utilizes available solutions rather than exploring new ones.

A new classification of emission level at construction sites is proposed to categorize projects precisely in order to better understand construction emission ambition. Moreover, considering Lia's goals and size, open procedure found appropriate to achieve its emission-reduction targets. Finally, the decision to invite machinery suppliers to the market dialogue paid off, as this enabled Omsorgsbygg to introduce the fossil-free solutions.

5.1.2 Tåsenhjemmet

5.1.2.1 Understanding low-emission & zero-emission; stage 1

Similar to Lia project, Tåsenhjemmet will be shortly reviewed against the principles of sustainable construction described by Hill and Bowen (1997): social, economic, biophysical and technical principles of sustainable construction, see Figure 19.

Tåsenhjemmet is also a public project, which performed to create new nursing home for elderly people. Its purpose is to develop and construct a new nursing home that has single rooms (125 residents capacity) suitable for elderly persons with compound medical diagnoses, including cognitive decline. The project improves the quality of human life and fulfil society needs by provide extensive social care and space for elderly people, and thus it achieves some aspects from the social principle.

The project's economic returns stem from creating value for money, as it's completely financed by the government from tax payers. Tåsenhjemmet is a big project, and therefore, it's expected to have broader economic returns, both during and after the project is finished such as material suppliers (Martland, 2011). Similar to Lia, it's difficult to decide at this stage the extent of economic returns in Tåsenhjemmet as data does not show how many jobs are created or how full-cost accounting have been done. However, the procurement data shows that Omsorgsbygg introduced several measures and practices, in order to choose the best contractor suitable for this project. The project has several ambitions that led to more competitiveness among the contractors such as building with Woods (CLT). Moreover, the

project has high environmental demands that are expected to stimulate the development of new solutions, which might reflect positively on the market economy.

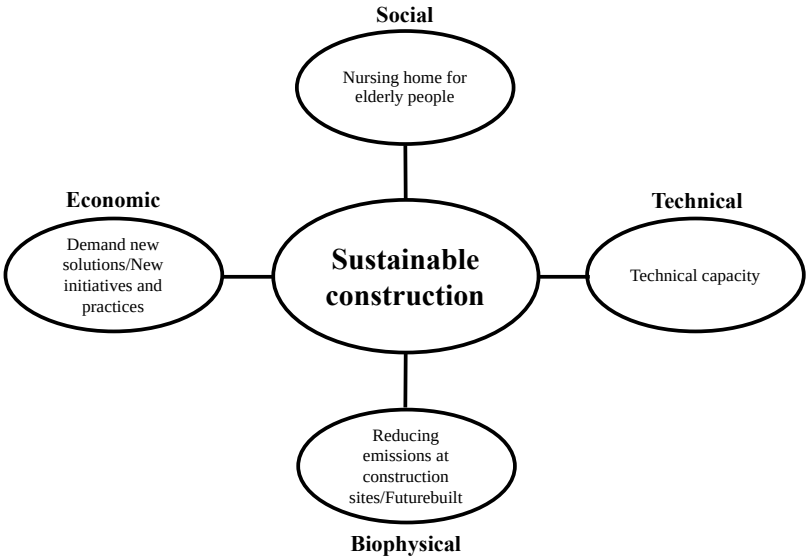

Figure 19 Sustainable construction principles (Hill and Bowen, 1997)

As mentioned in the project goals of Tåsenhjemmet project, the project aims to: produce more energy than it uses; be environmentally certified in BREEAM-NOR, with 'outstanding'; use wooden supporting constructions; and reduce emissions from the construction site as much as possible. Minimize global and local air pollution resultant from construction operations, which is part of the biophysical principle, is mentioned clearly as one of the project goals. In addition, being part of Futurebuilt initiative, which attempts to develop neutral carbon urban areas. Tåsenhjemmet has high ambitions when it comes to achieving the biophysical principle due to the combination of different environmental requirements.

Finally, the technical principle describes the performance and quality aspect of construction operations. Omsorgsbygg has good technical capacity with building nursing homes projects. Similarly, as said in Lia, this principle will not be analysed any further as it's beyond the scope of the study.

The previous classification constructed in section 5.1.1.1 in Table 16 is used again for Tåsenhjemmet project, to decide which category or class does the project belong to. As illustrated in Figure 20, Tåsenhjemmet project belongs to low-emission (C2), since it applies the definition at advanced level, in which solutions other than fossil-free are also used or encouraged to be used in the project. First, the project has plans to reduce transport intensity by consolidating deliveries and pushing the contractor's suppliers and sub-contractors to use

biodiesel. Second, the project will use massive wood elements (CLT) instead of concrete as main building method, which has good potential to reduce the emissions from heating and drying even further.

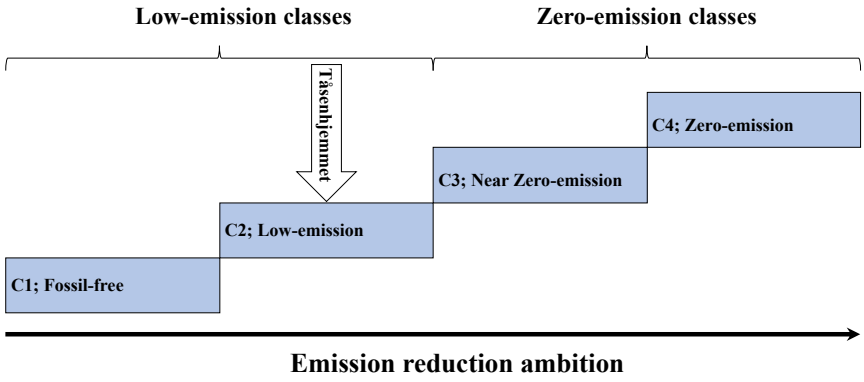

Figure 20 Tåsenhjemmet's emission-reduction ambition

Third, the project has plans to test and use several electric construction machineries in the project site. Finally, the project will also implement fossil-free policy at construction site. However, the project team still believes that intra-logistics might create emissions elsewhere, and it's not certain how far in the supply chain the project can push to use biodiesel vehicles. In conclusion, we found Tåsenhjemmet belongs to the high level of low-emission spectrum.

5.1.2.2 Public procurement toolbox; stage 2

Following the second stage of the theoretical framework, Tåsenhjemmet project's procurement process is investigated to track how the public procurement toolbox is utilized to target emissions at construction sites.

Define and refine demands

Tåsenhjemmet goals cover environmental impacts during the construction phase and the project lifetime. Such explicit focus in the project goals enables public procurers to develop clear low-emission requirements at construction sites and reflect them later as independent criteria in the award stage. The step of identifying the needs and specifications in Tåsenhjemmet project influenced by two factors. First, Omsorgsbygg wanted to build a regular project but with high ambitious environmental demands. Second, the project's environmental specifications build upon a combination of environmental demands such as BREEAM, Futurebuilt, Low-emission construction sites and building with woods (CLT).

Omsorgsbygg wants stricter low-emission requirements where they can push toward electric solutions in addition to fossil-free ones. The project was also chosen as one of the pilot

projects in Futurebuilt initiative to create neutral carbon urban areas. As a result, Omsorgsbygg decided to heighten BREEAM requirements and make it 'outstanding'.

The procurement of Tåsenhjemmet preceded by two market dialogues. The first dialogue conference, held in March 2016, unfolded available bio-fuel solutions capable of reducing emissions at construction sites. The dialogue mainly benefited Lia project, amongst other similar projects. However, the same feedback used again to build up for Tåsenhjemmet project. This highlights the information sharing culture among projects in Omsorgsbygg. During the interviews with Omsorgsbygg officials, it was noticed how they know about several projects at the same time, which enabled them to compare their requirements and use useful results from one project to feed the other.

The second dialogue conference, held in May 2017, benefited specifically Tåsenhjemmet project when it focused on zero-emission solutions. The nature of the second dialogue conference was about development of new solutions which fits the profile of Tåsenhjemmet, as the project was set to broaden the boundaries of low-emission concept beyond just fossil-free. Although both conferences targeted machinery suppliers, equipment rental firms and contractors, the second conference was different when Omsorgsbygg teamed up with other public buyers, which in return allowed more cooperation among public players.

As described earlier industry relationships have a major influence on construction innovation (Blayse and Manley, 2004, Dubois and Gadde, 2002a), as they facilitate knowledge flows through interactions among individuals and firms (Blayse and Manley, 2004). Omsorgsbygg was able to improve the quality of low-emission criteria due to the early interactions took place before commencing with Tåsenhjemmet procurement.

The feedback from two market dialogues enabled Omsorgsbygg to develop clear demands for the project including low-emission requirements. For example, the transport issue is added to the award criteria, in which contractors need to explain how they will reduce emissions from transport in their bids. Another important factor helped Omsorgsbygg to develop realistic demands is 'innovation brokers'. Brokers act as information intermediaries and have better visibility over the market. For example, cooperation with The National Programme for Supplier Development, BELLONA, SINTEF, and NASTA AS (local supplier of Hitachi and Siemens machines). Furthermore, some of these collaborations resulted in development projects such as 30 tonnes excavator running on hydrogen. In this way Omsorgsbygg became more confident to introduce stricter low-emission requirements.

The choice of procurement procedure

The restricted procedure, see Figure 8 in section 3.3.1, is a two-stage bidding procedure. As mentioned by Omsorgsbygg, restricted procedure is selected in Tåsenhjemmet to cope with *"its innovative characteristics"* and size of the project. Omsorgsbygg was concerned if an open procedure is selected, they will receive less bidders due to the excessive demands and low winning chance. Besides, in open procedure, bidders will be reluctant to bid when their winning chance is reduced. While in restricted one, they are more confident as only five bidders will compete with 20% chance of winning, which makes it more appealing.

Another reason why Omsorgsbygg favours the restricted procedure, is the effort needed to process the bids. Omsorgsbygg needs longer time and more resources to process large number of bids to such a large project. It can be argued that choosing restricted over open procedure can affect the competition factor in bidding due to less number of participants in the competition. But according to Omsorgsbygg, this did not make any difference as only small number of the contractors in the market are capable to execute Tåsenhjemmet considering its innovative and demanding characteristics. Therefore, selecting restricted one would eliminate wasting resources from both sides; Omsorgsbygg and contractors. See the features of Tåsenhjemmet procurement process in Table 19.

Table 19 The main features of Tåsenhjemmet's procurement process

Project	**Tåsenhjemmet**
Low-emission requirements	Reduce emissions as much as possible; not only fossil-free
Procedure	Restricted
Supplier qualification Requirement [13]	Technical capacity: buildings with high environmental ambitions; collaboration partnering; environmental management system; and quality assurance system
Award criteria	Reducing emissions at construction site is explicitly mentioned in award criteria. Quality/price ration is 75%/25%
Market dialogue	Dialogue conferences, workshop
Contract type	Design and build
Contract model	interaction model in the preliminary phase, then total contract in implementation phase
Winning proposal to reduce emissions	Detailed and comprehensive: fossil-free; more electric solutions (i.e cranes); building with woods; and transport

[13] Other qualifications like company registration certificate and financial capacity are not mentioned in the comparison since they are identical in both procurements

Reducing emissions at construction sites was mentioned in Tåsenhjemmet's tendering documents in several places. It was included in project goals and the project's environmental specification. Reducing emissions at construction sites was also mentioned explicitly in the award criteria as part of the quality criteria. Yet, it was missing from the qualification requirements.

With reference to GSS strategies as described by Igarashi et al. (2015), integrate strategy is found to be followed in Tåsenhjemmet, as emission-reduction criteria were present in the award criteria. This strategy according to Igarashi et al. (2015) is called ''value integration''. Other criteria like cost and quality are traded off against environmental performance, in which several independent, explicit criteria are included in the award criteria. However, since low-emission requirements are missed from the first qualification stage, this might raise a question on the capacity of the shortlisted 5 contractors, as said by (Igarashi et al., 2015) including criteria in qualification act as 'real qualifiers'.

Challenges and difficulties

Projects with high ambitious, environmental requirements have a great potential to reduce the negative environmental impacts, but they do come at price. The interview process unveiled that public buyers face several challenges during the procurement process of Tåsenhjemmet.

Knowledge: Omsorgsbygg emphasized the important role of public procurers to take risk and push the limits by doing more untraditional projects with untraditional requirements to develop their knowledge. However, some knowledge related difficulties are reported by Omsorgsbygg. First, Omsorgsbygg was not familiar with interaction contract model that planned to be used during the preliminary project, as it was their first time to apply it. Omsorgsbygg said that they overcame this gap by getting the necessary knowledge from the National Programme for Supplier Development, who acted as 'innovation brokers' in this context. Even though Omsorgsbygg said they overcame it, both Omsorgsbygg and the contractor confirmed that this phase was poorly planned.

In addition, Omsorgsbygg mentioned that the expert knowledge about the environment is very significant to achieve success in such type of procurements. New environmental demands require new types of knowledge. Omsorgsbygg starts hiring BREEAM experts to manage the 'outstanding' requirement in Tåsenhjemmet. Moreover, it was the first time for Omsorgsbygg to build a large building with massive wood (CLT), in which they have no

previous knowledge about with respect to requirements or standards. As a result, this knowledge gap raised another challenge for Omsorgsbygg during the preparation of procurement documentation. However, the workshop took place later in the procurement process helped to transfer knowledge about woods from external experts to both Omsorgsbygg and the five shortlisted contractors.

Quality of documentation: high environmental demands must be expressed as clearly as possible in all procurement stages, as it serves to select the right contractors who are interested to be part of such new, innovative and demanding projects. Additionally, explicit demands are the basis for the contract clauses, and any ambiguity in demands will be reflected on contract which might lead later to conflicts and struggles among buyer and contractor. Besides, public buyers usually depend on standards to formulate their demands. In the case of Tåsenhjemmet, the combination of different ambitious, environmental requirements makes the process of formulating the requirements difficult and challenging.

According to Omsorgsbygg, preparing procurement documents, including environmental criteria, took a lot of time. Project manager 1 emphasized there is no trade-off when it comes to documentation in such procurement as it's the key to *"understand the competences and know-hows of contractors"*. Good example of documentation difficulty is preparing the description of the initial design phase (preliminary project phase), where this phase was poorly planned, and the procurement documents lacked a clear description about it.

According to project manager 2, *"thinking out of the box does not always comply with standards''*. Omsorgsbygg seemed to struggle during preparation of documentation (i.e building with woods) due to lack of standards. This seems true in light of the feedback obtained from the contractor, who mentioned that some information during the procurement process was not enough for them to make a detailed proposal, because there are no standards behind them. Furthermore, Tåsenhjemmet's procurement consumed a lot of time and resources, which is reflected on the amount of documentation required in the process. However, Omsorgsbygg perceives this as necessary especially when introducing new requirements to the market.

Innovation mindset: it looks like there is a mismatch between the innovation mindset of Omsorgsbygg and contractors. This seems obvious in the case of developing a grid-connected 50 tons excavator (through a cable connecting it to the grid). Contractors believe it will complicate logistics and restrict machinery's movement, while Omsorgsbygg perceives it as a

potential to reduce the emissions from the machineries used in intra-logistics. It's possible that this mismatch can be resolved once contractors perceive the new challenges as opportunities. This means more interactions among the parties might be needed to tackle the issue of different mindset and align them on the same page.

Strategy

Similar to Lia, aligning supplier selection process with environmental strategy, allows Omsorgsbygg to produce more effective criteria towards targeting greenhouse gas emissions at construction sites, especially when they make them part of the award criteria.

5.1.2.3 Public procurement toolbox; stage 3

Although Omsorgsbygg mentioned that Tåsenhjemmet has more innovative characteristics, its procurement process is analysed in light of the key influences of Blayse and Manley (2004) to ensure that. If the analysis reveals that the key influences drive innovation, then it belongs to the third stage rather than the second one. In which Tåsenhjemmet's process will be characterized as encouraging extra innovation possibilities. Otherwise, the procurement process will be labelled with limited innovation possibilities.

Key influences on construction innovation

Following the analysis results in Table 20 below, we notice that 5 aspects drive for innovation, and thus, lead Tåsenhjemmet for more innovation possibilities. Especially the ones related to clients, relationships and organizational resources.

Table 20 Key influences in Tåsenhjemmet project

Key influences	**Tåsenhjemmet**
Clients and manufacturers	Omsorgsbygg put more pressure on contractors to improve environmental performance and demand higher low-emission standards
Structure of production	One-off nature reduces both values of innovation and incentives to innovate
Relationships; interactions among individuals and firms	Two market dialogues preceded the tendering process; workshop and use of interaction model; and collaboration with several 'innovation brokers'
Procurement systems	Design and build improve design constructability
Regulations/standards	Lack of standards, regarding some requirements such as building with woods, is believed to improve innovation. Because when regulations and requirements become too strict for current technology, the industry players are forced to develop new technology to comply with those requirements
Nature and quality of organizational resources	Omsorgsbygg generally supports innovation. Besides new knowledge is built during the procurement to develop ambitious requirements.

Therefore, the third stage of the theoretical framework is found more suitable than the second one for Tåsenhjemmet procurement process as it as it includes more innovation possibilities. This also confirms Omsorgsbygg description of Tåsenhjemmet as it has more innovation characteristics. The previous analysis done in the second stage will not repeated in the third stage as it will lead to the same results. However, more attention will be given to the role of interaction in the following, in order to understand how it opens up the innovation possibilities.

More innovation possibilities

Tåsenhjemmet's tendering process was preceded by two market dialogues before contract notice or invitation to participate. The feedback obtained from these dialogues helped Omsorgsbygg to develop explicit low-emission demands and challenge suppliers to propose innovative solutions in their bids. The second dialogue allowed Omsorgsbygg to spread their demands around the market and understand the market potential. After the first qualification stage, Omsorgsbygg added a workshop for the shortlisted five contractors, it took place before launching the competition. With help from external experts, the workshop contributed to broaden the vision of participants and raise the expected level of innovation in the project especially regarding building with wood (CLT). Moreover, the workshop helped the contractors to align with Omsorgsbygg's expectation and produce better bids.

Using interaction model during the initial design phase (preliminary project) enabled Omsorgsbygg to push more towards innovation as it opens up more opportunities among the buyer and suppliers. According to Omsorgsbygg, they were able to test out 50 tons grid-connected excavator and involve the start-up community because of such process. The contractor seemed to agree with Omsorgsbygg, as they claim that such process enables them to develop their solutions and then discuss them with Omsorgsbygg in an open, transparent and trustful environment. One can argue that this process (preliminary project) occurred after the selection process is finished, and thus, the interaction has nothing to do with improving procurement results. However, this stage falls under 'expediting' which is crucial part of any purchasing process as described by (Weele, 2014, p.28), see Figure 9.

Similar to open procedure, restricted procedure provides also standardized or specified interface with suppliers (Torvatn and de Boer, 2017). The interface prior to the bidding process in Tåsenhjemmet is considered interactive because the tender was preceded by two market dialogues, while the interface during the bidding process itself is considered

translation. This is mainly because there was a workshop took place during the bidding process. We claim that the two types of interactions (early and late interaction) are responsible for improving the interface with suppliers during procurement process.

The early interaction happened before contract notice; market dialogues and 'innovation brokers'. While late interaction took place after the contract notice; workshop and using interaction model during the preliminary project. The former impacted the process of demands development, while the later improves the contractors' knowledge of user context, which then enable them to propose better bids and develop wide range of solutions.

5.1.2.4 Project identity and key findings

Based on Tåsenhjemmet analysis, we believe the following characteristics form Tåsenhjemmet's identity: first, the project ranks high on low-emission spectrum (C2 low-emission); second, the project has good interaction level because Omsorgsbygg interacted with their suppliers before and after the contract notice; and lastly, the project is perceived as innovative since it explores new solutions to reduce emissions at construction sites such as the use of electric cranes.

Although the development projects happened in cooperation with other players are not part of the procurement process, but they make Omsorgsbygg feels more confident to introduce stricter low-emission requirements. Open procedure could have given similar results, but the restricted eliminated wasting resources from both sides. Moreover, several early dialogues encouraged Omsorgsbygg to develop explicit low-emission demands and challenge suppliers to propose innovative solutions in their bids. Finally, the workshop with suppliers helped participants to align with Omsorgsbygg's expectation and produce better bids.

5.2 Cross-unit analysis

In the previous two sections, we performed single-unit analysis for both Lia and Tåsenhjemmet projects following the theoretical framework. At the end of each analysis, we identified several characteristics that represent unique identity of each project. When positioning the projects' characteristics against each other, as shown in Figure 21, three main aspects are emerged: environmental ambitions; level of interaction; and level of innovation. Those aspects will be used to drive the cross-unit analysis among the two projects.

The purpose of performing this analysis is to help us determine if the above-mentioned aspects are related in the context of reducing emission. In other words, the identities resulted

from single-unit analysis suggest that relationships exist among those aspects, in which different levels of low-emission require different levels of interaction and innovation. Thus, the projects' identities will be compared against each other following the below, in order to further verify or diminish this result. Additionally, the comparison will help us to further understand how those aspects affected procurement process differently in each project.

Lia	**Environmental ambitions**	Tåsenhjemmet
Low	**General ambitions**	High
Low level of low-emission spectrum	**Low-emission ambitions**	High level of low-emission spectrum
	Level of interactions	
One dialogue ; Collaboration	**Type of interactions**	Two dialogues ; One workshop ; Collaboration ; interaction contract model
Before the contract notice	**Timing of interaction**	Before and after the contract notice
	Level of innovation	
Traditional: concrete and woods	**Construction methodology**	Massive wood building (CLT)
Utilize available solutions	**Solutions that reduce emissions**	Explore and test new solutions

Figure 21 Main project identities of Lia and Tåsenhjemmet

5.2.1 Environmental ambitions

Omsorgsbygg applied BREEAM and Plus house requirements in Lia project as those requirements enhance the environmental performance of the buildings and make their projects more attractive to contractors. In the case of Tåsenhjemmet, they even pushed further by adopting building with woods and selecting the project as one of the pilot projects in the Futurebuilt initiative. These pilot projects are set to reduce greenhouse gas emissions from transport, energy and material consumption by at least 50 percent. They will involve high quality architecture and contribute to a better environment for urban dwellers. As mentioned by the contractor, Tåsenhjemmet has a combination of environmental demands which reflects its high ambition. This proves that Tåsenhjemmet has higher general environmental ambitions than Lia.

The two projects are also very different in light of low-emission ambitions. Each project attempts to achieve different levels; Tåsenhjemmet has higher low-emission ambition than Lia. This difference influenced the procurement of each project significantly. Lia used implicit low-emission requirements, where requirements are included under environmental

specification. Tåsenhjemmet used explicit low-emission requirements in several places: project description, specification, and award criteria.

This difference in low-emission ambition comes to surface again in the submitted bids from contractors. It was obvious that Tåsenhjemmet's proposal is more detailed and covers further features in construction sites. For example, several solutions were proposed to reduce transport intensity and intra-logistics. The contractor expressed their intention to explore further solution during the project and involve more electric solutions like electric tower cranes. Moreover, the contractor mentioned that more pressure will be exerted on suppliers and sub-contractors to cooperate in this issue such as pushing material suppliers to deliver their shipments through using vehicles running on biodiesel.

Large projects give public buyers more room to challenge contractors and impose additional requirements considering time and resources devoted for the project. This might justify why Tåsenhjemmet has higher ambitions than Lia. Tåsenhjemmet project is five times bigger than Lia project, considering its building cost. The size plays here an important factor in the procurement process as it imposes different technical and environmental demands.

5.2.2 Level of interaction

Tåsenhjemmet had wider interaction role during the procurement process than Lia. The interaction exercised in Tåsenhjemmet's procurement process, occurred in different time periods and contained different types. See the below illustration in Figure 22.

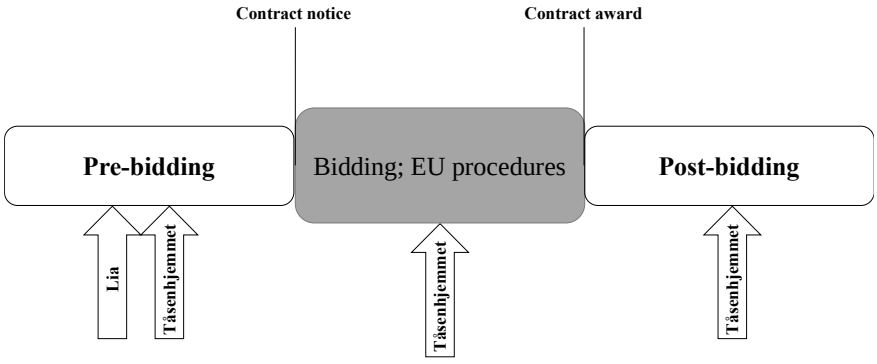

Figure 22 Timing of interaction in each project.

First, Tåsenhjemmet has interactions before and after the contract notice or when contractors are invited to participate. This enabled Omsorgsbygg to stay close with their suppliers before and after the procurement is launched. While in Lia, the interaction took place prior to the contract notice, where it involves one market dialogue and cooperation with external organizations. On the other hand, Tåsenhjemmet used results from two market dialogues to

develop clear requirements. Interaction opportunities also occurred after the contract notice, such as workshop, contributed to develop the contractors' knowledge and allow them to prepare better bids.

Tåsenhjemmet used interaction model to discuss users' requirements and technical solutions. Although the interaction during the preliminary project phase (initial design phase) had very limited direct impact on reducing emissions, but still it contributes to reduce emissions indirectly through for example choosing efficient technical solutions (i.e. building methods) and optimize logistics. After all it serves as common platform among the contractor and Omsorgsbygg to explore further solutions such as involving the local start-up community and ask them for suggestions. While in Lia, total contract model is selected, and thus, such interaction is completely missed from Lia project's initial phase.

The cooperation among Omsorgsbygg and other organizations, including innovation brokers, took higher level in Tåsenhjemmet. According to Omsorgsbygg, they participated in technology development projects with other partners to help the market move faster, such as the development project of 30 tonnes excavator running on hydrogen. As mentioned earlier in the interviews' section, these development projects are initiated by The National Programme for Supplier Development. Although these projects are neither part of the procurement process or part of Omsorgsbygg's projects portfolio, they serve Tåsenhjemmet's emission goals, since the outcome solutions will be tested and used in Tåsenhjemmet project. This could not be possible without the close cooperation took place between Omsorgsbygg and The National Programme for Supplier Development. Thus, it's safe to say that the role of innovation brokers in Tåsenhjemmet evolved significantly.

5.2.3 Level of innovation

The most apparent aspect in Tåsenhjemmet is its non-traditional building method. Building with woods (CLT) not only helps to reduce the construction time significantly, but it also decreases environmental impacts throughout the project lifetime. For example, emissions from concrete deliveries (concrete truck and concrete pumps) are eliminated, and extra heating and drying are also reduced. Furthermore, using woods will eliminate the massive use of interior material, and as highlighted by the contractor less material means less machinery work and eventually less emissions. Lia project follows traditional way of building (concrete and woods).

Another major difference between the two projects is use of available solutions. Lia utilize what the market offers, while Tåsenhjemmet employs its wider interaction role to cooperate with other organizations to introduce further solutions. Unlike Lia, Tåsenhjemmet pushes for solutions beyond fossil-free ones even if such solutions are still preliminary and under development. According to Omsorgsbygg, a new 50 tons excavator to be tested in Tåsenhjemmet project with a cable connected on the grid. Another example is when the contractor proposed using electric tower cranes to install CLT wood elements instead of diesel mobile cranes, even though CLT sub-contractors prefer mobile cranes for this task. Intra-logistics in Tåsenhjemmet project are also seen as potential to reduce emissions at construction sites. Although such process requires extensive planning (i.e. BIM model) and coordination (i.e. just-in-time) among concerned parties, it's concluded that it can minimize the movement of material around the site, which in return reduces emissions from machineries running on bio-diesel.

Another aspect is found to encourage innovation in Tåsenhjemmet is the payment method during the initial phase. Omsorgsbygg chose to pay the main contractor on hourly basis instead of lump-sum. As mentioned by Omsorgsbygg earlier, such arrangement will encourage the contractor for innovation and explore further solutions to avoid cost limitations. The contractor's perceived it as good sign as this enables them to push their consultants and technical team to propose further solutions.

More about Omsorgsbygg

In the following, we will focus on Omsorgsbygg itself in order to evaluate its role in the procurement process. First of all, Omsorgsbygg uses its strategic vision as departure point to support their procurements. As shown earlier, Omsorgsbygg aligned supplier selection process with their environmental strategy. This helped Omsorgsbygg to produce effective criteria towards targeting greenhouse gas emissions.

Second, one of Omsorgsbygg's strategic objectives is to develop the necessary expertise and knowledge through establishing collaborative agreements. Thus, Omsorgsbygg has established several agreements in order to reduce emissions at construction sites. Their collaboration with Bellona was mainly to acquire new knowledge regarding emissions, while their collaboration with the National Programme for Supplier Development was more intensive. The programme helped them with setting up market dialogues and getting them involved in several development projects.

Lastly, Omsorgsbygg pays good attention to its internal and external communication. Internal communication is obvious from their advanced information sharing culture among projects, while they were able to lift their external communication through establishing several agreements with market players and third parties.

In summary, Omsorgsbygg utilized effectively their strategic vison, internal communication and relationships with others in order to enhance their organizational performance. For example, it was clear from both projects, how ambitious and advanced Omsorgsbygg is, especially when it comes to exploring or adopting new solutions. Thus, we believe that improved organizational performance and features reflect positively on procurement processes.

5.3 Summary and highlights

Apparently low and zero-emission construction sites require different types of solutions. Despite both Lia and Tåsenhjemmet are characterized as low-emission projects, they still have different ambitions and require different solutions as both possess different levels on the low-emission spectrum; C1 and C2, refer to Table 16. Therefore, it was necessary to introduce a proper classification with unambiguous terms to clearly reflect the level of emission-reduction at construction sites. Another important result to highlight here is that the three main aspects are closely related, as illustrated in Figure 23. In which higher emission-reduction demands require higher level of innovation to meet those demands, and then higher level of innovation requires higher level of interaction to improve the innovation potential.

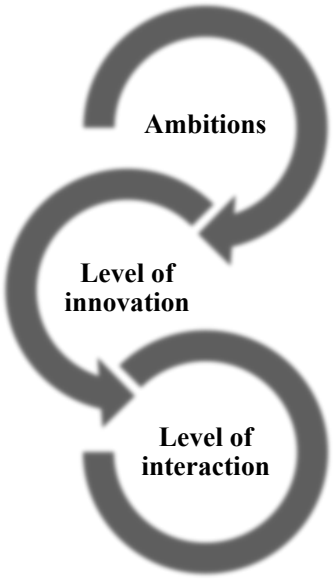

Figure 23 Relationships among ambition, innovation and interaction

Lia experienced low interaction level because of its minimum low-emission (C1 fossil-free) requirements, while Tåsenhjemmet experience higher interaction level because of its innovative and demanding characteristics. Finally, Omsorgsbygg has several good organizational features such as advanced information sharing culture and good collaborative agreements with others. Moreover, such features do not only reflect the importance of internal and external communication but also influence the procurement process positively.

6 Discussion

As shown previously in the analysis chapter, the different levels of interaction identified for each project, made us wonder about the potential of interaction occurring at different stages of the procurement process. Understanding the potential of different types of interaction help us to better assess the right contribution of the EU procurement tools towards achieving low or zero-emission construction sites. Therefore, in order to achieve this goal, this chapter will focus on three main issues.

First, potential of interaction will be discussed in light of the following stages of procurement process; pre-bidding, bidding, and post-bidding. Innovation potential will be also discussed besides interaction, since these two are interrelated. Second, we will discuss if zero-emission construction sites can be achieved in the future through the current public procurement procedures. Additionally, other scenarios will also be explored to enrich the discussion. Finally, the original theoretical framework will be revised. The new framework will employ key findings from data analysis and discussion, and particularly interaction, in order to better reflect the potential of the current public procurement toolbox in terms of reducing construction emission.

6.1 More about interaction

Figure 24 illustrates the purchasing process of public building, the process builds upon the general purchasing process from Weele (2014, p.28) and the supplier selection process from Igarashi et al. (2013). It is broken down into three main stages; pre-bidding, bidding, and post-bidding. As shown below, pre-bidding stage constitutes of two steps: identify needs and formulate criteria. Then public buyers use one of the current EUs public procurement procedures during the bidding stage. In the post bidding stage, we mainly follow Weele's steps, where we shortened it to three main steps: contract agreement, management, and evaluation.

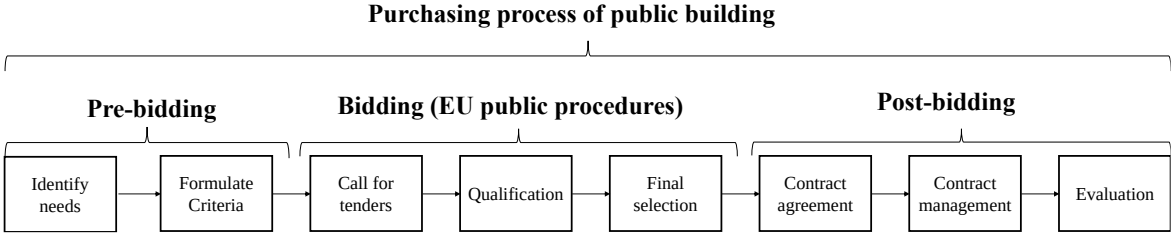

Figure 24 Illustration for purchasing process of public building, source: (Igarashi et al., 2013, Weele, 2014)

The above process will be used to drive the discussion regarding interactions and their related interface types. It might be easy to say that each stage of the above process can offer interaction possibilities, however, it's still difficult to describe the level of interaction by just using the word 'interaction'. Therefore, we apply Araujo et al. (1999), four different types of supplier interfaces, into the above process, in order to show what possible interfaces are available to public procurers when they plan to buy a building. Interfaces provide buyers with different ways to access the resources of their suppliers to achieve innovativity and productivity objectives (Araujo et al., 1999). Positioning the interfaces against the three stages of the above purchasing process will be done in line with the latest EU public procurement.

Pre-bidding

Interaction with contractors and suppliers during the pre-bidding stage can take place in the form of market dialogues. The interface during the pre-bidding stage can be labelled as interactive (Torvatn and de Boer, 2017). These dialogues provide common platform for both public buyers and suppliers to learn about each other. And as a result, *''purchasers may be able to write more realistic and inspiring, innovation-driven specifications''* (Torvatn and de Boer, 2017). In other words, buyers can learn about the market capabilities, while suppliers learn about current and future demands. This enable the buyers to steer and influence the market. In the case study, public buyers used such dialogues to test the waters before introducing low-emission projects into the market. Some solutions were found available, and others are still under development. For example, Tåsenhjemmet project sent a strong signal to the market that whoever possess the ability to deliver a project with zero-emission construction sites, will have the competitive advantage needed to win future competitions.

Following the results of Lia, we believe that the role of market dialogues to deliver an interactive interface is somehow arguable. We claim that the interface during the pre-bidding stage can be labelled as translation and may be sometimes interactive. We follow this claim with several explanations drawn from the case. First, the feedback from market dialogues was helpful but still limited. For example, in Lia the market dialogue focused on the use of fossil-free solutions, and no major feedback obtained regarding the development of further electric solutions. This required another market dialogue, which took place in Tåsenhjemmet. Second, the construction methodology in Lia was set to be traditional, where other alternative methods for building were neither discussed nor explored, such as using alternative material

in the building that might lead to simpler operations and less emissions. Finally, it's not obvious to what degree participants understood the users' context. As without such knowledge, participants will struggle to develop relevant solutions. An interface to become interactive, the supplier needs to develop solutions (Araujo et al., 1999) or at least serious efforts to explore new solutions must be done.

Bidding stage

It becomes a bit complex in the bidding stage due to various number of procedures available at the disposal of public buyers. Work of Torvatn and de Boer (2017), refer to Table 7, will be used to draw a better picture about the available interactions during the bidding stage, see Table 21 below. The negotiation procedure is overlooked from the previous table because it's used in exceptional situations like lack of time in case of emergency situations

Table 21 Potentials of the different EU public procurement procedures

Procedure	**Open, restricted**	**Competitive dialogue**	**Innovative partnership**
Source of interaction	None. But buyers can influence the procedure by adding ad hoc interactions (i.e. workshops) with specific rules in place to ensure equal treatment and transparency.	Parallel dialogues among the buyers and the qualified suppliers	Development phase among the buyers and the qualified suppliers
Interface type	Standardized. Specified or translation (with ad hoc interaction)	Translation, interactive	Interactive
Innovation potential	Low -utilize available solutions in the market to satisfy requirements such as using biofuel driven equipment. Medium (with ad hoc interaction) -exploit available solutions	Medium -modify available solutions to satisfy requirement -intensive interaction with suppliers allows solutions to emerge such influencing execution methods through particular design to reduce site emissions	High -develop state of art solutions

The open and restricted procedure are very alike, except the qualification of suppliers in the restricted procedure takes place on two stages. According to their definitions, there are no original interaction windows during the procedure implementation; from contract notice to contract award. However, it's still possible to add some 'ad hoc interaction' as long as public buyers respect the legal framework of public procurement, including the four principles. We chose to call such interactions 'ad hoc' because they are created or done to achieve a particular purpose. One good example of 'ad hoc interactions' is drawn from the case study, when Tåsenhjemmet had a workshop. The workshop took place before launching the

competition among the 5 qualified contractors, Omsorgsbygg, and external experts in order to improve the knowledge of contractors.

Unless such 'ad hoc interactions' are added to the classic procedures, the interface stayed standardized. Having 'ad hoc interactions' will position the interface closer to translation or at least specified because suppliers can propose alternatives or solutions based on their current resources. Usually open and restricted procedures have minimal innovation potential, but with the 'ad hoc interactions', the innovation can be improved.

Back to the case, the contractor of Tåsenhjemmet said that there was no difference for them if the procurement is done through open or restricted. One can argue that having an open procedure in projects would affect participants negatively, as open procedure allows more competition. However, only few contractors have the required competencies to do ambitious projects like Tåsenhjemmet. Moreover, according to Omsorgsbygg, the workshop itself could have been done under open procedure as well. One result can be that the two procedures are capable to deliver the same results with respect to reducing emissions, but restricted procedure was favoured to simplify the process and avoid wasting resources. Not to mention the time and resources needed to set up a workshop for large number of participants if an open procedure was selected.

On the other hand, both competitive dialogue and innovative partnership have built-in rooms for interactions. These interactions enable suppliers to acquire knowledge about user context and develop their solutions during the procurement lifetime. However, innovative partnership has bigger role in this scenario. The procedure combines both development and purchasing elements. It has an interactive nature that enables public buyers to have 'state of art' solutions, unlike translation, which can limit the innovation possibilities to slightly new or modified solutions. These two procedures will be revisited again in the next section to check their capability to deliver zero-emission construction sites.

Buyers are highly recommended to have a variety of interfaces to achieve their objectives (Araujo et al., 1999), especially that the current public procurement directives in the EU offers wide range of interaction opportunities that public purchasers can take advantage of.

Post-bidding stage

After the bidding stage, the winning contractor signs a contract agreement with the public authority to perform the work. The project execution commences during this stage right after

signing the contract. According to the Project management Institute, 'control procurement' is *"the process of managing procurement relationships, monitoring contract performance, and making changes and corrections as appropriate"* (PMI, 2013a).

In Figure 24, we used the term 'contract management' to describe the process of control procurement. A key benefit of this process is to ensure that both the public buyers' and contractors' performance meets procurement requirements according to the terms of the legal agreement (PMI, 2013a). This process is very important to align the project deliverables with procurement requirements. Public buyers usually follow their national standards to establish and manage construction contracts. However, there are some models that allow for interaction at the beginning of this stage, such as the interaction model used during the initial design phase in Tåsenhjemmet project. As mentioned previously, the phase itself did not benefit reducing emissions at construction sites, but instead it helps to improve innovation potentials of other solutions, which can reduce emissions indirectly such as exploiting the quality of timber construction or reduce the intensity of project intra-logistics.

The post-bidding stage is vital, not only because it covers project execution but also because it has the potential to explore further solutions, especially if the contract is 'design and build'. As it is one of the approaches that *"integrate design and construction ... leading to improved design constructability and economy, through innovation"* (Blayse and Manley, 2004).

However, unlike the previous two stages (pre-bidding and bidding), the interaction in this stage takes place with only one contractor, and more specifically the contractor who won the contract. Its controlled and organized by signed agreements, in which the contractor follows the contract agreement. Figure 5 in section 3.2.3 illustrates how the cost of making changes increases largely as the project approaches its completion. Similarly, when the project moves into the post-bidding stage and start moving forward with design and execution, making changes and suggesting new solutions become costly and time-consuming. Thus, we claim that the benefits from post-bidding's interaction are limited, especially when we are talking about developing or exploring new solutions. In other words, interactions during pre-bidding and bidding stages are more effective to generate solutions and reduce emissions.

One can argue that planning and design efforts that precede real construction work have a great potential to influence project features and improve reducing emissions at construction sites. We believe that this potential is highly overrated. Usually during the initial design phase there is some room to influence for example the choice of material in order to simplify

the execution and produce less emissions, however, initial design phase is likely to focus on the building itself and users' expectations rather than detailed, future execution processes. Besides once this phase is done, it is very difficult and costly to explore or employ other solutions.

It was noticed from the data of Tåsenhjemmet that some Omsorgsbygg officials put expectation on the initial stage when it comes to reducing emissions. While others mentioned that the main purpose of such stage is only to understand the user needs and design the technical systems to fit those needs. However, while it's still possible to influence solutions during this stage in order to reduce emissions indirectly, it's still arguable how much impact does this stage have towards reducing emissions.

All in all, unlike the interactions of previous stages, interaction during the post-bidding stage is important to achieve project goals but it does not necessarily contribute to reduce emissions at construction site.

6.2 Potentials of EU procedures to reduce emissions

Since the current EU public procurement toolbox offers public purchasers a larger innovation potential than before (Torvatn and de Boer, 2017), we want to look at the ability of public procurement toolbox, including interactions, to achieve zero-emission construction sites. Zero-emission will be given more attentions because it's not achieved yet and both projects covered in the case study were targeting low-emission requirements.

It's quite obvious that the main barrier to achieve zero-emission construction sites is the availability of new technological solutions such as electric heavy-duty construction vehicles and machinery. As mentioned by Omsorgsbygg, achieving the first zero-emission construction site is likely to happen in the level of small project like kindergarten to avoid further complications. Small projects allow also both client and contractors to have more control over the project. According to Omsorgsbygg, such scenario will exclude some transport to and from construction site such as material delivery and discharging of waste. While other staff and material transport will be included, since electric cars are already available. In other words, heavy-duty transports are likely to excluded. Although such transport from and to construction site emits large amount of emissions, but it is still arguable if it is a real part of the construction site or not, see the study's system boundary in Figure 6. Nevertheless, we believe that both buyers and contractors should try to influence the project

supply chain to reduce emissions as this will exert pressure on suppliers to adopt more environmental-friendly transport options such as trucks running on bio-fuel.

Classic procedures

The classic set of public procurement procedures; open and restricted, did well in Lia and Tåsenhjemmet in terms of achieving low-emission targets, since both projects' ambitions fit perfectly under low-emission category. On the other hand, we claim that those classics are incapable to achieve zero-emission level in building projects. Our claim builds upon several points. First, the classic procedures are built to utilize market available solutions rather than develop new ones. This is very clear in their frameworks. Specifications inform suppliers about needs and requirements, while qualification and award criteria drive the selection process of the most capable supplier. Therefore, we do not see the potential to develop further solutions within their current framework.

Second, classic procedures do not allow for enough dialogue among buyers and suppliers during the tendering process. Following the argument in previous section about the potential of pre-biddings' interactions (market dialogues), their impact to develop further solutions is very limited. Even if more ad hoc interactions (refer to Table 21) are added to the classic procedures, they are still incapable to develop new solutions since the main benefit of ad hoc interactions could be to advance the suppliers knowledge and improve their bids.

Finally, time is central issue in the case of zero-emission construction sites. Because zero-emission solutions dose not only require new solutions, but also it requires excessive planning to ensure all construction operations work in a cohesive manner. We claim that intensive planning, targeting zero-emission, is somehow underrated since buyers tend to believe that once zero-emission solutions are developed, then zero-emission construction sites can be achieved. Yet, using electric construction machinery in the construction sites (i.e. excavators) are not enough to achieve zero-emission construction sites, in fact there are dozens of activities that need to be planned carefully such as how all minor energy-dependent activities will be connected to the grid. The construction site is very crowded place filled with light and heavy-duty tools ranging from drilling to compactor machines. Consequently, classic procedures do not offer enough room for such high intensive planning.

Competitive dialogue

As mentioned previously in the theory chapter, the legal rules of public procurement from different levels hinder establishing and engaging in long-term relationships with suppliers

(Telgen et al., 2007). The competitive dialogue has medium innovation potential (see Table 21) due to its translation and interactive interface. The interface takes place in form of parallel dialogues among the purchaser and the qualified suppliers, where each supplier suggests a technical solution for the purchaser during dialogue.

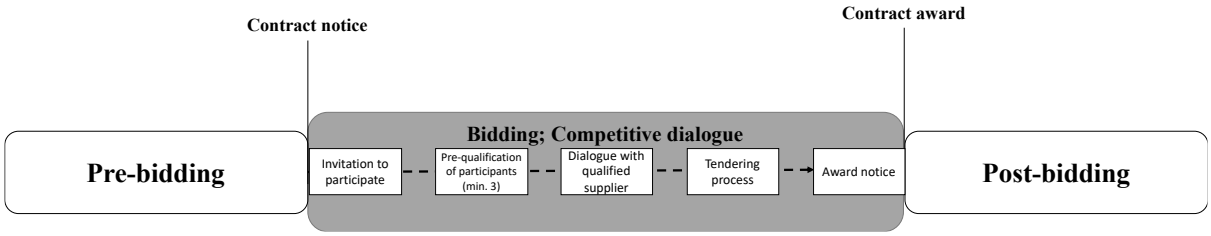

Figure 25 Purchasing process using competitive dialogue

Although competitive dialogue can enable sustainable public procurement in construction projects (Uttam and Roos, 2015), the procedure's ability to achieve zero-emission construction sites remains questionable. The procedure offers intensive rounds of dialogue and discussions during the bidding stage, that can lead to high detailed implementation plan including full considerations of intra-logistics and transport. However, the procedure does not seem to provide enough time for development of new solutions, especially if these solutions are very technical such as heavy-duty machinery.

We believe this procedure can achieve zero-emission construction sites if technical solutions were developed and available in the market prior to the bidding time. Then intensive planning and building site optimization take place during the procedure's dialogues.

Another possibility is if intensive cooperation happened before the bidding among several public buyers. Since cooperating with other public entities is virtually not restricted (Telgen et al., 2007). Then solutions developed in cooperation with other partners can be discussed in dialogues, where suppliers can modify them or propose better solutions.

Overall, if the project was small enough and limited number of electric machinery were ready at the time of the tendering. Competitive dialogue might have the potential to achieve near zero or zero-emission construction sites due to its intensive dialogue and discussion rounds. The purchasers and suppliers will be able to optimize the construction operations during those rounds. Noteworthy, the main purpose of the intensive planning and site optimization are to ensure that all construction operations (including intra-logistics and machinery), are emission-free.

Innovative partnership

It's difficult to assess the potential of innovative partnership to achieve zero-emission construction sites due to its newness. The procedure was added to the new EU directive 2014/24/EU, which replaced EU directive 2004/18. According to The National Programme for Supplier Development, there are currently 5 running innovative partnerships in Norway; 50% of innovative partnership procurements in Europe. The programme role is involved in facilitating and brokering these partnerships. Innovative partnership can be a great way in solving issues when we have more challenging needs, to help coming up with new innovative solutions. Unlike the pre-commercial procurement, innovative partnership has the option to buy the solution that has been developed.

Following Figure 26 below, the procedure can be broken down to three phases: suppliers selection, solution development, and final selection. The main value of this procedure is its potential to institutionalize and integrate the development process within procurement. Thus, unavailable zero-emission solutions can be thoroughly developed during this process. Early interactions (market dialogues) can help buyers to narrow down unavailable solutions and then select suppliers based on their capacity to develop those solutions.

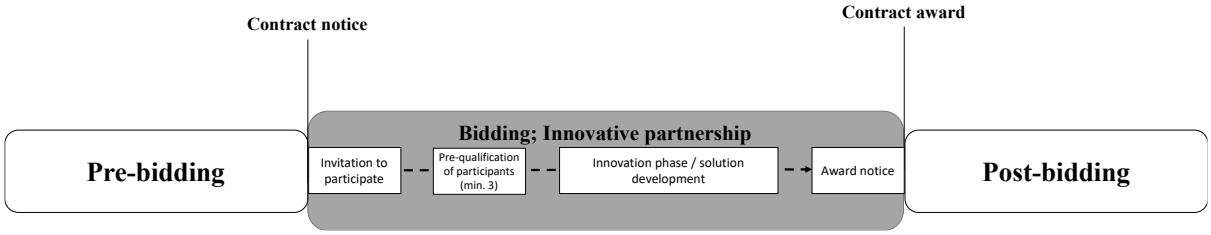

Figure 26 Purchasing process using innovative partnerships

Public building projects are usually contracted to construction contractors who are specialized in design and building activities. These contractors along with their consultants and subcontractors are capable to develop new solutions to fit users' requirements. And although machinery development is not part of their expertise, it's possible through cooperating with other suppliers who are specialized in machinery development during the development phase.

Still, this scenario is problematic for many reasons. First, there are so many different machines in one constriction site, so if a project wants to achieve zero-emission, one innovative partnership will not probably be enough to develop the entire set of machines.

Unless a very small project is considered. Second, the developed product is a prototype, and thus, its performance and accuracy remain questionable.

In the following, we attempt to understand the cost and time impacts of this procedure. Increasing level of involvement will cause relationship costs to increase accordingly (Gadde and Snehota, 2000), but such costs could be justified if the relationship led to a new solution. Time impact measures how long each procedure takes time to select the right supplier. Projects with low-emission requirements take less time with open or restricted procedure, since developing new solutions from scratch is not in the agenda for such projects. On the other hand, innovative partnership or competitive dialogue are expected to take longer time to come up with new ideas or develop new solutions.

What's next…

Obviously achieving low-emission construction sites is something public procurement are capable of. Achieving zero-emission construction sites, on the other hand, is still challenging, considering that new machinery is badly needed in order to make the entire construction operations fully emission-free. In the previous discussion, we have reviewed interaction and innovation possibilities that exist within the current public procurement toolbox. No doubt that some procedures have more potential than others in terms of innovation.

However, public builders use public procurement to procure a whole building, and not just several solutions. Moreover, the building itself, as shown previously in section 3.2.3, constitutes of many project life cycles and stakeholders. Therefore, performing procurement process to develop couple of prototypes for zero-emission machinery, instead of focusing on the project as a whole, is not a realistic solution at all. Such approach is not only unrealistic, but also it will consume a lot of time and money. Nevertheless, the closest procedure to execute such scenario is innovative partnership.

With respect to the context of low and zero-emission construction sites, we believe that public procurement's role starts after the required solutions become available in the market. Therefore, separate development projects similar to what have been described by Omsorgsbygg and The National Programme for Supplier Development are needed, prior to the public procurement process, see Figure 27. These development efforts can be occurred in the form of development projects or pre-commercial procurement (PCP).

Based on the previous discussion, we propose an approach modified towards achieving the first zero-emission construction site. It starts with launching several development projects in

order to develop several construction equipment, and in particular heavy-duty ones. Then, the process follows a traditional purchasing processes framework along with recommendations. In this scenario we assume that public buyers are looking to achieve the first project with zero-emission construction site, therefore, the project is expected to be simple and small. Classic procedures are excluded from this scenario because they lack for proper interaction possibilities.

As shown in Figure 27, there is big emphasis on preparation, which take place during the pre-bidding stage. This stage allows to uncover new solutions through different interaction platforms: dialogues, innovation brokers, and cooperation with other public entities. Such early interaction will mainly help public buyers in cooperation with the market to define the project's specific zero-emission requirements and spot all available, relevant solutions.

Afterwards, the public buyers are left with two procedures to choose from. Competitive dialogue is favoured when solutions are already available in the market. While innovative partnership is recommended when solutions still need further development and modifications. The interactive nature of those procedures allows contractors and public buyers to perform intensive planning properly, where all construction operations are put on the table for discussion such as building methodology, intra-logistics and staff transport. Interaction rounds are recommended to continue during the post-bidding stage, as once execution phase started, there will be a strong need for continuous dialogue in order to monitor and control zero-emission processes.

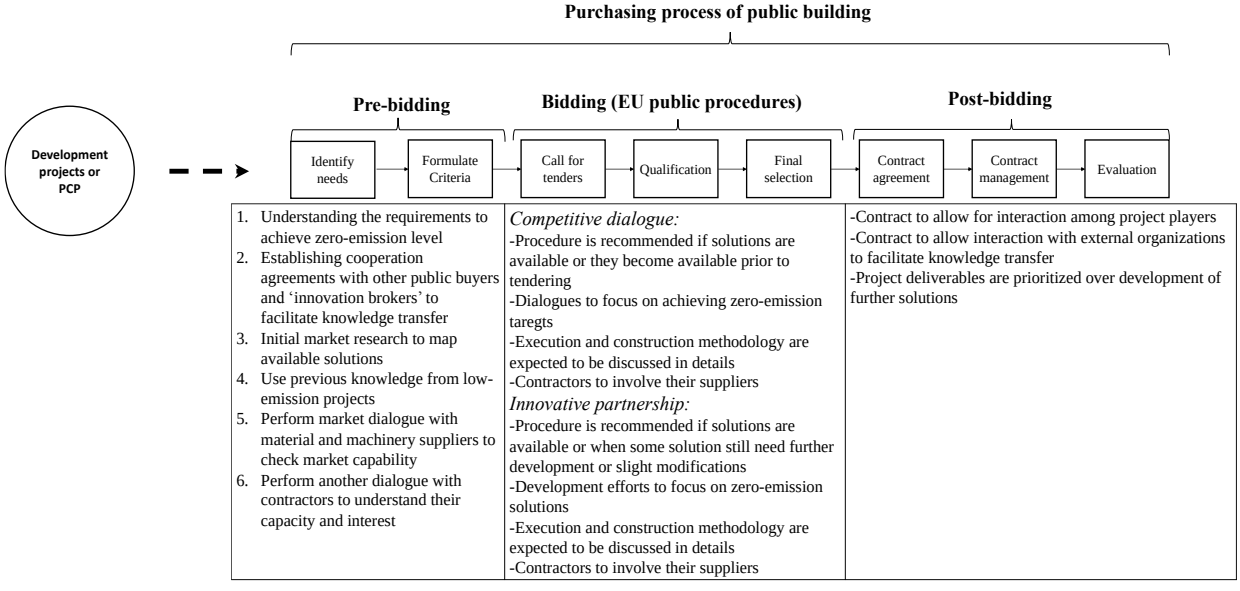

Figure 27 Proposed approach to achieve the first zero-emission construction site

We believe the previous approach is realistic and achievable, taking into account that such development projects can be established. It would be more difficult and complicated for a public buyer alone or even several public buyers to initiate such projects because they lack the connection and relationship with the private sector.

In the case study, Omsorgsbygg demanded from suppliers during market dialogues electric machines, but for suppliers Omsorgsbygg is only one customer and does not represent big market for them. Afterwards, the programme gathered 8 additional public buyers who have similar interests. And since achieving zero-emission construction sites can't be accomplished without development of new technology, several development projects were initiated.

6.3 Revised theoretical framework

In this section, we will present the new revised theoretical framework, see Figure 28 in the following page. The original framework, presented at the end of chapter 3, was divided into three stages to address the research problem statement, and more specifically to drive the analysis for each project. After starting with the empirical cycle and analysis, we acknowledge three main motivations to revise the framework. First, the original framework lacks a proper definition for both low and zero-emission construction sites. In the first stage, it was a little bit unclear how projects can be classified. Therefore, the first stage is slightly revised to incorporate the new classification.

Second, the original framework did not highlight the interaction role properly. It was noticed from the case that interaction was central in the context of reducing emissions in projects. We also discussed the interaction role during the whole purchasing process to further explain its relationship with innovation. Therefore, we decided to dedicate a whole stage (stage 2) in the new framework for interaction.

Third, the original framework failed to address the relationship among emission ambition, innovation and interaction. In which higher emission-reduction demands require innovative solutions to meet those demands, and then higher level of innovation requires higher level of interaction to help create the required solutions. Consequently, we modified the second stage in order to reflect how interaction goals are defined. It all starts in the first stage when a proper classification is chosen, and the project's emission ambition is realized. Then these demands are reviewed to propose suitable, relevant solutions, in which some solutions require different levels of innovation.

In the following, we will walk through the revised framework stage by stage. The framework starts, similarly as the old one, with building the required understanding of both low-emission and zero-emission construction sites. Principles of sustainable construction, as described by Hill and Bowen (1997), are reviewed to draw clear picture of how sustainable projects look like. Then, several studies such as (Hong et al., 2015, Ren et al., 2012, Yan et al., 2010), are reviewed to narrow down the wide sustainability goals in construction towards reducing greenhouse gas emissions and make it compatible with the study's context.

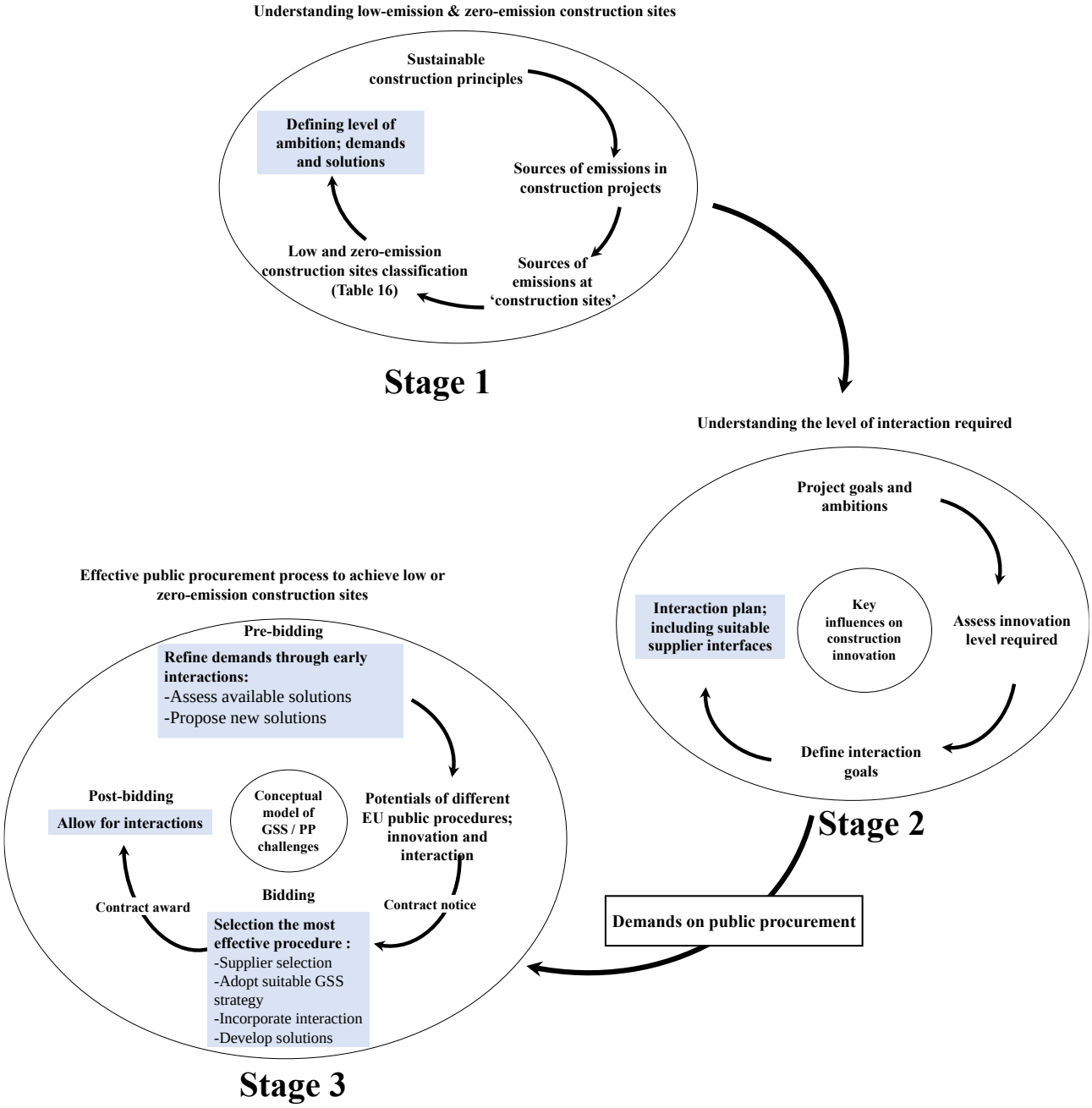

Figure 28 Revised theoretical framework

Afterwards, only sources of emissions at construction sites are summarized in Table 3 and in accordance with the study's boundary as illustrated in Figure 6. The resulted sources are still not enough to act as point of departure for public procurers to formulate their requirements and criteria as proper classification describing the level of emission-reduction is significant. Therefore, Table 16 is incorporated, it builds upon Table 3 and findings from the case. The last step of stage one is to define the level of ambition based on emission requirements and relevant solutions.

In the second stage, the framework attempts to understand the level of interaction required following the project environmental ambitions, and more specifically emission ambitions. This stage will embrace the relationship among emission ambition, innovation and interaction. For example, if higher ambitions found necessary, then interaction type and amount need to be planned and spread over the procurement process.

Another major change is placing the key influences on construction innovation, described by Blayse and Manley (2004), in this stage. After understanding project goals and ambitions, the key influences will serve to assess the innovation level. Innovation requirements to achieve the project's emission ambition are uncovered. Afterwards, interaction goals are established since different innovation levels require different interaction plans. For instance, uncovering available solutions from the market needs market dialogue, while developing new solutions require higher state of interaction, which usually takes place during the tendering process itself. Lastly, interaction plan is decided based on timing and type of interaction needed. Work of Araujo et al. (1999) on buyer-supplier interfaces can be used to describe the degree of interaction needed with suppliers.

Unlike private firms, public authorities are restricted with many limitations, therefore, it's vital to be familiar with the various demands on public procurement.

The third stage divides the procurement process into three parts; pre-bidding, bidding, and post-bidding, as shown previously in Figure 24. During the pre-bidding, buyers and suppliers learn about each other. Afterwards, potentials of different procedures in terms of innovation and buyer-supplier interface are reviewed following work of Torvatn and de Boer (2017).

The choice of procedure decides the level of interaction available during the tendering phase. For example, a project aims to achieve low-emission level (C1 fossil-free), will probably not need more than market dialogues. This leaves the project with classic procedures. While a

project aims to achieve low-emission level (C2) or higher, might need further interaction. This will likely to affect both the choice of the procedure and interface type accordingly.

Afterwards in the tendering phase, public procurers chose the most effective public procedure in addition to a suitable GSS strategy from Igarashi et al. (2015).

Other interaction possibilities are also available through the last part, post-bidding. However, as mentioned in the discussion chapter, interaction during the post-bidding is important to achieve project goals but it does not necessarily contribute to reduce emissions at construction site. Therefore, buyers are encouraged to perform this interaction if needed, but they should aim to develop solutions during the tendering phase rather than post-bidding phase.

Furthermore, the conceptual model of GSS by Igarashi et al. (2013) is centred in the middle of stage 3, to provide guidance to public buyers through the whole process. For example, alignment dimension describes how the defined demand relates to the public authority's overall green strategy. General challenges, drawn from previous studies (Bouwer et al., 2006, Testa et al., 2012, Uyarra et al., 2014), facing public procurers when performing green public procurement are also placed in the centre.

6.4 Summary and highlights

In this chapter we have first discussed the role of interaction at different times during procurement process. All types of interactions that take place during both pre-bidding and bidding stages can contribute positively to reduce emissions at construction sites. However, interaction during the post-bidding stage is critical to achieve project goals but it does not necessarily contribute to reduce emissions at construction site.

Then we reviewed the potential of EU public procurement procedures to reduce emissions at construction sites. Classic procedures are found effective to achieve low-emission construction sites (both classes C1 & C2). It's very obvious that the main barrier to achieve near zero-emission or zero-emission construction sites is the availability of new technological solutions such as electric heavy-duty construction vehicles and machinery, see Table 16. Competitive dialogue is recommended if the solutions are already developed and available in the market, in which its intensive dialogue rounds allow for intensive planning.

Innovative partnership has obviously a lot of potential, but since it is very new, it's hard to judge its effectiveness. Nevertheless, an approach to achieve zero-emission construction sites, using public procurement, is proposed.

Lastly, following Dubois and Gadde (2002b) recommendation, looking into real world observation was necessary to develop better theoretical perspective and understand how public procurement tools function in such context. Therefore, a revised theoretical framework is presented. It offers modified approach to address the research's problem statement based on findings from the empirical cycle.

7 Conclusions and implications

7.1 Conclusions

In the following, we will draw the study's conclusions per research question. Answers will be structured to address each research question based on previous chapters, refer to Figure 1.

R.Q.1: What is the theoretical potential of the current public procurement toolbox and particularly interaction with suppliers, to achieve low or zero-emission construction sites?

In theory, it's safe to say that the current toolbox of public procurement has a good potential to reduce emissions at construction sites. This is mainly because the purchasing of public buildings with low or zero-emission construction sites is form of green public procurement, as it aims to reduce adverse environmental impacts, which in our case reducing GHG emissions at construction sites. With respect to green public procurement literature, environmental benefits can be realized if relevant environmental criteria are included systematically in public tenders (Parikka-Alhola, 2008). In other words, emission-reduction must be included systematically to cut emissions at construction sites.

Following the above, in order to develop clear criteria, we need first to understand the sources of emissions at construction sites. Literature is rich with studies addressing the sources of emission in construction projects, but it lacks the concentration on construction sites. However, by applying the study's boundary (see Figure 6), we were able to sort out sources of emissions at construction sites (see Table 3). Yet, we were not able to appropriately distinguish between low and zero-emission construction sites. Clearly one can assume that zero-emission is achieved when all processes at construction sites must become emission-free, yet it's not simple to define what low-emission construction sites stand for. However, we assumed that when emission is reduced to any level then the construction site can be labelled as low-emission.

The current EU toolbox covers wide-range of procedures that have different levels of innovation and interaction, besides all procedures can be preceded by a market dialogue. This early interaction helps buyers to understand the market capabilities in terms of available solutions, so they avoid unrealistic demands. Both contractors and suppliers can also improve their knowledge about emissions and produce better proposals.

Although the procedures have different structures, they all allow criteria inclusion through specifications, qualification and award criteria. From ignoring to integration strategies

(Igarashi et al., 2015), public procurement allow buyers to choose the level of emphasis they desire when they include their criteria. Therefore, we claim that the internal structure of public procurement is capable to properly address reducing emissions at construction sites. Moreover, the use of internet tools on GPP, for example 'Buying Green: a handbook on green public procurement', released by EC, helped to tackle some traditional barriers such as lack training for public purchasers (Testa et al., 2012).

In order to unfold the real, theoretical potential of public procurement to achieve low or zero-emission construction sites, a closer look at innovation is needed. In general, the more innovation possibilities we have at our disposal, the more confident we are to reduce emissions, especially when some emission-reduction solutions are closely connected with developing new low-carbon solutions. New solutions can range from technical to methodological ones. For example, with the aim of cutting emissions from construction operations, a contractor can either replace fossil fuel with renewably-produced electricity or adopt alternative operations that emit less emissions.

According to literature, the degree of involvement of buyers with suppliers defines the innovation potential. Classic procedures offer no interaction, but if preceded with market dialogues then innovation potential of those procedures is improved. Translation and interactive interfaces take place during competitive dialogue or innovative partnership procedures. Hence, in theory innovative solutions can be developed if higher degree of interaction become available between public buyers and their suppliers. This means that contractors learn about demands and buyers learn about solutions during the course of early dialogues. And later the supplier selection process focuses on selecting the best supplier capable to cut emissions at construction sites, including developing new solutions.

In summary, there are two ways to evaluate theoretically the potential of public procurement regarding the study's context. First, the ability of public procurement tools to address emission criteria effectively and select the most qualified supplier. Second, the capacity of public procurement to develop new low-carbon solutions. Do procedures for example allow suppliers to propose and develop innovative solutions that promote reducing emissions. The theoretical answer to the previous is yes. The remaining doubt is yet knowing to what extent public procurement have the capacity to develop state of art solutions to cut emissions.

R.Q.2: What challenges do public buyers face when procuring buildings to achieve low or zero-emission construction sites? And what role did interactions play?

Literature mentioned several challenges that face public procurers when they perform green public procurements, see section 3.3.3. Our case study shed light on challenges that face public builders in the context of reducing emissions at construction sites. Projects with high ambitious, environmental requirements might have a great potential to reduce adverse environmental impacts, but they do come at price. The case study unveiled mainly the following four challenges: lack of relevant environmental knowledge, documentation process is very demanding, unavailable technology, and divergent innovation-mindset.

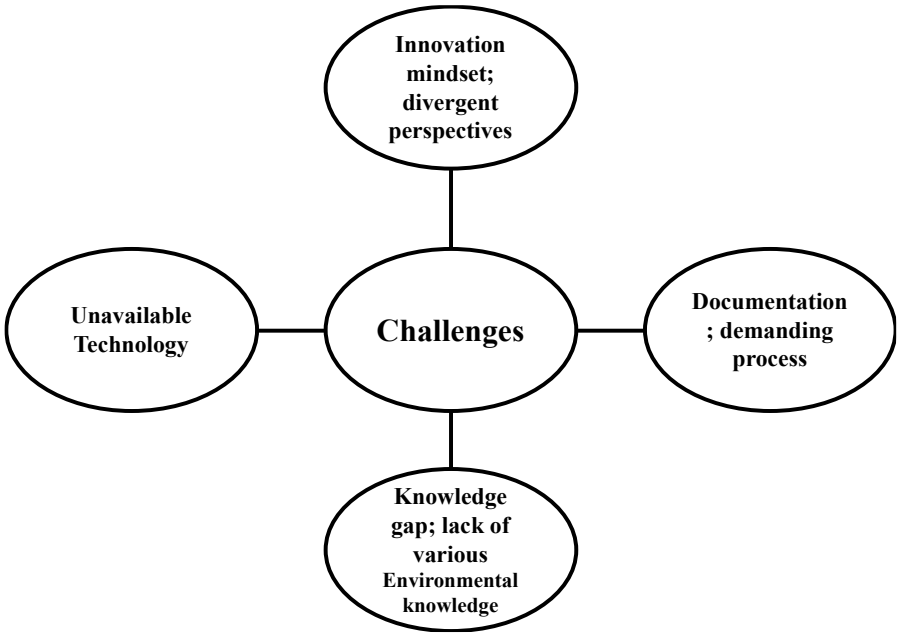

Figure 29 Challenges face procurers in the context of reducing emissions at construction sites

First, a combination of different environmental requirements requires public buyers to expand their environmental knowledge. Public projects with goals to reduce emissions at construction sites are expected to be heavily loaded with environmental requirements. From the case, Omsorgsbygg believe that different environmental requirements complement each other, make the project more attractive, and help to maintain the ambitions high during the project life time. Omsorgsbygg said that the expert knowledge about the environment is very significant to achieve success in such type of procurements. For example, they were lacking good grasp over BREEAM and building with woods (CLT).

The interaction played a significant role here, early cooperation with 'innovation brokers' such as Bellona, developed Omsorgsbygg's knowledge of GHG emissions. Additionally, 'Ad

hoc' interactions during the procurement process allowed to expand their knowledge regarding building with woods.

Second, the process of documentation can be very demanding when targeting emissions at construction sites. Public buyers need to prepare high-grade documentation for their procurements in order to attract and select the right contractors. Although making requirements explicit in the process can be very challenging to procurers, it helps to avoid ambiguity and future conflicts. Depending on the level desired, targeting construction emissions suggest sometimes following alternative building methodology to cut emissions, however, some of these methods lack proper standards. Thus, lack of proper standards in place can affect the process of documentation, since public buyers use mainly national standards to produce their procurement's documentation. Moreover, the combination of different ambitious, environmental requirements makes the process of formulating clear award criteria challenging.

The case shows how Omsorgsbygg has such an advance sharing culture. Having efficient communication and information sharing culture improves the procurement process positively. We believe that this organizational feature can tackle difficulties coming from documentation process.

Third, unavailable technology restricted public buyers from targeting additional emissions at construction sites. This challenge acts more like a barrier here, however we chose to consider it a challenge as such technology develops with time as long as buyers keep asking for it. Omsorgsbygg could not raise their procurement ambitions to zero-emission classes (see the classes in Table 16) because such zero-emission technology, such as electric heavy-duty machinery, is not developed yet.

Since Omsorgsbygg is determined to achieve zero-emission construction sites in their projects, they expanded their role in cooperation with The National Programme for Supplier Development. The interaction here takes place outside the procurement playground in the form of development projects.

Lastly, unparalleled innovation mindset between public buyers and contractors might limit the buyers' ability to reduce emission at construction sites. Such mismatch can be resolved once contractors perceive the new innovative demands as potentials to further grow their business. A good example from the case, when Omsorgsbygg wanted to introduce a grid-connected 50 tons excavator (through a cable connecting it to the grid). Contractors believe it

will complicate logistics and restrict machinery' movement, while Omsorgsbygg perceives it as a potential to cute extra emissions from intra-logistics work. Moreover, when both parties were asked about the time horizon needed to achieve zero-emission construction sites, the contractor was more conservative than Omsorgsbygg.

This means more interactions among the parties are needed to tackle the issue of divergent mindset and try to align them closer. In the first market dialogue, Omsorgsbygg mentioned that machinery suppliers were invited to avoid inaccurate feedback from contractors, which unfolded that bio-fuel solutions are already available in the market.

R.Q.3: What is the realized potential of current public procurement toolbox and particularly interaction with suppliers, to achieve low or zero-emission construction sites?

In the first research question, it was concluded that public procurement theoretically has good potential to reduce emissions at construction sites. However, this question examines the potential based on the case study in hand to see if that result holds, besides this time the answer will distinguish more between low and zero-emission construction sites by using the classification, proposed earlier in Table 16. It serves to categorize projects precisely in order to better understand construction emission ambition, in which for example Lia and Tåsenhjemmet ranked as C1 fossil-free and C2 low emission respectively. We will start our answer by reviewing relevant findings from analysis and discussion parts to highlight the contribution of different public procurement tools. Then we will summarize the realized potential of the toolbox.

Since the pre-bidding stage, interactions played a dynamic role to improve the procurement potential in reducing emissions. Public buyers were able to learn about the supply market and signal their plans. Feedback from several dialogues made Omsorgsbygg more confident to develop explicit low-emission demands and challenge suppliers to propose innovative solutions in their bids. Moreover, dialogues trigger inter-organizational cooperation between suppliers and contractors, especially when both are involved in similar projects or tendering for the same public buyers systematically. The collaboration is not limited between suppliers and contractors, but also it extends to the public players themselves. Several public buyers for example teamed-up together, in cooperation with the National Programme for Supplier Development, to develop solutions under Pilot E scheme.

However, despite the above, we claim that market dialogues do not necessarily have interactive nature, as an interface to become interactive, either new solutions need to be

developed or at least serious efforts to explore new solutions must be done. ‘Ad hoc interactions’ used during one of the classic procedures in the case study left positive impacts on both the buyer and suppliers. However, using these ad hoc in the classics must respect the legal framework of public procurement, including the four principles. Having ad hoc interactions will position the interface closer to translation or at least specified because suppliers can propose alternatives or solutions based on their current resources. Usually open and restricted procedures have minimal innovation potential, but with the ad hoc interactions, the innovation can be improved.

It’s still difficult to establish long-term relationship within the procurement time span. Nevertheless, the toolbox offers low and high-degree interactions both before and after the contract notice. Low-degree interaction can be in the form of early dialogues or ad hoc, while high-degree can be through the procedure itself such as competitive dialogue or innovative partnership. But as mentioned by Torvatn and de Boer (2017), these low and high-degree interactions take place in relatively short time span. This suggests that developing new zero-emission solutions in the course of public procurement can be challenging. In the following, we will quickly walk throughout the various procedures offered by the EU directives with respect to their potential in achieving low or zero-emission construction sites.

In addition, it was noticed from the case that using explicit criteria with integrate strategy led to better results than using implicit criteria with incorporate strategy. However, following incorporate strategies in Lia was necessary because the project introduced new requirements to the market at that time.

As shown in Table 22, the classics are incapable to achieve zero-emission level in building projects. They are suitable to utilize market available solutions rather than develop new ones. Additionally, they do not allow for enough dialogue among buyers and suppliers during the tendering process even if ad hoc interactions are added. Another important result from the case is both classics are capable to deliver the same results with respect to reducing emissions, but restricted procedure may avoid wasting resources.

Both competitive dialogue and innovative partnership have built-in rooms for interactions, see Table 21. We believe that competitive dialogue has a potential to achieve zero-emission construction sites, but it cannot be recommended unless technical zero-emission solutions were available. On the other hand, innovation partnership is the closest approach to achieve zero-emission scenario, mainly because development is embedded in its genetic structure.

Although zero-emission seems possible with innovative partnership, this scenario remains unrealistic. As mentioned in the discussion before, there are so many different machines in one constriction site, so if a project wants to achieve zero-emission, one innovative partnership will not probably be enough to develop the entire set of machines.

Table 22 Recommended EU procedures to reduce emissions

Emission ambition	Potential procedures	Recommended procedures
Low-emission targets	Open, restricted, competitive dialogue, innovative partnership	Open or restricted
Zero-emission targets	Competitive dialogue, innovative partnership	Innovative partnership

In the context of public building, and specifically reducing emissions at construction sites, one could say that limited buyer-supplier relationships is as a barrier to develop the required solutions. This justifies why several organizations public and private, including Omsorgsbygg, agreed to initiate development projects with specialized suppliers. This scenario and others like PCP are not part of EU directives, but they do contribute to serve the public procurement later by making the required low-carbon solutions available.

All in all, the public procurement toolbox and EU directives offered great potential to reduce emissions at construction sites through its various procedures. Moreover, the procurement process has a lot to offer if used wisely by the buyer. At the end of the day, public procurement is just a tool, and it's up to the procurers to steer it effectively towards their goals. However, with respect to the context of low and zero-emission construction sites, we claim that public procurement effective role starts after the required low-carbon solutions, and particularly high-technical ones, become available in the market. Hence, the toolbox of the EU public procurement, including interaction with suppliers, is found effective to achieve low-emission construction sites, but its role is limited in terms of achieving zero-emission construction sites.

7.2 Implications

Implications for Omsorgsbygg

Despite Omsorgsbygg is seen as an ambitious, innovation-driven organization in the eyes of themselves, their main contractor and the National Programme for Supplier Development, there are a few rooms for improvement. Therefore, we have several implications that we believe could enhance Omsorgsbygg's environmental performance in the context of reducing emissions. First, we would like to suggest using competitive dialogue procedure in one of

their upcoming projects, and preferably a project that have similar size and ambitions like Tåsenhjemmet. Omsorgsbygg's project managers pointed out several times during the interviews that there are few technical obstacles associated with adopting new methods or solutions such as intra-logistics. As mentioned earlier in section 6.2 under competitive dialogue, we believe this procedure is ideal to tackle such technical and site-related complications because it offers intensive rounds of dialogue and discussions during the bidding stage, that can allow enough time and interaction for proper planning, including full considerations of intra-logistics and transport.

Second, since public procurement do not allow public buyers to establish long-term relationships with suppliers, teaming up with third parties like the National Programme for Supplier Development sounds like a great idea. However, although Omsorgsbygg already has them on their side, we believe the relationship is not well-managed. Omsorgsbygg needs to invest more time and staff in those relationships in order to maximize their benefits and take the full advantage, especially when those third parties have extended, trustworthy relations with suppliers.

Lastly, Omsorgsbygg has good organizational features in place such as knowledge sharing culture. This mainly because Omsorgsbygg as public builder deals continuously with the same users, concerns and buildings types. However, Omsorgsbygg is strongly encouraged to embrace and exploit this culture even further. One way to exploit it is to standardize this process, and then incorporate it within their systems and goals. Another way to do this is to encourage project managers to document both obstacles and outcomes for each project phase separately, and then convert them into lesson learned categorized by phase. Afterwards, the resulted lesson learned can be circulated internally with other project managers, and even other public builders.

Implications for public builders

Our first implication for public builders comes from the case study, Omsorgsbygg showed high degree of communication and coordination within its organizational structure. It was fascinated how employees from different departments share the same vision. We felt like their environmental strategy is present in the heart of all employees. Therefore, we strongly recommend public buyers to follow the footsteps of Omsorgsbygg and endorse the culture of knowledge share, especially among ambitious projects. This sharing reflects positively on the

procurement process of projects. Buyers can for example insert common demands among their projects portfolio in order to share results of future interactions like market dialogues.

Another implication for public builders is that they should be aware of the amount of planning and preparation needed when introducing new technology such as electric equipment. The construction industry comprised of many on-shelf, old technologies that need to be maintained while introducing new technologies. As replacing old technologies with new ones straight away will not necessarily bring value even if those new ones are available, it will rather take time until new technologies adapt and add values. For that reason, new, innovative products should be introduced on steps to allow the current construction setup enough time to absorb new changes and adapt accordingly. For example, some new technologies might not be fully compatible with some building methodology. Proper amount of planning with related suppliers during the early phases of the project or procurement process can help to downsize the impacts. It's also part of risk management process since old processes will be altered and new processes will be introduced.

Implications for contractors

In light of today's technology, firms and particularly construction firms, need to start thinking about their future plans in order to prepare for the next era of construction projects. Omsorgsbygg mentioned that there was a shift in the contractors' mindset at the beginning of introducing emission-reduction goals.

Our first implication for contracting firms is related to their organizational goals. Contractors need to align their objectives with public procurers' expectations. It's not enough these days to mention bold environmental goals but instead more broken-down environmental goals are required. For example, contractors are encouraged to cover environmental issues in construction sites such as reducing waste, water management and reducing emissions.

Second implication builds upon the IMP approach, which views relationships as invaluable for organizations (Snehota and Hakansson, 1995). Relationships in the construction industry cannot be described as cooperative because of the competitive nature of construction contracts. New relationships have the potential to boost the innovation and amplify environmental performance. In the case study, Omsorgsbygg pointed out how market dialogue gave the chance for different layers of suppliers (i.e. contractors and equipment suppliers) to communicate and talk about the available equipment in the market. It's expected that relationships, between first and second tiers of suppliers, to become more and more

important while introducing challenging, innovation-driven demands in public projects. Hence, contractors are urged to advance their relationships within their supply base; including main and secondary suppliers.

Such well-developed supply base will not only help contractors to adapt faster to new demands, but it will also increase their chances in winning more public project contracts. Managers involved in both public procurement and the construction industry, should invest more in building partnerships with other players. According to a study by Sedita and Apa (2015), *"investing in direct ties with multiple partners leads to greater access to information and increased success in public procurement projects practices".* For instance, when the main contractors keep using the same subcontractors or suppliers from one project to the next, this develops strong and repeated collaborative ties.

Implications for policy makers

Our implication here for policy makers is mainly to support third parties that play similar role as the National programme for Supplier Development. As mentioned in the case, this programme has strong relationships with both the public and private sectors, and therefore, such position allows the programme to coordinate interactions (i.e. dialogues) and bridge the gap between these two sectors. Policy makers are strongly encouraged to facilitate the role of such third parties as it can bring a lot of value to the public procurement process, especially when there are newly introduced innovative demands. Third parties can also play a vital role in knowledge transfer, for example they can transfer knowledge from private to public or even within the public sector itself.

8 Future research

This study unveiled a number of departure points for further research in the field of public procurement. The first departure point for further work would be to improve and expand this study by addressing the identified limitations of this study. Thus, a future research can build upon this study and expand it by employing a multiple-case design, including cases from other European countries besides Norway. For example, a project procured through competitive dialogue in order to achieve near zero or zero-emission construction sites would be very useful to understand the real potential of this procedure. This expansion allows researchers to collect a wide-range of data, where multiple-cases can lead to more analytical benefits and direct replication. More analytical benefits could be realized when the empirical study involves more key parties from the supply chain such as machinery suppliers, while direct replication allows for proper generalization. Furthermore, having international cases on-board enriches research with insights about innovative procurement practices in the context of reducing emissions in construction projects.

Second, inspired by the role of the National Programme for Supplier Development, we encourage researchers to study the ability of collaborative public procurement to stimulate innovation and sustainable practices. The case showed how the National Programme for Supplier Development gathered several public buyers in order to initiate several development projects outside the public procurement framework. Usually collaborative purchasing is used to achieve goals such as economies of scale, efficiency, specific expertise, or standardization. However, taking into account the accumulated purchasing power and common interest of public buyers, we believe the collaborative procurement has a lot of potential to develop and promote new innovative solutions. Therefore, a future research could focus on how the collaborative procurement functions in this context, besides to what extent such thing fits within the current framework of public procurement.

Third, although market dialogue is one of the critical steps in the public procurement, not much is written about dialogue's process itself and its critical success factors. The process of organizing the dialogues preceding a procurement is still very complex because many parties are involved, and new demands are introduced. Therefore, a new research focusing on the early interaction phase (pre-bidding phase) is highly recommended. For example, the study can focus on addressing the real drivers and barriers of innovation during this phase.

Finally, Omsorgsbygg is a public builder, however, they become involved in technology development projects that aim to improve the environmental performance of their projects. Those development projects opened new interaction channels for them. Omsorgsbygg is also constantly trying to improve their procurements' outcomes through adopting inspiring, innovation-driven methods. Moreover, Omsorgsbygg showed during the case study distinct organizational features such as advance culture of internal communication. Consequently, we believe a study focuses on Omsorgsbygg's organizational and projectized features would be fruitful by exploring how the internal features of public building organizations could affect the procurement performance.

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10 Appendices

10.1 Appendix 1: Literature list

No.	Author	Year	Title	Journal	Intended use
General					
1	De Wit, Bob Meyer, Ron	2014	Strategy: An international perspective	Book. Publisher: Cengage Learning	The shareholder perspective
2	Pinto, Jeffrey K.	2013	Project management: achieving competitive advantage	Book. Publisher: Pearson	The stages of project life cycle
3	Schumpeter, Joseph A	1934	The theory of economic development. Cambridge	MA: Harvard	Definition of innovation
4	PMI, Project Management Institute	2013	A Guide to the project management body of knowledge: (PMBOK guide)	Book. Publisher: Project Management Institute	Definition of control procurement, changes in project's cost and risk
Innovation in Construction					
5	Blayse, Aletha M/Manley, Karen	2004	Key influences on construction innovation	Construction innovation	Key influences on construction innovation
6	Bygballe, Lena E./Ingemansson, Malena	2014	The logic of innovation in construction	Industrial Marketing Management	Innovation in the construction
7	Dubois, Anna /Gadde, Lars-Erik	2002	The construction industry as a loosely coupled system: implications for productivity and innovation	Construction Management & Economics	Innovation in the construction
8	Havenvid, Malena Ingemansson	2015	Competition versus interaction as a way to promote innovation in the construction industry	IMP Journal	Characteristics of projects
9	Slaughter, E Sarah	1998	Models of construction innovation	Journal of Construction Engineering and management	Differences between innovation and invention
Sustainable Construction					
10	Changbum R. Ahn/SangHyun Lee	2013	Importance of Operational Efficiency to Achieve Energy Efficiency and Exhaust Emission Reduction of Construction Operations	Journal of Construction Engineering and Management	Emissions from construction projects
11	Anthonissen, Joke/Van Troyen, Dirk/Braet, Johan	2015	Using carbon dioxide emissions as a criterion to award road construction projects: a pilot case in Flanders	Journal of Cleaner Production	Emissions in award criteria
12	Brundtland, Gro Harlem	1987	Report of the World Commission on environment and development:" our common future."	Publisher: United Nations	Sustainable development
13	Chang, Yuan/Ries, Robert J./Wang, Yaowu	2011	The quantification of the embodied impacts of construction projects on energy, environment, and society based on I–O LCA	Energy Policy	Emissions from construction projects
14	Freeman, R Edward/Reed, David L	1983	Stockholders and stakeholders: A new perspective on corporate governance	California management review	Definitions of stakeholders
15	Gransberg, Douglas D Popescu, Calin M Ryan, Richard	2006	Construction equipment management for engineers, estimators, and owners	Book. Publisher: CRC Press	Construction machinery
16	Griggs, David Stafford-Smith, Mark Gaffney, Owen Rockström, Johan/Öhman, Marcus C Shyamsundar, Priya/Steffen, Will Glaser, Gisbert Kanie, Norichika Noble, Ian	2013	Policy: Sustainable development goals for people and planet	Journal of Nature	Sustainable development goals
17	Hill, Richard C Bowen, Paul A	1997	Sustainable construction: principles and a framework for attainment	Construction Management & Economics	Sustainable construction
18	Hong, Jingke Shen, Geoffrey Qiping Feng, Yong Lau, William Sin-Tong	2015	Greenhouse gas emissions during the construction phase of a building: a case study in China	Journal of Cleaner Production	Direct and indirect emissions during the construction phase of a building project

	Mao, Chao				
19	Kim, Byungil Lee, Hyounkyu Park, Hyungbae Kim, Hyoungkwan	2011	Greenhouse gas emissions from onsite equipment usage in road construction	Journal of Construction Engineering and Management	Emissions from construction machinery
20	Labuschagne, Carin Brent, Alan C. Claasen, Schalk J.	2005	Environmental and social impact considerations for sustainable project life cycle management in the process industry	Corporate Social Responsibility and Environmental Management	Sustainability definition
21	Martland, Carl D.	2011	Toward more sustainable infrastructure: project evaluation for planners and engineers	Book. Publisher: Wiley	Sustainability in construction
22	Peña–Mora, F Ahn, C Golparvar-Fard, M Hajibabai, L Shiftehfar, S An, S Aziz, Z Song, SH	2009	A framework for managing emissions during construction	National Science Foundation Cairo, Egypt	Emissions from construction projects
23	Ren, Z Chrysostomou, V Price, T	2012	The measurement of carbon performance of construction activities: a case study of a hotel construction project in South Wales	Smart and Sustainable Built Environment	Sources of CO2 emissions during the construction of a hotel project
24	Tam, Vivian WY Le, Khoa N Wang, Jiayuan Wang, Xiangyu	2016	Development of a sustainable checklist in construction	Proceedings of the Institution of Civil Engineers - Waste and Resource Management	Sustainable checklist for construction projects
25	Tam, Vivian W. Y. Le, Khoa N.	2014	Driving criteria for environmental performance assessment in construction	Proceedings of Institution of Civil Engineers: Waste and Resource Management	Environmental impacts of consruction
26	Varnäs, Annika Balfors, Berit Faith-Ell, Charlotta	2009	Environmental consideration in procurement of construction contracts: current practice, problems and opportunities in green procurement in the Swedish construction industry	Journal of Cleaner Production	Environmental criteria weighting
27	Waris, M Liew, Mohd Shahir Khamidi, Mohd Faris Idrus, Arazi	2014	Criteria for the selection of sustainable onsite construction equipment	International Journal of Sustainable Built Environment	Selection of construction equipment
28	Yan, Hui Shen, Qiping Fan, Linda CH Wang, Yaowu Zhang, Lei	2010	Greenhouse gas emissions in building construction: A case study of One Peking in Hong Kong	Building and Environment	Sources of greenhouse gases in construction projects
29	ISO,	2006	ISO 14064	International Organization for Standardization, Geneva, Switzerland	Definition of direct and indirect emissions
30	ISO,	2017	ISO 14001:2015(en) Environmental management systems	International Organization for Standardization, Geneva, Switzerland	Environmental management systems
Public procurement					
31	Telgen, Jan/Harland, Christine/Knight, Louise	2012	Public procurement in perspective	In Book: Public procurement: international cases and commentary. Publisher: Routledge	Demands on public procurement
32	Richard Baron	2016	The Role of Public Procurement in Low-carbon Innovation	OECD	Green public procurement
33	Bouwer, M Jonk, M Berman, T Bersani, R Lusser, H Nappa, V Nissinen, A Parikka, K Szuppinger, P Viganò, C	2006	Green Public Procurement in Europe 2006–Conclusions and recommendations,		Green public procurement
34	Christopher, Martin	2011	Logistics & supply chain management	Book. Publisher: Financial Times Prentice Hall	Sustainability definition for businesses
35	Igarashi, Mieko/de Boer, Luitzen/Fet, Annik Magerholm	2013	What is required for greener supplier selection? A literature review and conceptual model development	Journal of Purchasing and Supply Management	Conceptual model of GSS

36	Igarashi, Mieko/de Boer, Luitzen/Michelsen, Ottar	2015	Investigating the anatomy of supplier selection in green public procurement	Journal of Cleaner Production	GSS strategies
37	Palmujoki, Antti/Parikka-Alhola, Katriina Ekroos, Ari	2010	Green public procurement: analysis on the use of environmental criteria in contracts	Review of European, Comparative & International Environmental Law	Green public procurement and Environmental criteria
38	Parikka-Alhola, Katriina	2008	Promoting environmentally sound furniture by green public procurement	Ecological Economics	Green public procurement and Environmental criteria
39	Testa, Francesco/Annunziata, Eleonora Iraldo, Fabio/Frey, Marco	2016	Drawbacks and opportunities of green public procurement: an effective tool for sustainable production	Journal of Cleaner Production	Benefits and obstacles of green public procurement
40	Testa, Francesco/Iraldo, Fabio/Frey, Marco	2011	The effect of environmental regulation on firms' competitive performance: The case of the building & construction sector in some EU regions	Journal of environmental management	Green public procurement
41	Testa, Francesco/Iraldo, Fabio/Frey, Marco/Daddi, Tiberio	2012	What factors influence the uptake of GPP (green public procurement) practices? New evidence from an Italian survey	Ecological Economics	Obstacles of green public procurement
42	Torvatn, Tim/de Boer, Luitzen	2017	Public procurement reform in the EU: start of a new era?	IMP Journal	Positioning the different EU public procurement procedures against Araujo et al. (1999)
43	Uttam, Kedar/Roos, Caroline Le Lann	2015	Competitive dialogue procedure for sustainable public procurement	Journal of Cleaner Production	competitive dialogue procedure
44	Weele, Arjan J. van	2014	Purchasing & supply chain management: analysis, strategy, planning and practice	Book. Publisher: Cengage Learning	Purchasing process and definition
45	Araujo, Luis/Dubois, Anna/Gadde, Lars-Erik	1999	Managing interfaces with suppliers	Industrial marketing management	Interfaces between buyers and suppliers
46	Gadde, Lars-Erik/Snehota, Ivan	2000	Making the most of supplier relationships	Industrial marketing management	Model of economic consequences of supplier relationships
47	Snehota, Ivan/Hakansson, Hakan	1995	Developing relationships in business networks	Book. Publisher: Routledge London	IMP approach view on relationships
48	Uyarra, Elvira/Edler, Jakob/Garcia-Estevez, Javier Georghiou, Luke/Yeow, Jillian	2014	Barriers to innovation through public procurement: A supplier perspective	Journal of Technovation	Barriers hinder supplier innovation: what prevents suppliers from proposing innovative solutions.
49	European Union,	2016	Buying Green - a handbook on green public procurement	Publications Office of the European Union	Green public procurement
50	Europen Union,	2014	Directive 2014/24/EU of the Europen Parliament and of the Council of 26 February 2014 on public procurement and repealing Directive 2004/18/EC	Official Journal of The European Union	Public procurement procedures and rules
51	OECD	2013	Mapping out good practices for promoting green public procurement OECD meeting of Leading Practitioners on Public Procurement	OECD	Green public procurement benefits
52	PricewaterhouseCoopers, Significant and Ecofys	2009	Collection of statistical information on Green Public Procurement in the EU: Procurement in the EU Report on data collection results		Green public procurement benefits
Methodology					
53	Bryman, Alan	2012	Social research methods	Book. Publisher: Oxford university press	Research design
54	Bryman, Alan/Bell, Emma	2011	Ethics in business research	Business Research Methods	keyword search and journal search
55	Dubois, Anna/Gadde, Lars-Erik	2002	Systematic combining: an abductive approach to case research	Journal of business research	Systematic combining definition and benefits
56	Wilson, Jonathan	2014	Essentials of business research: A guide to doing your research project	Book. Publisher: Sage	Research design
57	Yin, Robert K.	2014	Case study research: design and methods	Book. Publisher: SAGE Publications, Inc	Case study design

10.2 Appendix 2: Interview guides

Interview Guide-01

Ask permission to record the interview

Introduction: short description and goals of the research study.

Background information

Name; Position; Assigned project; Name of employer/company

Discussion (with focus on questions relevant to the case study)

Sources of emissions

1. What are the main sources of GHG emissions, resulting from the process of project execution?
2. How each of those emission sources can be eliminated or reduced?
3. What you have done to identify those emission resources? Any kind of collaboration? (if yes) please elaborate more about this collaboration?
4. Have suppliers contributed in any way to identify any of these emission resources or related emission-reduction solutions? (if yes, please elaborate when and how)
5. Please describe how drying and heating operations produce emissions during construction?
6. Could you please describe the role of the design phase to reduce emissions at construction sites?
7. Do you think achieving free-emission construction sites is something will occur anytime soon?

Procurement process

8. How many projects does Omsorgsbygg award so far with a purpose to reduce emissions at construction sites?
9. What type of public procurement procedures have been used to award projects intended to reduce emissions at construction sites?
10. Which is the most ambitious project among them in terms of mentioning emission-reduction requirements?
11. Could you please elaborate on the status of Tåsenhjemmet and Lia projects?
12. Please describe the process of procurement for Tåsenhjemmet project?
13. What is the role of the document named ‘’contract strategy’’ in the procurement process? Does it help to address the issue of emissions?
14. How the requirements of plus-house and BREEAM help to emphasize emission-reduction during construction? (if yes, please elaborate your answer)
15. Which part of the procurement process do you find it best suitable to address such requirements?
16. How do you measure the emissions at site? Does Omsorgsbygg notice any improvements? (if yes, is this related to the requirements in procurement process)

17. How do you supervise the suppliers/contractors' commitment during the process of execution to reduce emissions?
18. Does Omsorgsbygg as a client and owner receive any kind of reporting regarding emission levels during construction operation from their contractors?
19. What are the barriers (if any) that hinder preparation of a more effective procurement actions? (if yes, please elaborate)
20. To what extent the procurement methods are helping to reduce emissions at construction sites?
21. Are there any pre-procurement documents or factors that help to facilitate incorporating emission requirements into the procurement process?
22. Do you think something could have been done in different way during procurement preparations?
23. As dialogue conference / Tåsenhjemmet workshop with market was done during pre-procurement phase, what were the main concerns of suppliers during those meetings?

Interaction

What types of collaborations/interactions/partnership were done prior to the procurement process to facilitate the purpose of emission reduction?

24. How the interface among you and main contractor is handled in terms of emission-reduction requirements? (Tåsenhjemmet project)
25. Does the main contractor in Tåsenhjemmet have other subcontractors and suppliers? (if yes, could you please elaborate more on the collaboration among them to facilitate reducing emission during construction)
26. Does introducing new requirements impact the contractor performance in any way? (if yes, could you please explain those impacts)
27. Describe the pre-project phase? How the pre-project phase in Tåsenhjemmet project contribute towards reducing emissions?
28. How the new requirements will impact general project management goals (quality, time and cost)?

Thank the interviewee and end recording

Interview Guide-02 (For the contractor)

Ask permission to record the interview

Introduction: short description and goals of the research study.

Background information

Name; Position; Assigned project; Name of employer/company

Discussion (with focus on questions relevant to the case study)

1. Has the main contractor done any studies during tendering process to identify emissions during construction execution?
2. Has the main contractor made any sort of collaborations with other organizations to help identifies sources of emissions and potential reduction opportunities?
3. How does the contractor plan to reduce emissions at construction sites?
4. How does the main contractor feel about Tåsenhjemmet tendering process? Was it intensive or demanding?
5. Has the main contractor executed building projects with similar requirements (emission reduction) in the past?
6. Do you consider executing similar projects in the future? Is this a new market for the company?
7. How the main contractor's organization plans to expand their knowledge in this field?
8. Does the main contractor think such new requirements will stimulate the innovation in the construction industry?
9. What types of procurement procedures the contractor is familiar with, based on previous experience?
10. Does the contractor consider Tåsenhjemmet a challenging project?
11. Could you please elaborate on the status of Tåsenhjemmet project status?
12. Does other building requirement such as house plus and BREEAM help to emphasize emission-reduction during construction? (if yes, please elaborate how)
13. Which part of the procurement process do you find it the best to address such requirements? (specification, qualification, award criteria, contract clause)
14. How the contractor approaches the award criteria regarding reducing emissions?
15. Do you intend to measure the emissions at site? Is it your responsibility? (if yes, is this related to the requirements in procurement process)
16. How do you plan to supervise the suppliers/sub-contractor's commitment during the process of execution to reduce emissions?
17. Do you intend to provide any kind of reporting regarding emission levels during construction operation from their contractors? How?

18. What are the expected barriers (if any) that you feel will hinder effective emission-reduction during construction? (if yes, please elaborate)
19. Was the information provided during the procurement process clear enough for the main contractor to prepare a good proposal?
20. Why do think you won this project?
21. Do you think something could have been done in different way during procurement preparations or in the procurement process?
22. As dialogue with market was done during pre-procurement phase, what were the main concerns during those meetings? Have you received answers from Omsorgsbygg?
23. What types of collaborations is being done to facilitate the purpose of emission reduction?
24. How the interface among you and Omsorgsbygg is handled in terms of emission-reduction requirements? (Tåsenhjemmet project)
25. Does the main contractor team, involved in the pre-project phase, employ specialists to study reducing emissions during construction?
26. Does the main contractor in Tåsenhjemmet have other subcontractors and suppliers? (if yes, could please elaborate more on the collaboration among them to facilitate reducing emission during construction)
27. Does the main contract have any concerns, that could impact the performance during execution phase because of introducing new requirements? (if yes, could you please explain those future impacts)
28. How does the pre-project phase in Tåsenhjemmet project contribute towards reducing emissions? (if yes, could you please explain)
29. Do you think having more projects with similar requirements will impact the construction industry?

Thank the interviewee and end recording