Accelerating the Transition to Emission-Free Construction Machines Through Public Procurement

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Abstract

Reducing greenhouse gas emissions is of an ever-increasing importance. This requires an energy transition from fossil fuels to emission-free alternatives in a wide range of industries and vehicles. One of these is construction machines. The objective of this thesis was to investigate the potential to accelerate the transition to emission-free construction machines through public procurement. The basis for the thesis is a pilot project in Olav Vs gate in Oslo, Norway, where electrical construction machines were tested out. By being a major customer to the construction industry, the public entities could potentially force change by setting requirements and criteria in public tenders. However, based on a selection of interviews with key stakeholders conducted in this thesis, there are several obstacles standing in the way this transition. The obstacles – ranging from policy, via economics, to communication – is discussed in this thesis. In a wider context, these findings are discussed based on analytical frameworks related to transition theory. In conclusion, there is need for collaboration between actors in the private and public sector to secure an efficient transition to emission-free construction machines.

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Introduction

To cope with the current climate crisis, several countries have agreed to reduce their greenhouse gas emissions (United Nations, 2015). This entails a wide energy transition, whereby conventional energy sources that emit large amounts of greenhouse gases – need to be phased out. The public sector has the potential to play a significant role in this transition. Questions of how we accomplish this is, however, contested. Taxation of greenhouse gas emissions has been one of the main approaches this far (Klima- og miljødepartementet, 2021; Miljødirektoratet, 2020a). Alongside taxation, subsidies for green technology and practices has also been of significance (Enova SF, 2021a; Innovasjon Norge, 2020; Siva, 2021). However, research is lacking focus on the role of public procurement as a governmental tool in the sustainable green transition. By neglecting this, governments lose a potential useful tool to reach their climate obligations. To bring forth this tool, my thesis, *Accelerating the Transition to Emission-Free Construction Machines Through Public Procurement*, investigates how public procurement can play a vital role in a government-driven green transition.

Through a case study of the construction site in Olav Vs gate in Oslo, which started in 2019 – a project initiated by Oslo Kommune, I research how public procurers play an essential role in triggering innovation for the green transition to emission-free construction machines. The research is conducted through analysis of interviews with actors involved in the construction industry's energy transition, with an eye on the project in Olav Vs gate. Ultimately, I argue that procurement is an important tool for governments to trigger and accelerate change in a wide range of industries.

The problem statement of the thesis is as followed: How can public procurement accelerate the transition to emission-free construction machines in Norway – a case study of the construction site in Olav Vs gate in Oslo. To investigate this problem statement, I have constructed two research questions. The first one is linked to the findings made throughout this research and appears in the Findings chapter. The second one encompasses the wider context in which this transition can be discussed. These questions provide a sound base for analyzing the complexity of this energy transition.

- *Which dynamics shape the transition to emission-free construction machines in Norway?*
- *How can criteria in public tenders play a part in overcoming obstacles of the energy transition and innovation?*

In this thesis, I investigate how requirements and criteria in public tenders can reduce the climate footprint in Norway. More specifically, I will research the construction industry and how its green transition can be influenced by public procurers. The scope of the thesis is limited to how to reduce the direct emissions on construction sites by transitioning from conventional fossil fuel machines to emission-free machines. By procuring green and sustainable, public procurers on local, regional, and national level can trigger innovation to successfully change the construction industry.

The transition to implementing emission-free construction machines offers some challenges. Firstly, there are several technological challenges related to this. Such challenges can be the maturity of battery technology, hydrogen as an energy carrier, electrical grid infrastructure or hydrogen infrastructure. Related to this, there is also economic obstacles hindering the transition. Secondly, market availability of emission-free construction machines is limited, which makes the cost intolerable for private actors. Thus, the public sector could potentially be the deciding factor in this transition by nurturing innovative technology, both technologically and economically.

The energy transition to emission-free construction machines requires development in battery and hydrogen technology, and is currently in a pilot-phase (Wiik et al., 2020, 2018). A report by Energi Norge et al. (2018) presents a wide perspective on challenges and opportunities related to transitioning to fossil- and emission-free construction, including material use and energy consumption – from both machines and heating during the construction period. Enova is currently increasing their focus on reducing emissions from the construction industry by providing financial support to suppliers willing to test out innovative solutions (Enova SF, 2021b). This is one of several initiatives by the Norwegian government in reducing greenhouse gas emissions. Procurers in the public sector is obligated by law to take environmental considerations into account in every procurement they make (Lovdata, 2016b). This is also being focused on in a number of different public documents (Commision of the European Commmunities, 2008; European Commission, 2020; European Commission & ICLEI – Local Governments for Sustainability., 2016; Klima- og miljødepartementet, 2021; Samferdselsdepartementet, 2021).

The period for this project was set between January 2021 and June 2021. In January, deciding on direction and approach dominated the agenda. Figuring out questions of which angle I was

going to research the topic, and how to gather information. Writing background information was the main objective of February. March and April were the period of interviews and detailed information gathering. Conducting interviews, transcribing them, and connecting them to the thesis was the main time consumer. In the latter part of April, and the first half of May, most of the time went writing, presenting, and discussing the findings from the interviews and other data sources. From the mid of May re-writing the thesis were the main time consumer. In addition, I spent time on sorting out formalities related to formatting, referencing and other general work on the esthetic presentation of the thesis.

The purpose of this thesis to contribute to the discussion and development for the transition to emission-free construction sites and to shed light on the opportunities of public procurement. Findings may also serve a purpose beyond the construction industry. By basing the thesis mainly on the innovation and procurement aspects, other industries in similar situations may also find the results relevant and useful. Also, procurers in both public and private sector may find it useful and beneficial. I expect the thesis to support and provide a foundation for future research.

1.1 Public Procurement

Public procurement in Norway is a purchase executed by a public entity for goods and/or services for more than 100.000 NOK (Lovdata, 2016a, 2016b). The Norwegian public sector procures goods and services for 560 billion NOK on an annual basis (Klima- og miljødepartementet, 2021). Such procurements represent 14% of the total Norwegian climate footprint (Miljødirektoratet, 2020b). By law, procurers in the Norwegian public sector is obligated to take environmental considerations into account when it is relevant (Lovdata, 2016b). According to MAPS, Norway's potential for sustainable public procurement is good, but it is not being implemented enough (2020). Sustainable public procurement takes a wide range of societal and environmental aspects into account. This thesis focuses on a more specific aspect of procurement, namely Public Procurement of Innovative Solutions (PPI).

Plans and strategies for procuring greener goods and services can have a significant impact on market demand, thus triggering innovation and sustainable solutions (Miljødirektoratet, 2020a). By being a major customer for several industries, the public sector has a great influence on demand in markets and can use its purchasing power strategically.

Innovation procurement

Public Procurement of Innovative Solutions (PPI) is a governmental strategic tool to incentivize innovation through criteria and requirements in tenders. Moving away from the traditional solution-based requirements, PPI unconventionally use functional-based requirements, opening up an opportunity for non-traditional solutions (Lember, Kattel, & Kalvet, 2015; Nasjonalt program for leverandørutvikling, 2021). By implementing PPI, the public sector can create shifts in demand for products which previously has not been eligible for market application. This type of procurements has several innovation benefits (Lember et al., 2015). First, it provides an entry for unexperienced niche technologies, thus creating a knowledge base and giving feedback. Second, it serves as a research and development tool to cope with future market uncertainties. Third, it is a policy instrument to solve major societal challenges, e.g., the energy transition and emission reduction targets.

There are several ways of implementing PPI. Lember et al. divides implementation of PPI into four different strategies: *"PPI as experimental innovation policy, from fiscal policy under austerity to PPI, mission-oriented PPI and shifts in administrative culture towards PPI"* (2015, p. 403).

Sufficient knowledge of the market to define requirements for end-solutions?

YES		**NO**	
		Preliminary market consultation	
Need R&D services prior to procurement?			
YES		**NO**	
Do you wish to acquire innovative products or services on a commercial scale, as part of the same procedure?		***Can a specification of the end products / services to be procured be developed?***	
YES	**NO**	**YES**	**NO**
Innovation Partnership	**Pre-commercial procurement**	**Competitive procedure with negotiation**	**Competitive dialogue**

Levels of competition or time / resources inadequate for above procedures?
Consider joint procurement or, in exceptional cases only, derogation from the directives.

Table 1. Choosing a type of PPI, based on Semple (2015, p. 18)

Tools for innovation procurement

Before publishing a tender, public procurers may take measures to make sure they facilitate innovative solutions. First, procurers and other involved actors need to define the needs of the users for the product or service. This is to map out where and by whom the procurement will be used. Second, having a dialogue with market actors about available options is important. Third, functional requirements regarding quality and use should be specified. In this part of the procurement, it is important that the requirements are formulated based on criteria for function, not as detailed product-based criteria. This is important in the sense of not excluding out-of-the-box solutions. Fourth and last, deciding whether the tender should be competition-based or development-based. Some innovative solutions may not be sufficiently developed to compete in a regular tender and needs to be nurtured through cooperative development. In such cases, development-based or innovation-based projects may be the best option (Direktoratet for forvaltning og økonomistyring, 2021a).

If the dialogue with the market reveals that it is lacking solutions to fit with the functionality and user need, development- and innovation projects may be necessary. If this is the case, a number of procurement procedures is available: Innovation Partnership; Pre-commercial procurement; competitive procedure with negotiation; and competitive dialogue (Semple, 2015). Figuring out which one is the most relevant for the given situation, is described in Table 1. By answering the questions, working your way downwards, one ends up at the most suitable approach for each specific case. Which one of these are most suited for each procurement is dependent on factors regarding market knowledge, maturity of development, number of involved actors, the scale of implementation, and time and resources (Direktoratet for forvaltning og økonomistyring, 2021b; Semple, 2015).

1.2 Context - Research nexus

The structure and analytical approach of the thesis (see chapter 4.2) provides a foundation to put stakeholders into three categories: Policy, Market, and Innovation. In Figure 1 below, these aspects are illustrated. Each of these aspects affect each other, shown by the arrows outside the triangle. The boxes beside the main aspects are ways of affecting the other aspects. The dynamics of this interplay serves as a foundation for further discussion in Chapter 6. Each of the aspects are described in the following paragraphs.

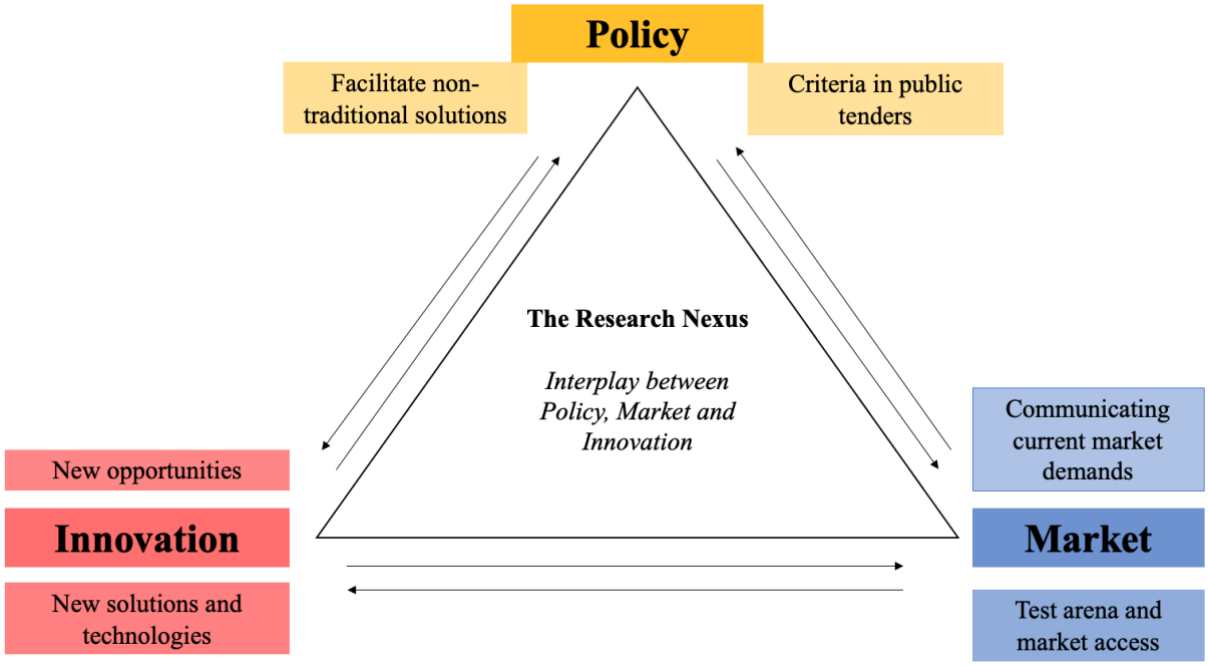

Figure 1. The Research Nexus. Illustration of the interplay between Policy, Market, and Innovation.

In the first category, Policy, is represented through policymakers and actors from the public sector. This is the actors who execute national, regional, and local legislations, and publish tenders and contracts. Thus, they represent the demand-side of this research. Also, intermediate actors between public and private sector are included here. Surrounding this, all government white papers, (inter)national plans and other regulations are dominant and shape the behavior of involved actors. Public procurement represents one of many available tools for policymakers. In this case, the act of innovative procurement and the ripple effects it has for both market and innovation are studied.

Second, the Market. This is the contractors and companies which compete to win tenders and contracts. Incumbent construction companies, machine suppliers and entrepreneurs are included in this category. As construction is a rigid industry, radical change rarely comes about. Heavy machines make the transition both economically and technologically challenging. However, due to the importance of winning public tenders (Byggenæringens Landsforening, 2016), the industry is likely to alter behavior if necessary. Intermediate actors are key to bridging the gap between the public and private sector, and to facilitate communication and realistic expectations from both sides. In addition, Market actors represent the current structure, and can communicate to actors in Policy about current market demand and status.

Third, innovation, represented by niche actors such as renewable energy companies and suppliers of emission-free machines. These actors represent radical technological innovations, which attempts to gain market access. However, due to the immaturity of the innovations, gaining market access may be practically impossible – without the help of policy – and market actors. The innovations represent new opportunities and is crucial for policy actors in achieving the desired change. The same goes for market actors which struggle to respond to change in policy.

These three categories together make up a solid foundation to analyze the perspectives and perceptions of various actors. The collaboration, interplay and influence of these categories is of great importance for a successful transition. It can also be related and used in the context of the analytical framework (Chapter 3).

1.3 Structure

In this introduction I have presented the foundation of this thesis, which is public procurement. In addition, I present the context where this transition and research is located, and the dynamics which may be decisive in the success of the transition. In the following chapter, the case of Olav Vs gate is introduced in Chapter 2. The introduction of the case consists of a brief presentation of the experiences with emission-free construction machines, and other learnings by Bymiljøetaten (2020). The case provides the foundation for discussing emission-free construction machines in Norway, as it is one out of few cases where such machines have been tested out. In addition to this, it is an example of where public procurement has been used as a tool to facilitate and gain experiences with innovative technologies. Later, during the interviews – presented in Chapter 5 Findings – this case is discussed with the informants. In the theory part of the thesis, Chapter 3, a framework for analyzing transitions, technology development and policy is presented. This analytical framework is used to analyze the project in Olav Vs gate, the informants' opinions, and the larger perspectives of energy transitions and innovation.

In Chapter 4, the methodology of the thesis is presented. In this chapter, I provide an explanation and statement of how the research has been conducted, and consideration which has been made throughout the process. In this chapter the context of the research is presented as well. The structure of the data collection and the approach in data analysis is further discussed in Chapter 4. In addition, the informants and their relevance are presented.

The Findings, Chapter 5, is a presentation of the key findings from the interviews conducted with relevant stakeholders. By using a Thematic Analysis, which is further discussed in Chapter 4, I have condensed the findings into six main themes which encompass the complexity of the transition. These are presented by taking excerpts from the interviews and comparing the different opinions and perspectives of the informants. In this chapter I aim to answer the first research question.

After this, in Chapter 6, there is a discussion which is based on a combination of findings, theory, the case study and the context of the transition. By doing so, transitions in general can be discussed. Other aspects, such as innovation and technological development are also discussed. This chapter is aimed to answer the second research question.

Ultimately, I conclude the thesis by providing concise answers to the research questions, implications for both policy and research, and the limitations of this study.

2. Case: Olav Vs gate

The emission-free construction site in Olav Vs gate in Oslo was conducted between September 2019 and December 2020 (Bymiljøetaten, 2020). As a part of Oslo Kommune's goal of having all construction sites emission-free by 2025, this project was a pilot initiated by Bymiljøetaten – a public entity in Oslo Kommune (Bymiljøetaten, 2020).

2.1 Approach and project limitations

In this project, the direct emissions from the construction site were emphasized, thus making the machines used on site the main focus. This perspective excludes emissions such as production of materials; transport of workers, mass, machines, materials, and waste; and demolition. By making the perspective on emissions narrower, the contractor was able to have more comprehensive focus on fewer tasks. With the majority of the focus on machines such as electrical excavators, wheel loaders and surface plate vibrators, the focus was mainly on reducing emissions by replacing conventional diesel-fueled machines with electrical machines (Bymiljøetaten, 2020).

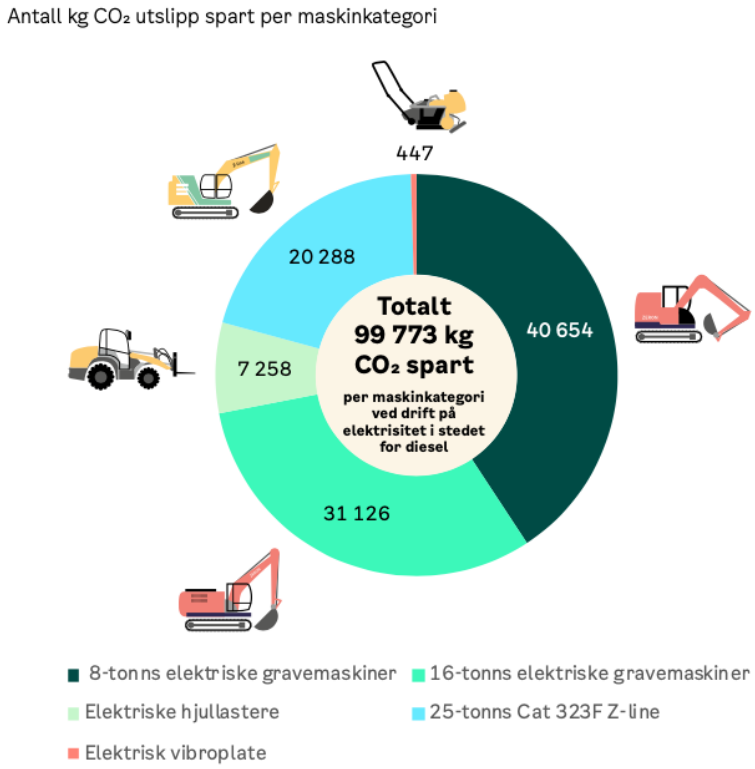

Figure 2. Emissions of CO2-eq saved in total and from each machine category in the project in Olav Vs gate (Bymiljøetaten, 2020, p. 44)

Based on Bymiljøetaten's calculations, the emissions were reduced by 99% compared to conventional machines - equaling 99 773 kg of reduced CO_2-eq-emissions. These numbers are based on the expected emissions from conventional machines for the same type of work and hours. As there were some technological challenges related to using electric machines in all phases of the project, some biodiesel was used. There was also some propane used for propane burners to secure sufficient quality. The total emissions from the construction site was 1367kg CO_2-eq. Figure 2 above illustrates how many kilograms of CO_2-eq emissions were saved for each machine category, showing that the biggest reduction of emissions was from the 8-ton excavators (Bymiljøetaten, 2020).

Figure 3. 8-ton electric excavator in Olav Vs gate, Oslo (Bymiljøetaten, 2020, p. 24)

2.2 Learnings from the project

The project in Olav Vs gate is a way of gaining experiences and knowledge in the field of electrification. Other projects with a similar research, such as the project Zero Emission Digger (ZED). In ZED, SINTEF aims to gain experience using prototypes of emission-free belt excavators. The excavators are 17,5 tons and runs on hybrid and battery-electrical solutions. With limited knowledge on development of electrical machines, from both incumbent

construction companies and energy companies, electrification represents a large challenge for the construction industry. Experiences with construction companies and machine suppliers show that there is uncertainty regarding the development of the coming years. These challenges are of both technical and economic characters (Wiik et al., 2020), which will be further discussed in the Findings chapter.. In Olav Vs gate, a similar machine was tested: the 16-ton battery-electric excavator "Peakshaver+". This machine is connected to a cable in the back and has a battery to cope with peaks in power outtake. During the project, the cable was moved from the back of the house, to the undercarriage for practical reasons (Bymiljøetaten, 2020).

Figure 4. 16-ton "Peakshaver+" in Olav Vs gate (Bymiljøetaten, 2020, p. 27)

2.3 Life-Cycle Costing: Conventional vs Electrical excavator

Based on three examples, where one of them is the construction site in Olav Vs gate, Wiik et al. (2020) has calculated the Life Cycle Cost (LCC) of a conventional 17,5 ton diesel excavator and a 17,5 ton electrical excavator. The analysis consists of investment cost (i.e., cost of procuring the machines), operational cost, maintenance cost, residual value, and other cost. The expected lifetime of a conventional machine is 8 years, while the electrical equivalent is expected to have a lifetime of 10 years. The results show that after an accumulated time frame of 10 years, the cost of the two machines both end up at around 6,5 million NOK. Although the electrical machine has a significantly higher investment cost (i.e., up-front cost) than the

conventional machine, it also has lower cost related to maintenance, operation etc.. However, the market availability of electrical excavators is limited as it is still in a prototype-phase (Wiik et al., 2020), which is where public procurement may play a role in accelerating the maturity of the market.

3. Analytical Approach

The project in Olav Vs gate is a part of a larger context related to the transition to emission-free construction sites. In order to analyze the case itself, and the larger context, I used to Multi-Level Perspective (MLP) in combination with Transition Pathways (Geels, 2002, 2011; Geels et al., 2016; Geels & Schot, 2007, 2011). While the MLP provides a perspective on the large context of transitions, the Transition Pathways looks more specifically into the emergence of innovative technology. In addition, the perspective of Transition Management is presented and discussed. In total, these theories encompass the large context of transitions, more specific perspectives of the emergence of new technologies, and the act of deliberately adjusting behavior to reach set goals. Thus, these theories provided sufficient analytical framework to perceive the case in question from technological, political, and economic perspectives. This will be further presented and discussed in the following sub-chapters.

3.1 Transition theory

Transitioning from fossil fuels to emission free alternatives requires changes in several aspects of society. To analyze this complexity, I apply the Multi-Level Perspective (MLP). This is a middle range theory which provide an analytical framework for socio-technological transitions (Geels, 2002). Based on level of structuration, the theory has divided society into three main categories: Socio-technical landscape, Socio-technical regime, and Technological niches. The socio-technical landscape (from now on described as “landscape”) is the most stable level in the MLP. The landscape is the framework of large trends and patterns of society that is out of reach for regime actors. In the middle, the socio-technical regime (from now on described as “regime”) is operated by numerous autonomous actors bound by a set of normative, cognitive, and regulative rules. The rules make the actors co-dependent, thus stabilizing the regime. In the context of this thesis on public procurement and construction machines, policymakers and market actors are important. They, along with other actors, make the regime level, and represents the current structures of society regarding energy consumption, routines, and public spending.

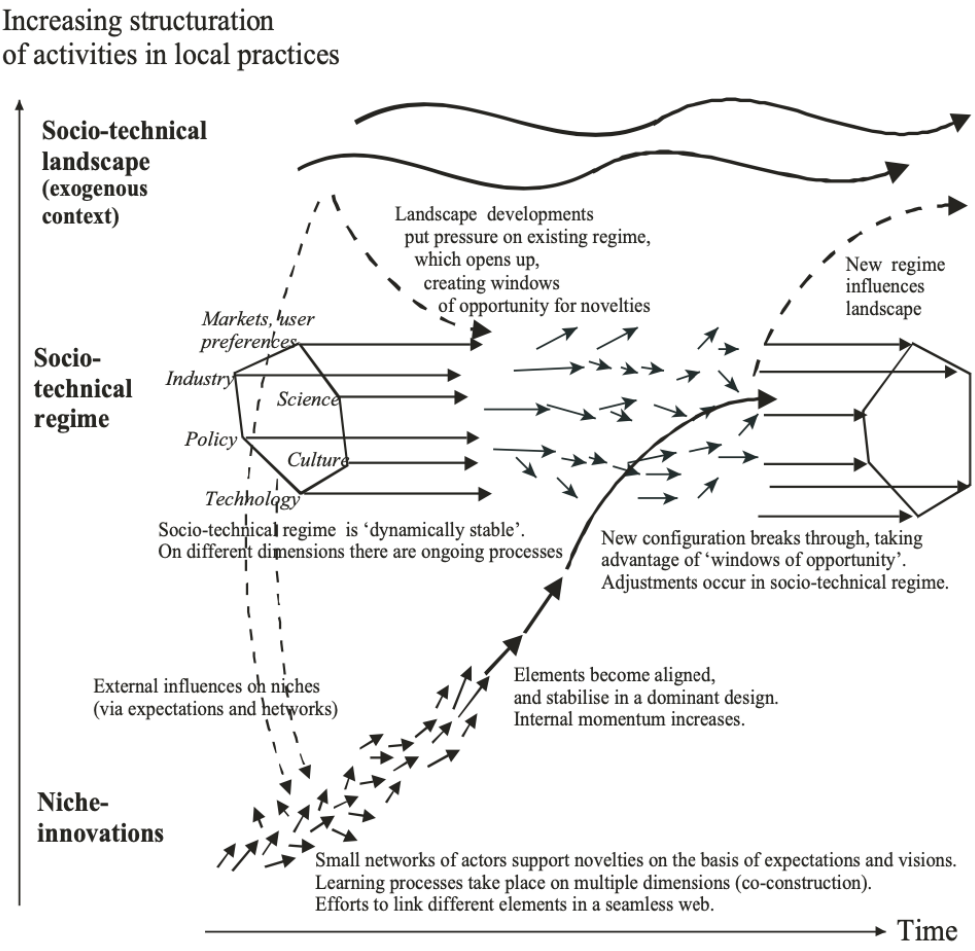

Figure 5. The Multi-Level Perspective (Geels, 2011, p. 28)

The least structured category is the technological niches (or just "niches"). This category represents radical innovations in protected spaces. Transitions occur when landscape changes destabilize the regime, creating windows of opportunity for niche innovations (Geels, 2011; Geels & Schot, 2007, 2011). In the transition of the construction industry, emission-free machines are regarded niche innovations. Due to its insignificant market share and lack of experiences using it, transitioning into the current regime is a challenge. However, interplay and interlinkage between regime actors and niche technology could make the transition feasible. By facilitating innovation in public tenders, procurers could potentially provide this necessary link. These levels are illustrated in Figure 5 below. The route for niche emergence is presented in the following sub-chapter and is illustrated in the lower part of Figure 5, where niches (small arrows) try to break through to the regime level (horizontal arrows in the middle).

3.2 Paths of change

To provide a more specific perspective sustainability transitions, based on Berkhout et al. (2004) and Smith et al. (2005), Geels & Schot (2007) constructed a typology of four different transition pathways: *Substitution*, *De-alignment and re-alignment*, *Transformation* and *Reconfiguration*. In order to separate the pathways, two main criteria are used. The first criteria, *timing of interactions,* represents the readiness of niche technology to seize the opportunity when landscape pressure occurs. Whether niche technologies are ready or not to seize the opportunity is crucial for which path the transition will take. The other criteria, *nature of interaction*, is related to the relationship between niche technologies and regime actors. If the nature of interaction is *competitive*, the niche technology cannot co-exist with the incumbents. Niches can also have a *symbiotic* relationship with incumbent actors, meaning they can co-exist (Geels & Schot, 2007, 2011).

Geels et al. (2016) increases the focus on regime actors and institutions in the emergence of niche innovation. They emphasize the fact that the timing of interaction does not necessarily depend solely on niche readiness, but also on actors' interpretation and mobilization in response to landscape developments. This perspective views transitions less as a processual mechanism and more as a complex actor-driven development (Geels et al., 2016). Actors' interpretation and recognition of the necessity of transitions is crucial to a successful transition. By taking action and adjusting, public procurers may respond to landscape pressure by implementing green and innovation criteria in public tenders. By doing so, the procurers use their market power to increase demand for innovative and sustainable solutions.

Substitution

In a *substitution* pathway, a niche technology has developed properly, and it is ready for its emergence into the regime. It is of a competitive nature. When the landscape pressure occurs, the niche competes with the incumbent technology. If the niche is able to push out the incumbent and replace it, a substitution pathway is completed (Geels & Schot, 2007). However, the competition between technologies may not replace the incumbent institutions and actors. The technological substitution can follow two different patterns: *incremental adjustments* and *disruption* (Geels et al., 2016). This translates into how comprehensive the transition is, and how significant its ripple effects are. Technologies and incumbent actors are bound by a set of rules, and each actor is related to others. If a change occurs in which source of energy

consumption is dominant, this will affect a wide range of suppliers and actors in the delivery networks built around the existing regime actors.

Transformation

In a scenario with moderate landscape pressure somewhat disrupting the regime, without a niche technology mature enough to seize the window of opportunity, a *transformation* pathway may occur. As a result of the landscape pressure, the regime modifies its activities and direction. However, the alteration of direction only happens if the regime perceives the pressure as relevant. Pressure from outsiders, such as scientists, activists, engineers and companies, provide an additional pressure on the regime actors (Geels et al., 2016; Geels & Schot, 2007, 2011). However, contrary to the traditional model of the MLP, Geels et al. (2016) proposes another aspect of technology development. Instead of viewing innovations from niches as radical, and innovations by regime as incremental, this new aspect looks at regime actors strategically reorienting themselves towards radical innovations. This can be viewed as a form of deliberate change in order to accelerate a transition in a desired direction (Roberts & Geels, 2019).

De-alignment and re-alignment

If the landscape pressure is dramatic enough, it may lead to that the regime *"(...) collapses, erodes and de-aligns"* (Geels & Schot, 2007, p. 408). This is what Geels & Schot (2007) characterize as a *de-alignment and re-alignment* pathway. In this case, contrary to a substitution pathway, the niches are not sufficiently developed. As a result, multiple niche innovations compete in the void left by the previous regime. Eventually one of the niches is victorious and emerges into the regime level. The now dominant technology will provide the foundation of the new regime structure (Geels et al., 2016; Geels & Schot, 2007, 2011).

Reconfiguration

Reconfiguration pathway is similar to the transformation pathway, the niche innovations are of a symbiotic nature, and can be implemented into the existing regime. The innovations are adopted as components into the regime to solve specific challenges. Eventually, this triggers further changes in the basic structures of the regime. As many industries/institutions use multiple technologies, adoption of one innovation may lead to changes in other aspects of the industry/institution. Building upon one another, multiple innovations may break through by competing with regime technologies. The regime actors survive, but the structures around them change substantially (Geels & Schot, 2007, 2011). This could potentially have a major impact

on actors which operate within the regime. Suppliers to the industry being left behind may need to reorient themselves towards the new reality. Some of these actors may even be replaced, depending on their willingness and ability to transfer their knowledge to be applied in another industry.

Mixed

A fifth alternative for a transition is that it does not follow just one of the four pathways, but a sequence of pathways – *mixed* pathways. Disruptive landscape pressure is of a slow moving, increasing nature. Regime actors may respond to the pressure by making moderate changes, leading to a transformation. If the changes are insufficient, and the pressure becomes more disruptive, the transition may move into a reconfiguration pathway, thus making even more substantial changes to the regime. Even this may prove to be insufficient if the pressure keeps on growing in amplitude. In this case, regime actors may lose faith in the incumbents, leading to a collapse of the regime. If this happens, one out of two scenarios are described in the mixed pathways. First scenario is that a niche innovation is sufficiently developed and ready for regime emergence, resulting in a substitution pathway. Second scenario is if the niche innovations are not ready for emergence, causing a competition between niches, resulting in a de-alignment and re-alignment pathway (Geels & Schot, 2007, 2011).

3.3 Managing transitions

Transition theories such as the Multi-Level Perspective and Transition Pathways illustrates a processual approach to transitions, where regime actors respond and adjust to landscape changes (Geels & Schot, 2011). Used as a complementary analytical framework, Transition Management can be applied to analyze how regime actors can influence *"(...) process of change of a complex system in a certain direction (...)"* (Rotmans & Loorbach, 2011, p. 141). Governance of transition can thus describe the interaction between regime and niche actors in driving change in a desired direction. The sustainable transition is governed by both short-term and long-term plans and strategies on multiple levels (e.g., local, regional, national, international), and is a goal-oriented transition. By setting a goal, a direction for the transition is created. However, the way to reach the goal is created along the way, and is forming based on societal, economic, and technological developments. By doing so, the governance of transitions make room for unconventional solutions and radical innovations.

Based on the perspective from the paragraph above, the question of how governance of transitions can determine and/or affect the transition pathway is relevant. Long-term plans and goal – such as the Paris Agreement (United Nations, 2015), the European Green Deal (European Commission, 2019) and the Norwegian Climate Plan 2021-2030 (Klima- og miljødepartementet, 2021) – provides an opportunity for regime actors to implement *"(...) radical change in incremental steps (...)"* (Rotmans & Loorbach, 2011, p. 145). As many other industries, the construction industry is bound by structures of energy consumption, economic models, and traditions. Large, radical changes is not always feasible due to technological challenges (Wiik et al., 2020). Incremental development towards a set goal makes the technological transitions involved in the industry more feasible. This provides an opportunity for actors to reorient and reconfigure the conventional structures of the industry, to adapt to changes.

Plans and strategies gives the construction industry a direction of which development will follow. However, the industry is still bound by the market forces of supply and demand. If making purchases and practices in more sustainable manners is a financial burden, the companies are unlikely to change their behavior. Niche technologies using renewable sources and carriers of energy, such as electrical and hydrogen machines, is not price-competitive with the conventional fossil fuel machines (Wiik et al., 2020). Thus, there is need for incentives for actors working in construction to make investments for sustainable solutions.

Regime actors can intentionally accelerate the sustainable transition by changing their practices and defecting from the lock-in mechanisms of the regime (Roberts & Geels, 2019). This is illustrated in Figure 6 below. Roberts & Geels (2019) analyze how regime actors, such as policymakers and powerful market actors, may contribute to the emergence of niche technologies in order to respond to landscape pressure. The landscape pressure, which is represented through climate change, is perceived with increasing importance to regime actors. Actors from the public sector are responsible for implementing policy to direct development towards a sustainable society. Figure 6 is similar to Figure 5, but with one important difference: A large arrow reaching down from the regime level to the emerging niches. This arrow implies that the regime, through different policy tools, can facilitate growth and support the emergence of niche technologies. Thus, the regime can proactively affect the course of the transition through deliberate action. One of the relevant policy tools is public procurement. How these dynamics operate will be further discussed in chapter 6 – Discussion.

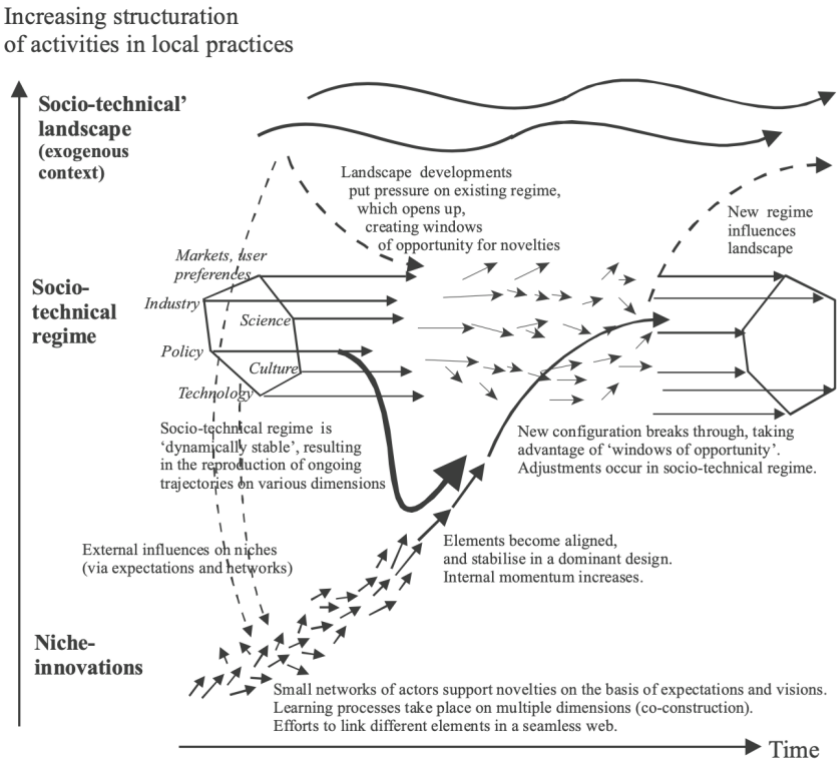

Figure 6. Multi-Level Perspective with modifications. Large arrow in the middle indicating regime actors helping niches (Roberts & Geels, 2019, p. 223)

By using different types of policy instruments, the public sector can make an impact on private actors' practices. One of these policy instruments is setting requirements and criteria in tenders for public procurement. This is a way for the public sector to guide private actors in a desired direction. Public procurers possesses a large share of the market in construction (Byggenæringens Landsforening, 2016) and has enough market power to cause fluctuations in relation to other regime actors, thus creating windows of opportunity for niche technologies. This way, the public sector can deliberately manage the transition in the construction industry to new practices.

4. Research Design

As the construction industry is large, complex and involves several different actors, some limitations to the scope of the thesis were necessary. The case of Olav Vs gate was conducted with a narrow focus on the emissions within the boundaries of the construction site, providing a more specific perspective on machine and energy consumption. As a result, procurement as a tool to incentivize and accelerate technological innovations of construction machines is emphasized. This limitation is also applied in this thesis. In addition, when discussing construction machines there is an implied focus on excavators, which also became apparent when interviewing the informants.

During a construction project, there are several aspects of where emissions occur. Some of these emissions happen inside the fences of the construction site and is mainly caused by traditional fossil fuel-dominated energy consumption by internal transport and use of construction machines. There are challenges related to experience and maturity of emission-free construction machines. Through procurement, the public sector can contribute to gaining experiences and making the technology more mature. By doing so, innovative technologies' trajectories into new markets may be accelerated, thus accelerating the transition to a low-/zero-carbon society.

The most recent Norwegian climate plan "Klimaplan 2021-2030" estimates that the direct emissions from building- and construction sites in Norway was a total of 2 Mt CO_2-eq in 2017. This includes transport to and from the sites, construction machines and temporary heating and drying of buildings (Asplan Viak, 2019; Klima- og miljødepartementet, 2021). The total climate footprint by the construction industry in Norway was 13,1 Mt CO_2-eq. This includes all business related to the sector such as import and export of goods and its contribution in other sectors in Norway (Asplan Viak, 2019). This thesis investigates how public procurement can act as an accelerator for innovation. The main focus is on the development of emission-free machines being used on site. By making such limitations, I exclude external transport, material use, disposal of materials, demolition, and water usage from being investigated this thesis.

The limitations to the scope of the thesis are done based on several different considerations. As this project is limited to the first half of 2021, and as gathering information is time consuming, reducing the number of aspects of the transition to be dealt with was necessary. As a result, the scope of the thesis was narrowed down to on-site emissions focusing on the energy transition

for construction machines. Thus, the thesis is specified to research how procurement can operate as a door-opener for technological innovations into the construction industry.

Thus, the hypothesis going into the interviews is that public procurement can, if formulated correctly, trigger and drive innovation in the construction industry. In order to research this, the interviews will be based around the overarching topics: procurement and the energy transition; innovation and procurement; and transitioning to emission-free construction machines. This will be more thoroughly elaborated in the sub-chapter 4.1.

4.1 Data collection

The research was conducted based on relevant literature and interviews with stakeholders involved in the transition of innovative procurement. Prior to the data collection, the research was approved by the Norwegian Centre for Research Data (NSD). As the approach to gather information from stakeholders were done through interviews, a selection of candidates had to be made. This selection was picked to include a wide range of perspectives from involved stakeholders. On this basis, I chose to interview procurers, actors in renewable energy companies, actors from the construction industry, machine suppliers and intermediate actors of innovation and procurement. By doing so, I gained a wide perspective of the needs and obstacles perceived by the different actors.

The selection has its limitations as well. As there are limited time, gaining several perspectives from within the same groups of stakeholders was a challenge. Thus, the informants are regarded as being a voice on behalf of their industry/group and represent several other actors who were not interviewed. It is important to keep in mind that these perspectives and voices are not absolute, and that there are different opinions within the same groups of stakeholders. However, the selection is sufficient to map out challenges and opportunities in the transition. Shedding light on obstacles and factors thwarting the transition is an important part of overcoming them. The interviews were conducted in Norwegian, thus the transcripts are also in Norwegian.

Interviews - Template and relevant topics

During the interviews, a list of topics was used to keep the conversations relevant to the thesis topic. The main topics are:

- Public procurement and its role in the sustainable and energy transition

- The link between innovation and procurement – creating new markets to overcome challenges related to the energy transition.
- Emission-free construction machines

These topics were applied in all interviews. However, how much each topic were emphasized varied between the interviewees based on their role and interest. By having a semi-structured approach to the interviews – which means the questions asked may vary based on the informants' background and statements, the candidates were able to freely present their perspectives within the framework of the thesis. In addition, questions are developed to increase the chances of the conversation being informal, which means open-ended questions allowing the informants to speak freely about the topics. The information gathered is general ideas and perspectives on the energy transition represented through the role of procurement, innovation, energy, and construction - which is important aspects of this transition, and to highlight the decisive dynamics of these aspects. In the next sections, the sub-topics and questions used during the interviews are presented.

Topic 1: Public procurement and the energy transition

The use of procurement as a tool for accelerating the sustainable transition is the foundational aspect of this thesis. Thus, it is also a major part of the interviews. In this part of the interviews, the candidates were asked questions related to how public procurement can be used to meet obligations for emission reduction, the use of the public sectors' market power and how procurement can contribute to the energy transition. The following questions were used to guide the interview:

- How is the energy transition and public procurement connected?
- Can public procurement function as a tool to reach national emission-reduction obligations?

Topic 2: Innovation and procurement – creating markets

Related to transition management and deliberate transitions, the link between procurement and innovation needed to be made clear. This was done through a range of questions related to how the public sector may operate as a door-opener for innovative technologies through procurement – represented as niches in the analytical framework. These questions aimed to

gather the views of the public procurement as a road to market entry for less mature technologies.

- Communication between market and public actors: how can market dialogues facilitate coordination and collaboration of the energy transition?
- In which capacity can public procurement create space in the market for innovative technologies which are not yet mature enough to compete in the mainstream market?
- Can public procurement trigger change in an industry as rigid as the construction industry?

Topic 3: Emission-free construction machines

As this thesis uses the case of Olav Vs gate in Oslo as a case to analyze the transition of construction machines, the views – and status – of emission-free construction machines was important. There are several alternative energy carriers, which is why these questions were not specified to any of them, because the questions could then exclude viable options. This section also includes prospects of the construction industry for a longer period and how the candidates perceived this.

- What are the biggest challenges and opportunities for the construction industry in implementing emission-free machines?
- How can these challenges be overcome, and opportunities be seized?
- Where does this transition start?

Privacy – Data management

As the thesis topic does not encompass any sensitive information, management of data did not serve a major challenge for the conduction of interviews. However, some measures were made. The informants signed a declaration of consent prior to the interviews. All interviews were recorded, transcribed, and anonymized. The candidates are coded into a system with names such as “Informant 1”, “Informant 2”, and so on. More detailed description on who the candidates represent are presented in chapter 5. Due to Corona-restrictions, I could not physically meet the informants. Thus, the interviews had to be conducted through digital channels. These channels were set up with end-to-end encryption, meaning no data were stored online. The recordings of the interviews were stored and encrypted locally on a hard-drive,

keeping it safe and sound from the cloud and other areas where the risk of falling into the wrong hands were possible. After transcribing the interviews, the recordings were deleted.

Informants

In total I have interviewed 10 informants, split into 9 interview-sessions. The informants represent a wide variety of involved actors in the transition. Table 2 gives a brief introduction to each informant:

Informant number	Description
1	Informant 1 leads a regional partnership for green and sustainable business development. Such partnerships operate as drivers, and an arena, for a specific cause, creating networking opportunities and knowledge sharing. With partners from a wide variety of industries – with sustainability as a common goal – this informant provides a big-picture approach to this research.
2	Informant 2 is a representative from DFØ - The Norwegian Agency for Public and Financial Management (DFØ). The agency which this informant represent is responsible for public procurement (frameworks, guidance, competence development) in Norway (Direktoratet for forvaltning og økonomistyring, 2021c). Thus, this informant is a solid resource for information from a national perspective.
3	Informant 3 represent Omsorgsbygg - an entity of Oslo Kommune. This entity is involved in several construction projects in the Oslo-region and knows the procurement framework in the municipality. In addition, the informant is familiar with the project in Olav Vs gate in Oslo.

4	Informant 4 is a representative from the suppliers' program for innovative procurement in Norway – Leverandørutviklingsprogrammet. This is a public program which is working on facilitating innovative solutions through innovation-friendly criteria in tenders. Their work is focused on the supplier's side of the procurement.
5	Informant 5 is a CEO of a Norwegian renewable energy company. This private-sector informant provides a perspective from a young, innovative industry, which may potentially provide useful solutions for construction sites in the time ahead. They are involved mainly in solar energy and battery technology.
6	Informant 6 represent UKE – Utviklings- og Kompetanseetaten, Oslo Kommune. They work on a strategic, overarching level with procurement and development in Oslo Kommune.
7	Informant 7 is working with private supplier of construction machines. The company is involved in development of emission-free construction machines. This is a useful perspective for both the technical side of the transition, market maturity and experiences with public procurers.
8	Informant 8 represent a rental company of construction machines and equipment as head of procurement and market. As a rental company, they can assist SMEs in this transition, as smaller companies may not yet be able to make investments towards emission-free machines. They are also operating closely to public actors and tenders.

9	Informant 9A and 9B represents a medium-sized construction company (European Commission, 2021). Informant 9A is the head of market, and Informant 9B is head of machines and equipment. As this company is not one of the major market actors, they provide a perspective from the construction industry with limited resources – both financial and human. As both informants represent the same company, they wished to conduct the interview together. The objective of this interview was to gain insight in a construction company, and two informants instead of one strengthened the content of this interview.

Table 2. List of informants with descriptions.

Transcription of data

Once conducted, the recordings of the interviews were transcribed, because this made the management and analysis of the data graspable. The informants were asked questions of which they were not fully prepared to be asked, and some of them may have struggled to find the right words to provide sufficient answers. This inevitably led to some mispronunciations and other noises between words. Such noises and corrections were not included in the transcribed interviews. As the topics of the interviews are uncontroversial, including mispronunciations and noises would merely harm the content of the data, rather than excluding important aspects. By not including these noises, the content can be presented more clearly and used more efficiently.

4.2 Data analysis

Interplay between different aspects of transitions serves as the foundation of my analytical approach. Public procurement can potentially provide new opportunities for market actors and innovative technologies. Thus, the nexus of policy, market and innovation is studied, which was introduced in Chapter 1.2. How the aspects in the nexus interplay, coordinate, collaborate and affect each other, can all be influenced by procurements. Shifts in one of these aspects may cause disruptions – and opportunities - in the other two, and even in between them. Changes in policy, implemented through procurement, can affect market shares and business relations between incumbent market actors and innovative start-ups. It may provide the necessary push to for innovative technology to gain market access, or it may disrupt market structures to provide opportunities for innovative actors to seize.

The public sector has a vast range of tools to implement policy change and to reach long-term goals when governing a transition. Public procurement, representing one of these tools, can facilitate change by setting requirement and criteria for sustainability in public tenders. In this thesis, I research how this tool can be utilized to trigger and drive the transition and to facilitate and accelerate use of emission-free construction machines. To successfully execute this transition, collaboration and dialogue between incumbent actors, niche actors and the public sector is a necessity. This is analyzed based on the principle of Public Procurement of Innovation and the analytical framework of transition theory.

Thematic analysis

As described in chapter 4.1, several topics were discussed based on the interview guide made in advance of meeting the informants. The informants, which represents a wide variety of stakeholders, spoke based on their own background and interests. As a result, the data collected contained several arguments. As a methodological approach to analyze and present the patterns of the data, I applied a thematic analysis based on Braun & Clarke (2006). This method is suitable for analyzing written, qualitative data. In this method, the data is divided into themes which consist of several codes. The codes are aspects of the data which appear interesting and highlights specific features of the data. By gathering several sentences and features from the data into a code, one can effectively analyze it. By putting several codes into categories based on their features, one can establish more general themes – which are linked to the research questions. These themes are the pillars providing the structure for analyzing the results and the discussion thereafter. The structure of the themes is illustrated in Figure 7 below, with a presentation of the themes from the finding, with their codes. How and why these themes and codes were constructed based on the interviews will be further discussed in Chapter 5.

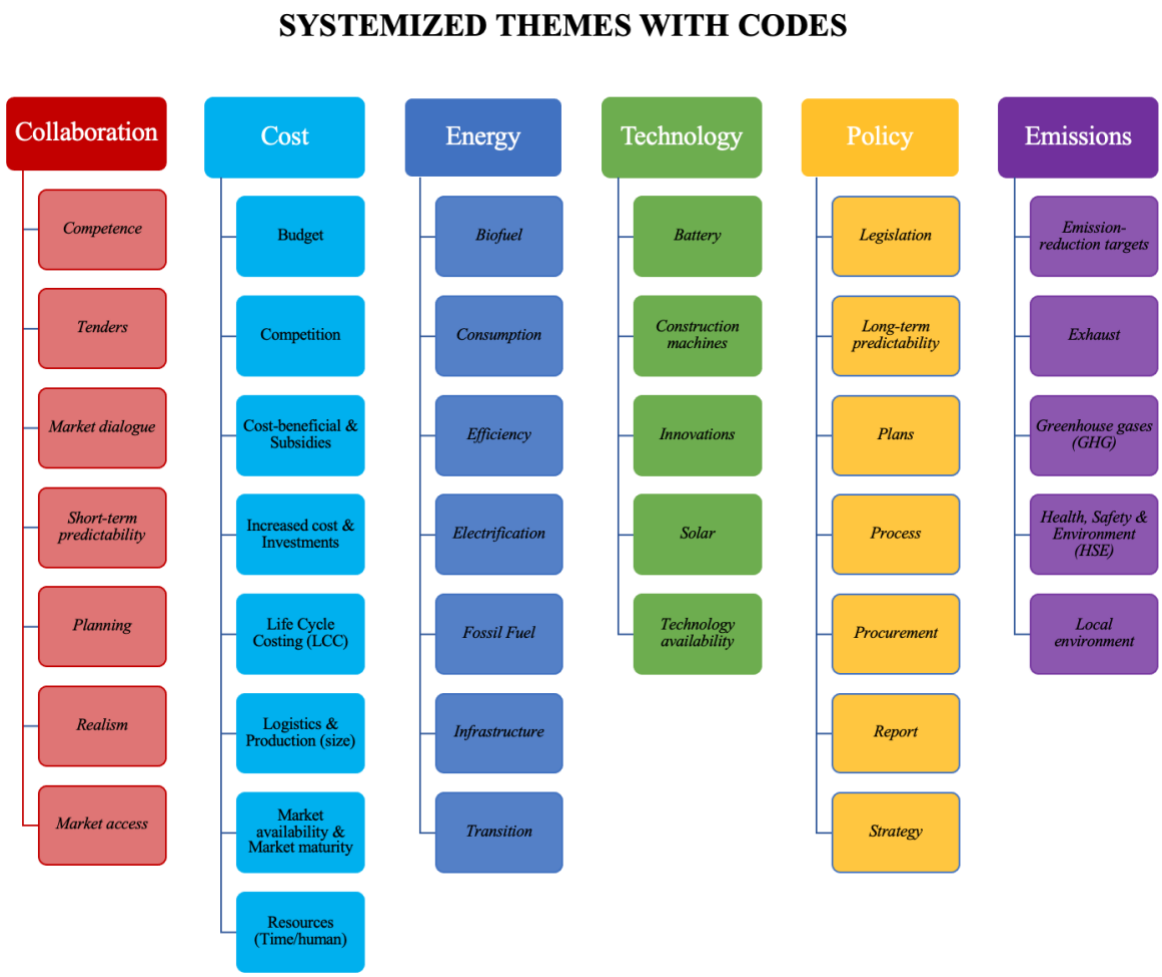

Figure 7. Systemized themes with codes.

Braun & Clarke (2006) provides a step-by-step guide to conducting a thematic analysis, which consists of 6 phases. In my analysis, this approach was used as a guide. However, due to the complexity of qualitative data analysis, not all aspects of the guide were relevant and thus not applied. Collected data can be handled in a wide variety of ways, and in the process of starting a thematic analysis some specifications were made. During the process of data collection, all informants were used. These informants represented different industries and sectors, thus also different perspectives. As this thesis mainly focus on the dynamics of the transition, and the interplay between them, looking beyond the statements of the informants were not considered necessary. The approach which were applied are described by Braun & Clarke as: *"(...) those that consider meanings across the whole data set, semantic themes, and are realist (...)"* (2006, p. 86). Thus, the research does not consider the informants motives or feelings into account – it simply presents the variety of perspectives. As I in this thesis investigate the dynamics of the transition, the perspectives themselves was the most important part – not the motives behind them.

Structuring the data

As mentioned above, Braun & Clarke (2006) provides a guide to conducting a thematic analysis – which were used to structure and inspire my process of data analysis. First, getting to know the data, its content and structure is important. This was done through transcribing the recordings, followed by reading and note-taking. Second, based on the notes from the first phase, codes were created. These codes represent important features of the data. Third, I found connections between the codes, and generated initial themes based on this. These themes, consisting of a number of codes, represented a larger context for the codes and were linked more closely to the research questions. Fourth, the initial themes were reviewed. In this phase, some relocations of codes were made, some boundaries of themes were altered, and some themes were even merged. Fifth, after reviewing the themes a number of times, and being able to locate clear and presentable patterns, the themes were given names and defining boundaries. During the first four phases, working titles had been used, and some themes were overlapping. In this fifth phase, the themes were being prepared to be presented and applied in the analysis. Sixth and last, the writing of the report itself. This phase is the result of the analysis and is found in 'Chapter 5 - Findings' and 'Chapter 6 - Discussion'.

To analyze these data more effectively, the software NVivo was used. This software made the practical side of the data analysis graspable and feasible within the timeframe which I operated in. NVivo is suitable and efficient when handling large amount of written data – such as transcribed interviews. It provides opportunities to code the documents – as one should in a thematic analysis – and map out number of occurrences and patterns. This made it possible to have a tidy organization of the data, thus making it easier to handle.

4.3 Research Quality

In order to ensure sufficient quality of the qualitative research which I have conducted, I applied a conceptualization based on eight points: *"(…) (a) worthy topic, (b) rich rigor, (c) sincerity, (d) credibility, (e) resonance, (f) significant contribution, (g) ethics, and (h) meaningful coherence (…)"* (Tracy, 2010, p. 839). These points operate as markers for quality in the research, as well as a template for what needs to be addressed. In the following sections I will highlight both strengths and weaknesses of different aspects of this research.

The chosen topic for this research is of great relevance for the energy transition to low-/zero emission societies. Due to the public sectors market power, public procurement is a policy-tool

of significance (Lember et al., 2015). By creating demand for new products, and setting criteria excluding non-desired solutions, public procurement can trigger change in several industries. Thus, the research conducted with emission-free construction machines is not limited to exactly that but can also be applied in other cases where innovative solutions are desired.

A combination of reports, white papers and peer-reviewed research serves as the foundation of this research. Built upon this, I gathered information through interviews, which was based on a wide variety of relevant stakeholders. In scope and depth of the research, these data provide thorough context, data samples, and theoretical constructs.

Prior to, and during, the research period, I have been motivated and driven by an interest in electrification and hydrogen technology. Due to my own lack of technical knowledge, I have relied on other research and stakeholders to provide the technical aspects of this energy transition. Thus, the focus of this thesis is not purely on the technical side of the transition, but rather a holistic view of technical aspects, economics, and policy.

All data used and gathered have been so based on the context of public procurement and emission-free construction sites and/or machines. These data have been put up against one another to make sure that the results and conclusions is based on a solid data foundation. Throughout the thesis, I have shown how the topic can be related to different examples, thus illustrating how the data is applied based on the context.

The aim of the research is not to produce a heavy, theoretical document for researchers – it aims to be a case within a larger context, which makes the findings and discussions transferrable. Ideally it is useful for anyone involved in energy transitions, whether it is public procurers, developers of battery technology or researchers within policy tools.

Placed within the frames of an ongoing energy transition, this thesis serves as a complementary research to the role of procurement of innovative technology. Thus, its significance is, depending on the receiver, practically, theoretically, and heuristically significant in its own way. It does however lack significance in the view of methodology.

During the interviews and data collection, I was in contact with several different people – some of them are informants in the Appendices. Although the topic which is researched is

uncontroversial, informants' privacy and data were handled in a cautious manner. Through transparent flow of information between the informants and me, we ensured mutual respect for one another, for the information which was shared – and how the information was intended to be used.

This thesis does not set out to provide a clear answer to the challenges facing public procurement and the energy transition. However, it embraces a variety of perspectives from involved stakeholders, and relates it to research and theoretical data. It embraces the complexity of the transition.

5. Findings

In this chapter, the findings from the interviews are presented. The data collected have, as described above, been coded, and put into a selection of themes. Based on frequency and relevance to the research questions, I have constructed six themes: *(1) Collaboration, (2) Cost, (3) Energy, (4) Technology, (5) Policy, and (6) Emissions*. These themes serve as a foundation to present, analyze, and discuss the data and the research questions. In sum, these themes grasp a wide range of relevant topics.

The themes are constructed to encompass and grasp the complexity of this transition. The transition is – as mentioned – complex. Thus, the themes used to analyze and present the data covers a wide area of interests. Some of these are strictly of a technical nature, others are more focused on the societal or human side of the transition, and others are viewed from an economic perspective. In total, I aim for this chapter to answer the first research question:

- *Which dynamics shape the transition to emission-free construction machines in Norway?*

As shown in Table 2 below, the most frequently appearing theme throughout the interviews was *Collaboration*. This theme includes codes relevant for communication, competence, and short-term predictability in the relationship between public sector actors and private actors. The second most frequent theme is *Cost*, and encompass economic perspectives such as profits, investments. Increased cost. It also includes resources - both time and human - and logistics. *Energy* comes in as the third most frequent theme. By including electrification, energy sources, consumption, efficiency and more, this theme comprehend several aspects of energy generation and use. Fourth we have *Technology*, which include innovations, excavators, battery technology, et cetera. *Policy* is the fifth, and includes talk about public plans, strategies, procurement as a policy tool, and long-term predictability. Sixth, and last, we have *Emissions*. This encompasses pollution of greenhouse gases, noise, and health. Some of the codes related to the Emission-theme are Health, Safety and Environment (HSE); local environment; emission-reduction targets; and greenhouse gases.

Theme	*Appearances*
Collaboration	264
Cost	218
Energy	160
Technology	147
Policy	117
Emissions	63

Table 3. Themes and their respective number of appearances in the coding process.

As Table 3 above shows, there are large differences in the frequency of occurrence between the themes. All themes appeared in each of the informants' transcriptions during the coding process. Thus, it is relevant to present all of them in this chapter.

As the questions from the interviews were loosely structured and tailored to the research questions, the frequency and definitions of the themes were not a major surprise. The codes can at sometimes be seen as overlapping, as it is rarely feasible to discuss one aspect of this transition without touching another aspect. An example for this is the use of two different codes: Tenders and Procurement. On one hand, we have Tenders, which are located in the Collaboration theme, and relates to the criteria set in public tenders, the dialogue it is based upon, and the competence of both the procurers and the market actors. Procurement, on the other hand, is a part of *Policy*. This code relates to the larger perspective of procurement as a policy tool, and how it can be strategically used to achieve set goals. Thus, even though they are similar, they represent different aspects.

5.1 Collaboration

Based on the interviews, *Collaboration* is a major theme and a decisive factor for the transition. To ensure sufficient competence and knowledge - and to communicate, coordinate and cooperate – collaboration is key. Throughout the interviews, *Collaboration* was the theme which occurred most frequently in the interviews. On several occasions the need for dialogue, competence sharing and planning in advance of a tender publication were mentioned. In short, *Collaboration* can be defined as: realistic and predictable criteria in tenders based on

competence-sharing and planning for both public and private actors. The codes which in sum make the theme *Collaboration* is:

Code	***Appearances***
Competence	67
Tenders	65
Market dialogue	59
Short-term predictability	24
Planning	23
Realism	14
Market access	9

Table 4. List of codes in the Collaboration theme

The importance of cooperation and dialogue were consistently brought up during all the interviews. There are several challenges related to how one would see this through, and the informants vary in both approach to solve it and in what they perceive as the largest obstacles. Informant 9, for instance, is provoked by the criteria in the tenders being far from what is realistic and available – showing lack of competence and dialogue from the public procurer, referring to a specific tender:

> And it [the tender] says that one of the machines has to be either electric or hydrogen-powered. I do not know how much you have been working on that, but if you do find a hydrogen-powered excavator in this world – let me know.

As this informant clarifies, keeping criteria in tenders realistic is of great importance. Lack of dialogue with market actors and sharing of knowledge may lead to situations just like this, where the procurer asks for unrealistic solutions. A procurer in a public entity is responsible procuring goods and services for a large number of different sorts for the different departments. Therefore, it is also difficult to keep up with developments in all the different industries. Talking to the market, seeing what is available and gaining knowledge from industry actors, is one of the ways of solving this challenge.

Another challenge, directly opposed to having too ambitious criteria in tenders, is the lack of criteria. This could potentially be hindering or slowing down the development – even though

the market may be able to provide solutions. Informant 5, being a CEO of a renewable energy company, views this as a challenge. The informant fears that lack of criteria and requirements in tenders may cause the large actors to sit back and relax, as there are no incentives to do things in a new way:

> When we speak to TS or Risa, they sit back on their ass and say there are no requirements – we are making money. But if you told them clearly that from this date on you have to do it like this, and from that date on you have to do it like that, and that is a public requirement – then I think that is the way to do it.

The importance of predictability and setting criteria in tenders – combined with market dialogue – is illustrated by informant 5. In the quote above, the informant describes large actors in the construction industry being unwilling to change, because they are already making profits, so why change? However, by communicating to the market that from a specific date there will be new criteria, even large companies would have to adjust. Once again, communication, predictability and knowledge are key to provide accurate criteria and pushing for development.

The importance of communication

According to the findings, to communicate across sectors is an important aspect of this transition. Procurers are less likely to know a lot about what the market can deliver – as one cannot know everything about everything. For the procurers to know what to procure, they need to communicate with relevant suppliers. As Informant 6, who is working with procurement in a public entity, put it: *"So, to speak with the market is always important, no matter what one is procuring – to know what to procure and what one can demand from them."*. Actors directly involved in a specific industry possesses knowledge and perspectives which the procurers are unlikely to have. Hence, communication is a key factor to ensure sufficient knowledge and insight for specific projects and industries.

When working with innovative technologies, such as electrical excavators, the involvement of suppliers is especially important. However, informant 7 is frustrated by the extent and timing of them being involved in projects.

> We feel that we are always involved after. The criteria are set, and then we have to run after them and ask, *'are you sure this is such a good idea?'*. We feel that

> we are always working on re-doing the process, rather than being a part of it from the start.

As informant 7 claims, doing things over and adjusting to make it feasible is not an efficient way to do business. It makes it difficult for suppliers to know what to expect in public tenders. Tenders as a code - not to be confused with Procurement, which is a part of the *Policy* theme – relates to the criteria used when publishing a tender. These criteria need to be realistic and predictable for the suppliers – based on what is available and what is still out of reach. Informant 8 has a similar perspective on the importance of cooperation in advance of setting criteria in tenders:

> Because, if you know the project, or know the inquiry, you can build around it, rather than receiving an inquiry where they say how they want it or how it should be. If you are involved, you can affect the inquiry so that it is feasible to deliver.

Related to competence, tenders are built upon the knowledge and routines of the procurers, strategies in the organizations and communication with the market. Informant 1 describes unclear and unprecise criteria in tenders as the biggest obstacle thwarting the transition in the construction industry: *"Unclear and unprecise orders from county government and municipalities. That is the biggest challenge for the construction industry – as simple as that."*.

As a contrast to these perspectives from suppliers, informant 6 has a different experience with tender criteria: *"(...) as a public procurer or a large procurer, one can ask for almost anything – and get it."*. Based on this, one can locate a gap in the communication and expectations between the public and the private. How does this affect the relationship between the municipalities and the companies?

Knowing what's ahead

Imagine driving on a winding road in the dark that is unknown to you. You cannot anticipate the twists and turns ahead, hence you need to drive slowly. The road is unpredictable. The findings show that the same goes for private actors predicting market development in the near future. Without them knowing when the change is happening, they cannot properly prepare for it, or actually know what this change entails. Informant 3 is certain what the change means, but the question of when is more challenging: "*We have some emission-free project in process, so*

it is coming. So, when does the rest come? When is it 80% electrified – when is it 100%?". Informant 3 represents OBY in Oslo Kommune, where they have communicated a goal for emission-free construction sites by 2025. This provides a certain predictability for entrepreneurs in the Oslo-region and justifies – at least to a certain degree – increased cost for pilot projects and other research related to it. Such plans, for even a short period of time, provide some predictability – a GPS showing the upcoming twists and turns.

When discussing predictability, the aspect of risk becomes apparent. When private actors are being innovative, they are taking chances. Then a question emerges: why would they take this risk? Which reason would they have to take a chance on emission-free machines, when conventional machines still demand fewer resources and costs less to operate? Informant 5 wants this burden to be shared:

> There needs to be some form of commitment, and it could of course fail – it is not certain that we will succeed – and then the risk needs to be on the procurer as well. They need to pay for the study being carried out.

Among the informants, most agree that there should be advantages for taking risks. A shared burden is one possible advantage, as informant 5 describes above. Such burden may be of an economic sense, to reduce the risk of investing in development of innovative technologies. This is also an opportunity for the public sector. Because, if the project is successful, benefits and gains from it is also shared, as it may open up for further development in other areas and industries as well. Informant 5, in particular, is clear on the case of innovation – this is something the public should facilitate, and the private actors should execute.

Criteria in tenders is also an important driver for change, and to avoid the unwillingness to change among suppliers. By setting criteria and requirements in tenders, suppliers are forced to adjust make sure they are not replaced by more innovative businesses, who follow the criteria. As mentioned by several informants, these requirements need to be based on realistic expectations of what the market can deliver – in other words, consistent and predictable development through communication. This will be further discussed in the sub-chapter, *'Carrot or Stick?'*.

5.2 Cost

Being an area of emphasis for most informants, economic aspects of the transition represent a common language for the involved parties – as all of them need some sort of financial benefit or justification for their actions. *Cost* is therefore considered one of the main themes in my research. It ranges from the potential economic benefits or burdens of the transition, to logistics and market development. Funding, such as subsidies and benefits, are also included. In sum, these codes were located and used for *Cost*:

Code	***Appearances***
Budget	17
Competition	16
Cost-beneficial & Subsidies	30
Increased cost & Investments	64
Life Cycle Costing (LCC)	8
Logistics & Production (size)	19
Market availability & Market maturity	41
Resources (Time/human)	23

Table 5. List of codes in the Cost theme.

Increased cost and large investment are a worry for several of the informants. The question of who takes the additional cost of transitioning to emission-free machines frequently surfaces. Informant 7 highlights not only the increased cost, but also how it will affect the amount of work being carried out: *"When things get more expensive you get less done for the same money. If we are going to do as much as we do now, someone has to pay in the other end. The question is who?"*. How are one to justify the increased expenses and investments for companies? What are the potential benefits of making such investments? As of yet, informant 9B is worried that the investing in a machine is a symbolic gesture – for almost triple the price.

> You have seen these large entrepreneurs, and we will probably end up there as well, where we have to have an electric excavator. What most of them have done is to purchase a 2-ton excavator which is not really doing any work – it is solely symbolic. And it costs 230-250 000 [NOK], and if you want it electric it cost almost 600 000 [NOK].

As this informant indicates, there must be some kind of compensation for making the investment. The publicity is one benefit for the companies making the investment, but for many that is not enough. When the investment increases by two- or three-fold, it is difficult for many companies to tag along. However, there are opportunities related to the competitiveness of involved actors in the market. Even though there is a lot of uncertainty, being a front-runner might pay off in the long run, as companies could establish a strong market position. Due to the uncertainty of the development of construction machines, there are need for either a carrot or a stick – or both – to accelerate this transition, and to make it an attractive option for private actors.

Developing the market - which at this point is not mature, according to the informants - is also a relevant economic factor being brought up by several informants. The scale of production is small – which is reflected in the high price of each machine. On the one hand, there are simply not enough electrical excavators available to have it as a criterion in tenders. On the other hand, producers need a certain demand to scale up the production. This is a transition from re-builds to mass production of emission-free excavators.

Carrot or Stick?

To drive change, there has got to be some sort of incentive. Either that incentive is a slap on the wrist for keeping to the status quo, or a bonus for being innovative, the economic aspect may be one of the most important drivers. Informant 5 claims that once a solution can be justified economically, it can take off:

> But when it becomes economically responsible – that is when it catches fire. There has got to be an economic carrot it in – either you pay a lot to have diesel-fueled engine running to make battery technology more profitable – or something which gives it an economic drive.

There are, as mentioned by informant 5, various ways to incentivize private actors adjust how they do their jobs. The informant is of the opinion that the key to getting through to these actors are the economic benefits – or potential consequences of not adjusting. Once it can be justified it becomes a feasible option. Informant 8 shares this perspective, emphasizing to compensate companies willing to adjust:

> If you are not getting paid more, you may get an advantage such as a deduction, so that it is approximately equal to being paid more. If you add it to the price, you get it back through the energy solution. I think it is about the cost of it, those frames. We need a thread through it from the public to the procurement.

The thread being mentioned relates to the predictability of criteria, and to permeate green or innovative strategies throughout the public entities. Public procurers, and actors from other departments in the entity, must be willing to take the increased cost.

Such benefits and compensations may be a good place to start. Based on the experiences of the implementation of electric vehicles in Norway and subsidies for renewable energy in fish farms, informant 5 suggests a three-phased plan:

> One thing is to set a date and say that from that day on it is not funny anymore. And maybe how it is done at the start where one subsidizes the solution in the first phase. Next phase there are no subsidies anymore. In the third phase it is a requirement to use it. It is probably the right way to do it politically, starting off a bit pleasant.

Incentivizing companies to implement new solutions, thus developing both the market and the technology, is important in the start of the transition. What informant 5 describes is simply helping the actors taking the first steps, and once the technology is more mature, they can walk on their own. Eventually, to avoid actors lagging too far behind, it needs to be a requirement. This last part, with actors lagging behind, is a concern for several informants. Especially smaller actors who does not necessarily have their majority of jobs coming from the public. As informant 3 said: *"(...) the private [actors] has no interest in changing how things are. They make money as it is (...)"*. Without incentives – without criteria and requirements in tenders – they are not willing to change, because why change a winning team?

With what money?

The question of resources – related to both time and budget – are referred to frequently by the informants. The sub-chapter, *'Carrot or Stick?'*, above addresses the need for incentives for the private actors to adjust and transition. But what about the public actors? How are municipalities

with limited budgets coping with implementing innovative/green criteria? Informant 1 points to this challenge:

> (…) we have user departments, which own the subject, does not necessarily want to go that way, because they have a budget to manage. So, a professional want to build something, a professional for building schools or municipal facilities. He has got this and this much money, and he must follow certain criteria. In those criteria, often put together by others, there is very little wobble room.

As pointed out, how are the professionals in the different departments going to prioritize? The different departments in municipalities are given limited budget which they need to exploit effectively for the necessary work that needs to be carried out. This concern is brought up by several informants and represent one of the public entities' largest challenges in this transition.

Another challenge for the public actors, and specifically the public procurers, is the issue of time. As the procurers are responsible for acquiring goods and services for many user departments, there are limited time to carry out each procurement. This is also addressed in chapter 5.1, where the importance of communication and cooperation is emphasized. Another perspective of this is time, which is linked to the cost and budgetary side of this issue. With limited time in disposition, it is easy to turn to the well-known and the familiar.

> A procurer today is not just one who sits and purchase these things – he purchases a lot of other things as well. He covers a large field. And then it is very easy to turn around and use the competition that was used the last time and copy for this school – do the same things over again.

As informant 2 describes, lack of time and resources makes it simpler to turn to an old tender and copy it, rather than drafting a new one with updated criteria. Consequently, the tender criteria may not be innovative and incentivizing private actors to adjust. And, as mentioned above, the private actors will therefore not change – thus, they are stuck in a loop.

Some opportunities related to this – low-hanging fruits, if you'd like – is to make the processes more efficient. Standardization of tender criteria, available across municipalities, to help guide

the procurers in the right direction. By using available templates, which in fact already exist, the procurer may save some time. Another way to make it more efficient, is incentivizing the private actors to have more efficient logistics. Informant 2 sees this as a big opportunity, pointing at shipments to and from construction sites are often transported by half-empty vehicles. Setting criteria for transport of goods may not even increase the cost of the tender significantly and could potentially have a significant impact. In a short-term perspective, such solutions with preferable – and acceptable – balance between cost and impact, may be an opportunity for municipalities.

5.3 Energy

There are several challenges – and opportunities – in the transition away from fossil fuels. The exact destination of the transition is unclear – but it will eventually cumulate into an emission-free construction industry. Whether that is by electrification of machines, hydrogen or some other solution remains unknown – which also makes the transition exciting. The theme *Energy* is defined within the boundaries of energy source and consumption, and the technical aspects related to infrastructure. Electrification is viewed as the most feasible approach to reducing emissions from construction machines by most of the informants – at least in the nearest of futures. Biofuels is considered a stepping-stone along the way by some of them. The codes used to define *Energy* as a theme:

Code	***Appearances***
Biofuel	14
Consumption	4
Efficiency	9
Electrification	53
Fossil Fuel	20
Infrastructure	21
Transition	37

Table 6. List of codes in the Energy theme.

The exact path of this transition is unknown. However, the informants do provide some predictions on how it comes about, and what it takes to switch away from fossil fuels. Some informants view biofuels as a stepping-stone in the transition, others view it as an unnecessary

step along the way. The end goal, however, is not contested: emission-free machines will be the norm. The perspectives of the informants vary – not only in the sense of their point of view, but also the perspective of time. Informant 8 and 9 A&B focused mostly on a shorter time frame and what can be expected by the industry right now. This is a practical perspective, and is exemplified by informant 8:

> Many times, the market wants, without seeing the consequences of what they ask for. Of course, you would like zero emissions from a construction, and it is open which alternative they ask for. They could ask for, if it is fossil-free, vehicles with HVO-diesel, then we can deliver it. What I think there is too little focus on is Euro 6 diesel engines, they are also almost emission-free if you look at the CO_2- table behind it.

In this energy transition, there are quite a few obstacles. One of which, when discussing electrification, is infrastructure. Having sufficient grid capacity to ensuring not only energy access (Wh), but also sufficient power outtake (W). In urban areas this is rarely an issue, but not all areas have the same availability of electricity as the cities. Informant 6 summarized it as *"(…) it is easier to demand electrical in Oslo than on Hardangervidda (…)"*. However, even urban areas may struggle eventually if every machine running in the city requires connection to the grid. Several informants brought up an opportunity related to this issue: mobile battery banks. These are, however, struggling to cope with larger machines – from 10 tons and upwards.

Phasing out fossil fuels

Unless the plan is to reduce the amount of work being carried out, phasing out an energy source consequently means to introduce a different energy source. In shorter terms, biofuels are viewed as the most viable option. According to several informants, either electrical or hydrogen may eventually become the main source and/or carrier of energy. However, none of these comes without hiccups.

Based on the statements of the informants, biofuels are a realistic option in the near future. Several municipalities and other public entities are already using it as a criterion – either as an option with a bonus or as a requirement. There are, however, a few concerns among the informants. Once again, the issue of cost presents itself. Biofuel is more expensive than

conventional fossil fuels, and it needs to be compensated to be competitive. Informant 9A is clear about how the public entities should spend their money in this transition:

> The technology which is available per now is diesel engines fueled by biofuels. That is what we should bet on and put our money in, but we have not done this. There are some criteria for fossil-free fuels, which is quite a bit more expensive than conventional fuels. And if they would use the money to equalize these differences – and to give fossil-free an advantage – then we would be on the right track.

As mentioned, in the long run electrical and hydrogen-powered machines is seen to be the most relevant. Electrification of machines would be a way of making the energy consumption more efficient. When converting the amount of energy needed to operate an excavator – or any other combustion engine – there is a large potential to consume smarter and more efficient, as Informant 2 estimates, transitioning from conventional machines to electrical machines would reduce the energy consumption from 60 TWh to 10-12 TWh on a national basis. This is because as an electrical engine is far more efficient than conventional combustion engines. But this does not come without complications – which will be discussed in following sub-chapter, *'Issues of the grid'*.

Issues of the grid

Electrification of different industries is widely discussed, also among the informants. In addition to the perspective of energy consumption, the power outtake needs to be considered. With a growing demand for electrical vehicles, machines, trucks and more, the distributional power grid is under pressure. Informant 1 describes the situation in Rogaland:

> (…) in many areas, in Rogaland as well, there is currently not good enough infrastructure to electrify everything. That means that we reach the ceiling very fast. If we were to electrify absolutely everything today, that would not be possible.

The power grid would simply not cope with the increased demand from a complete electrification. This is pointed out by several informants throughout the interviews. This is often viewed as less of a problem in urban areas, but the significance of this challenge grows as one

travels further away from the cities. Several solutions to this problem are discussed by the informants. Large, mobile power banks are frequently mentioned, and could provide opportunities to charge the machines in rural areas. Some mention hydrogen as a solution to this issue in the long run.

The need for electrical machines and the lack of infrastructure causes concerns. For private actors, making investments in electrical machines is currently a big investment. Few of these would make this investment if there were not available electricity to charge these machines. At the same time, expanding the electricity grid is expensive. These two aspects put up against each other is mentioned by several informants, here addressed by informant 5:

> On one hand you need the machines, and on the other hand you need the power or fuel. So, it is the chicken and the egg. If you got electric trucks without electricity, they would not work. And if you have electricity, but no trucks, that will not work either. You need both.

This challenge presents the need for both coordination and making the consumption of energy more efficient. The coordination between actors involved in infrastructure expansion and consumers is important. Either one need to make sure the power grid is adequate to handle large power outtakes of machines and other electrified objects, or there needs to be mobile charging solutions. These charging solutions, which is mainly battery banks/containers, also need to be charged at some point. Thus, charging stations and logistics built around this is also a part of this. The challenges related to infrastructure encompasses the complexity of aspects and involved actors in this transition.

5.4 Technology

The theme *Technology* is related to technological aspects of the transition. What technologies are available? How does the different informants view innovations? Renewable sources of energy generation, storage and use are included in this theme. Construction machines, both conventional and unconventional, are a part of this. It will operate under the definition: feasible innovations and technological aspects of generation, use and storage of energy.

Code	*Appearances*
Battery	27
Construction machines	48
Innovations	54
Solar	7
Technology availability	11

Table 7. List of codes in the Technology theme.

In general, most of the informants are optimistic and positive regarding the technological side of the transition. There are, although limited market availability, several available technologies which can potentially contribute to reducing emissions from construction machines. However, there are some concerns among the informants – especially for larger construction machines. Current technological status for remote, mobile energy sources are not good enough to compete on the mainstream markets.

Another technology aspect is time – the speed of development, and the rate of substituting the machines in the current machine park. With an excavator having an expected lifetime of 5 years, changing machines will take a long time. Procuring a new excavator is an investment for the companies, thus it will not be replaced until it has to be. However, the rate of replacing machines is – in an environmental and resource perspective – relatively high. Informant 7 views electrification of excavators as a big opportunity for the industry:

> (…) now we can keep the machines operative longer. We know that a combustion engine – the bigger, the more complicated and rougher use – starts to cough from 7000-12 000 hours. An electric engine last for 50 000 hours. This makes it possible to develop programs to reset the machines, so that you as an entrepreneur can have a machine for 10-15 years before thinking of replacing it. Today the rate of replacing is 5 years.

Technological optimism

By being innovative, rethinking solutions, the construction industry has great potential. The informants vary in the perspective and optimism – and their level om ambitions for the industry. Informant 7 mentions the potential of autonomous electrical excavator – self driving machines. Other informants, such as informant 8, is optimistic in the belief in the smaller things – a

practical, step-by-step approach. The informant exemplifies this by referring to an ongoing project of making energy-neutral lifting cylinders. By using a generator to capture the energy from the slewing bearing and giving it to the cylinders. By doing so, they save 20% of the diesel consumption. Such projects are essential to gain experiences, boost competence and reduce energy consumption.

Across the board, there are optimism for the technological development in the construction industry. There is little doubt that the actors in the various industries will cope with the challenges they are facing. There are, however, some informants who are not convinced of the current technology for emission-free excavators. Informant 9A refers to the project in Olav Vs gate, where they had an excavator connected to a cable. There are practical aspects to this which makes cause for valid concerns for the informant. Referring to technology available in the 1980s, informant 9A cannot see the difference between then and now regarding electrical excavators from then and now. The excavator the informant refers to is a Brøyt X50EL, which is an electrical excavator that was in fact used in a project in the period of 1982-1985 (Fyksen, 1985).

Challenges facing large machines

There are, among many informants, skepticism related to electrification of large construction machines. The power outtake necessary from the batteries or cable is significantly higher than from a smaller machine. In addition, the cable coming out of the rear-end of one of the machines in Olav Vs gate is not popular among entrepreneurs, due to its impracticality. Several informants believe that they will overcome these obstacles in the long run. Informant 8 is positive that the technology will eventually be competitive:

> They are working a lot on it, but it is a question if it is moving fast enough related to how fast they want it emission-free. It will be challenging. I think it will take longer time than we expect.

There is need for development and changing the character of the production and the products will take some time. However, the most sold excavator size in Norway, 8 tons, are not regarded as a large machine in this context. Thus, ensuring sufficient solutions with access to electricity – either from grid or batteries – this is feasible within a shorter time frame. In general, the informants from private companies express a positive attitude towards the technological

transition, but are also firm believers in not sacrificing practicality for electrification. Incremental development seems to be the name of the game for these actors.

5.5 Policy

Plans and strategies for the transition - either by national, regional, or local public entities – are considered as important guidelines for long-term development for the construction industry. These documents and guidelines give an indication for how public authorities will act, and these indications provides what most informants are interested in: long-term predictability. Knowing where we are and where we are going is decisive when actors plan their investments, according to the informants. Procurement can serve as a tool for the public entities to guide the markets in their desired direction. Legislative aspects are also included in the *Policy* theme.

Code	***Appearances***
Legislation	7
Long-term predictability	22
Plans	28
Process	16
Procurement	30
Report	5
Strategy	9

Table 8. List of codes in the Policy theme.

The importance of plans and long-term predictability is a frequent aspect which informants highlights. Knowing where we are going, and which milestones there are along the way, can help both the suppliers and the public entities in reaching overarching goals – such as greenhouse gas emission reduction targets. Informant 1 describes the potential consequences of not planning and having a clear strategy as:

> (…) there is no plan for when the change is happening – it is just going to happen, thus the change will be expensive. As well for the companies which are delivering for tenders and the municipalities who are purchasing the services.

Informant 1 describes a lose-lose scenario, where none of the parties benefit from the lack of predictability. Plans and strategies can therefore shed light on the path – or at least the goal and milestones – to avoid fumbling in the dark looking for a solution. A tool which can be used effectively to carry out said plans, is procurement. To use procurement as a strategic tool, creating space for innovative technology and new actors, the public entities can accelerate the transition. When asked about the importance of predictability and a clear plan of what is going to happen, informant 5 replied:

> I think, on a scale from 0 to 10, it is close to a 10. Because, to say that now the plans are like this, and to set a plan for that in the time ahead it will be like this and this and this, and set a date – and describe the milestones. Then the technology suppliers will manage it.

A rigid system facing fast-paced companies

The legislative and bureaucratic perspective is also a source of frustration for some informants. Informant 3 is missing clearer directions and legislation from both Oslo Kommune and the national government. Informant 5, talking about solar arrays on public buildings, is worried about the pace of decision-making by public entities. The process and framework may, in some cases, be putting the brakes on the transition. Informant 6 and 4 is in contrast more positive to the legislation – and specifically the environmental paragraph of the procurement law.

> What may be a challenge is the pace – to avoid bureaucratic models to get this rolled out. We have a few ideas on how to do this. I also think that the public processes need to be simplified to get a faster pace on the implementation.

Informant 5, quoted above here - being the main voice of renewable energy companies among my informants, is frustrated by the bureaucratic and slow-moving processes of the public entities. There is a mismatch between the small, innovative companies in renewable energy and the public sector. Processes in the public sector may be a bit too rigid, too time consuming, for smaller actors.

What's on the horizon?

For the private actors it is important to have at least some idea of how the market and industry will develop over the next decade. According to Informant 1, investing in new, emission-free

machines prematurely is a risk few entrepreneurs are willing to take. On the flipside, when an entrepreneur is procuring a new, conventional machine today, it will be operative maybe 10 years. If the market is completely changed by then, and the market is solely interested in electrical (or any other emission-free) machines, the investment for the entrepreneur may be more costly in a lifetime perspective. In short, without knowledge and guidance of where we are going, and what to expect when, both the most optimistic and pessimistic actors could end up as losers in this transition. Consequently, actors may sit on the fence, waiting for directions. Informant 1 emphasizes the importance of a green strategy from public entities:

> Without such a strategy and without an approach, and a plan for dialogue with the market, this will move very slowly and many companies in private businesses – who are delivering services within construction – will most likely get burnt. Consequently, they do not dare to make investments because they do not get to capitalize on the investments.

The question this all boils down to is: where will the market be in 5, 10 or 15 years? The longer trajectories into the future, the more uncertainty. Such strategies serve as a pointing pin for where the development is heading. The details of the development are, of course, also bound by uncertainty. Informant 6, speaking on behalf of UKE in Oslo Kommune, considers predictability as a key factor for the construction industry. When discussing their procurement strategy, the informant says:

> So, what we are trying to do is to give them as much predictability as possible, by saying that in four years emission-free will be a minimum requirement, and that we try to award the ones investing towards this. I think it is very important for the construction industry, and that we stand by this strategy – so it is possible to plan around it.

By providing predictable frames which the entrepreneurs and other involved companies can plan around, is important. What UKE is doing, is to use procurement as a strategic tool to achieve the desired results regarding technology and innovation. By taking advantage of their market power, the public entities may use procurement to achieve their goals. Informant 9A, which in general was skeptical to a fast transition, considers procurement to be an opportunity for the public sector to influence private companies. The informant estimates that several

companies in the construction industry – both small, medium, and large – has around 80% of their turnover from public procurements. The impact can, if rooted in realistic expectations, be monumental.

5.6 Emissions

During the interviews, the main focus was on the energy transition and the construction industry – with procurement as a focal point. Even though the technology discussed are *emission-free* construction machines, the focus was on the technological, economic, and societal side of the transition – not the emissions itself. *Emissions* of greenhouse gases were not directly emphasized. However, even though not in focus, it was frequently mentioned throughout the interviews. Hence, it is regarded a separate theme in this analysis. It is important to note that emissions are relevant in a wider context, and the objective to reduce emissions serves as a foundation for the transition discussed with the informants. The following codes represent the theme *Emissions*:

Code	***Appearances***
Emission-reduction targets	16
Exhaust	7
Greenhouse gas (GHG)	21
Health, Safety & Environment (HSE)	4
Local environment	15

Table 9. List of codes in the Emissions theme

The interviews were conducted based on an assumption that the informants were aware of the international agreements and commitments to reduce greenhouse gas emissions. However, there are several ways of which to consider emissions. Informant 7 started off with the national target as a foundation for our conversation, and emphasized the importance of policy tools to achieve them:

> (…) if we are to reach the target by 2030… They do not fully agree how much CO2 we are going to cut by 2030, but between 50 and 55 percent is the latest

> number. And if we are to reach it, and the industry were to transition on its own, we would not reach it by 2030.

For the local environment, reduction of emissions is relevant in the sense of air quality and noise pollution. Informant 5 focuses on this, pointing at reduced diesel consumption by switching from diesel generators to batteries the fleet of a fish farm had positive effects for the environment which it is a part of. There is also a health and safety aspect of this, which were brought up by several informants. Opposed to combustion engines, the electrical machines do not make any noise. In urban areas this would reduce the noise impact for external actors, such as people living and working in the area around the construction site. In the construction site itself, communication is easier as the noise pollution is significantly reduced. Informant 6 refers to the report on Olav Vs gate by Bymiljøetaten (2020), pointing at an interesting aspect:

> Less noise pollution, less load for workers in general – the workers are less tired after the work day ends, compared to a normal construction site – that is a huge benefit for the entrepreneurs.

Planning products and logistics

There are several codes from other themes which would fit into Emissions – or at least some aspects of the codes. Logistics and planning could – in the right context – fit nicely into the emission-perspective of the transition. Reduction of emissions may also encompass waste. Informant 3 sees a bright future for prefabricated products and solutions, which could reduce the amount of waste on a construction site significantly. This would require more comprehensive planning of the projects, but there are clear benefits to it. Planning the logistics to and from the construction site could also contribute to emission reduction. There are both economic and environmental value of making such processes more effective.

Friendly neighbors

Nobody likes their noisy neighbor. And, for a long time, the construction machines have been the noisy neighbor. By getting rid of the combustion engine, the construction machines make less of a negative impact on the surroundings in terms of noise. Informant 7 presents some of these benefits:

> What we see is that the electrical machines do not make any noise anymore. So, the feedback from the pilot project in Olav Vs gate was, from the stores and restaurants and offices around (…) that one could work as normal, despite it being a big construction area right outside in the street.

Another benefit is the one on the local air quality. Without an exhaust, the electrical machines do not contaminate the air – thus reducing the local impact even further. Informant 6, who is working towards Oslo Kommunes goal of 95% emission-reduction by 2030, is keen on putting all exhausts to a halt, replacing it with a clean energy carrier. Reduced impact on externalities is a good argument to why this transition is desirable.

Safety first

A safe and healthy worker is a happy worker. The safety of the workers is inevitably an aspect to include. In addition to the positive effects for externalities, there are benefits inside the fences of the construction site as well. With reduced noise pollution, communication between the workers, and other possible long-term effects, are made better. This is emphasized by several informants – the HSE-perspective of getting rid of the combustion engine. Because, on one side you have the noise aspect, but the air quality is also better. Standing next to, or in the near proximity of a combustion engine, may have negative health-related effects on the workers, that one could avoid by using emission-free machines.

6. Discussion

In this chapter, aspects beyond the construction industry are discussed. The case in Olav Vs gate and the perspectives of the informants is – as well as a perspective on emission-free machines – perspectives on procurement, innovation, and the energy transition. None of this happens in a vacuum and can – and should – therefore be viewed in its context and relation to other aspects of the transition. The previous chapter, Chapter 5, focused mainly on the implications, challenges, and opportunities for the construction industry in Norway, with public procurement as the foundation. In this chapter, however, we will take a step back to get a greater overview of how this relates to other perspectives on innovation, energy transitions and procurement. Based on the analytical framework, the case and the findings, this chapter aims to answer the second research question:

- *How can criteria in public tenders play a part in overcoming obstacles of the energy transition and innovation?*

By connecting the findings from the previous chapter to the analytical framework of the MLP, Transition Pathways, and Transition Management, a bigger picture can be drawn. The transition to emission-free construction machines is a combination of several ongoing transitions which in sum is one large transition for the construction industry. And this large transition is merely a small part of the larger ongoing energy transition in a wide range of industries. It can therefore be viewed in steps, or themes, based on the desired perspective. On the one hand, this transition is the growth and development of battery technology, which is a transition of energy carriers and sources. The effects of this, as we will discuss later in this chapter, is not only related to the consumers, but it also has major ripple effects on the supply chain of incumbent companies and actors which operate in industries related to construction. On the other hand, it is a transition from traditional cost-dominated public procurement, to procuring and using public means to reduce greenhouse gas emissions and to trigger innovation. A shift in the way public entities use their market power, and weigh the award criteria in tenders, may have a significant impact on a wide range of actors.

Based on this, I have broken the discussion down to three main aspects and dynamics: cost and market power; the ripple effects of the transition; and the big picture. The latter aspect is related

to the research nexus which describes the interplay between policy, innovation and market. The nexus illustrates how different actors and dynamics operate in relation to one another.

6.1 Purchasing change

Changes come about both when actors expect it and when they do not expect it. Planning – making both the timing and nature of the change somewhat predictable – is crucial for how these companies cope with said changes. Being able to see what is ahead, and how one needs to adjust to changes, is a crucial factor in whether a company comes out as a winner or loser form the transition. Neither the public entity trying to achieve a set goal, nor the company supplying the necessary goods or service, benefits from an unpredictable path ahead. If there are changes on the horizon, and the public entities communicate this properly, the companies can reorient themselves. This is a strategy for public entities who may wish for a deliberate transition towards more sustainable practices (Roberts & Geels, 2019). For the private companies, this predictability may be key for them to prepare, get ahead of the change, and – frankly – stay in business.

Communicating the goals are important. However, communicating goals, without sticking to them, will not get you any further. When reconstructing the structures which in sum is today's society, using your policy-toolbox is good place to start. By subsidizing desired products, taxing undesired products, or setting criteria and requirements in public tenders – governments can alter the direction of development towards what they perceive as the right direction. This may create windows of opportunities for innovative niche technology which previously did not fit into the regime structures (Geels, 2011). Thus, one can even claim that requirements and criteria in public tenders express the current structures of the regime, and that the public entities have a significant role in this transition – especially in the construction industry.

In a deliberate government-driven transition (Roberts & Geels, 2019), public procurement may be a useful tool for the public entities. The market is likely to be shaped and adjusted to the current structures which the government now intends to alter. This entails consequences for both existing regime actors and emerging niche actors. In this case, emitting less greenhouse gases are the main goal. The current structures are emitting too much of undesired gases, hence there are need for change. By using procurement as a tool to carry out policy, the government – or any other public entity that may serve on behalf of the government – sets requirements and criteria in public tenders. These criteria and requirements may exclude some of the current,

conventional technology which the suppliers use. They may also encourage new, less-emitting, technology, and make it more competitive. In short, on one hand, what the government are doing is to open the door for new actors to access the market. On the other hand, the government incentivize regime actors to reconfigure and to be innovative within the new frames. Consequently, the government get innovative ideas and concepts in return, either as a result of regime innovation, niche emergence – or a combination and cooperation between regime and niche actors.

When setting requirements and criteria, as described in the paragraph above, communication and collaboration between regime and niche are important. However, equally important – or maybe even more important – is the communication and collaboration between the regime actors themselves. To keep the development at a realistic, feasible level – avoiding overly-ambitious plans – the regime actors need to cooperate. Unrealistic plans and goals, represented by ambitious criteria and requirements in tenders, may not lead to progress at all. As informant 9A described in the interview, having unrealistic requirements leads to frustration among the suppliers – and maybe even reduced faith in the ones publishing the tenders. However, the regime readiness is also of importance. Most informants agree that this transition is coming up, and a necessary step for the industry. Questions of how and when the transition will occur – or be finished – however, is contested. But, in a MLP-perspective on transition pathways, this perceived readiness makes it possible for the regime actors to reorient and take action before it is too late (Geels et al., 2016).

In situations where the communication and cooperation are good, such as the case in Olav Vs gate, the relationship between the procurer and the suppliers may be fruitful. By opening a dialogue early on, involving relevant actors, and sharing knowledge, involved actors may find common ground, and have shared goals which they want to fulfill.

Pilots as protected spaces

Throughout the interviews the concern of technological maturity of electrical machines surfaced frequently. At this point, these new machines are no way near good enough to compete with conventional machines – both in price and in operation. There are, however, there is an increasing need for emission-free machines which eventually can replace the conventional machines. Hence, there is a need for established businesses related to machines (regime actors) to support new businesses (niche innovations). This interaction, where the development is

managed towards a long-term goal, is crucial for both the suppliers of the niche innovation, and the regime actors – which is both construction companies and procurers.

Innovations at the niche level of the MLP occurs in protected spaces (Geels, 2011; Geels & Schot, 2007, 2011). This indicates development and research in arenas where there are limited outside factors causing disturbance and the risk of failure is not as dramatic. The case study of the pilot project in Olav Vs gate can be regarded as a protected space in this context. In this project, regime actors from the public sector, construction companies and grid operators cooperated and gained experiences with emission-free construction machines, seeing the implications of electrification. These experiences are of both technological, practical and procurement related nature, and can be used to shape the next innovative project. After the end of the pilot project the various involved actors may have different experiences and perspectives of what was learned. Sharing this, building the competence together, may be crucial for an effective transition.

Although there are some concerns about the technological maturity of these heavy machines, there are a fundamental positive and optimistic view of future development among the informants. If it is asked for, as criteria and requirements in tenders, the technology companies are likely to manage it – if given sufficient time to develop. Keeping this in mind, the helping hand from the regime in the MLP can be used. As described by Roberts & Geels (2019), the regime can, by managing and deliberately transitioning, help niches accelerate their growth into the regime. This may result in a faster transition with a clear direction – which is beneficial for both the private companies and the public entities.

As shown in Figure 6, one can see a large arrow coming down from the regime level to reach down and assist the niches emerging. This illustrates the act of regime actors deliberately transitioning by deflecting politically. One of the policy tools which can be applied to assist these niches, are public procurement. PPI, used strategically to carry out public policy, can thus be a way of providing necessary market access and experience for less mature technologies and actors.

Dynamics of niche emergence

As presented in chapter 3, there are several theories which can be applied to analyze and interpret this transition. The transition pathways provide a framework for understanding how

transitions come about – and how they develop. The timing and nature of the interaction is decisive (Geels et al., 2016; Geels & Schot, 2007, 2011). The immaturity of the current available technology makes a substitution close to impossible in the construction industry. At this point, being in the starting pit of the transition, it is difficult to see which pathway is most relevant. However, the paths where the niche is sufficiently developed are excluded. That leaves us with transformation and reconfiguration. The existing actors in both of these pathways are not directly threatened by the niche innovations, as there are opportunities to adjust to upcoming changes.

Procurement can be seen as a tool for the policy regime actor in affecting both other regime actors and niches. In the dynamics of the MLP, the regime actors are locked in by mechanisms providing stability and structures. Fluctuations from a policy regime actor, if significant enough, can cause breakage in the structure of the regime (Geels, 2011). One way to cause such fluctuations is to set requirements and criteria in public tenders. By using its market power, flexing financial muscles, the public procurers may demand the other regime actors to change. Being responsible for, according to informant 9A, approximately 80% of the turnover for construction companies, this market power is significant. When the largest customer of the industry is changing, the industry itself have to change as well in order to survive.

This could create a window of opportunity for niche innovations, such as batteries, or electrical or hydrogen excavators – or any other emission-free energy source and/or carrier, for that matter, to get a foothold. PPI (Public procurement of innovation) can be seen as a way to exploit the power of procurement to support niche technologies. In a way, when procuring innovative solutions, the regime actors reach down into the niches and help semi-mature technologies develop. As these innovations are not competitive – yet, at least – they need to be nurtured and helped along the way until they are mature enough. This is in line with a deliberate transition, where the end goal is formulated, but the way to get there is not. How extensive the effects of the transition turn out to be may be the decisive factor of whether a transformation or reconfiguration path is the best describing the transition.

Friend or enemy?

As emphasized by several informants, and also by Bymiljøetaten (2020), the issue of cost becomes apparent early on. With expected increased upfront cost, for both the public entities and for construction companies, there are need for making the technology economically

desirable. When deciding how to approach this, the public entities can be either friendly or play hard ball – a question of carrot or stick.

Being friendly to the suppliers is a good way of keeping a good relation and to help suppliers. This could be by giving bonuses or more weight to criteria which incentivize less-emitting alternatives. Oslo Kommune (2021) is already doing this in practice, and communicates it through standard requirements and criteria. By doing so, the municipality assists niche actors in gaining access to the market by bringing forth their solutions. Several of the informants agree on the fact that being friendly is the ideal way to do it for the public. There are, however, a few cost-related implications to carry out such policy. If the government is being friendly about it, avoiding putting heavy taxes on fossil fuels, how are they financing the increased cost of procurements?

Opposed to the friendly approach of giving bonuses to the desired solutions, are taxing undesired solutions. By punishing the use of conventional fuels, the public is less friendly. However, this approach may be just as effective in reaching their desired goals for the transition. This may even be more cost-effective as well, as the public sector makes money on this kind of taxes. The tax on emissions is one of the most important policy tools for the government in Norway (Finansdepartementet, 2020). To use a combination of the friendly and the less-friendly approach may be the most effective way to carry out government policy. Using the income from increased taxes on fossil fuels to subsidize emission-free/less-emitting alternatives can be done in a predictable manner and assist the industry in transitioning towards more sustainable solutions. Subsidizing, in this context, is both supporting the development of desired technologies, and giving advantages through award criteria in public tenders. This is in line with several informants' opinions, and necessary to change an industry who is unable to transition fast enough on its own.

6.2 Ripple effects

Related to a reconfiguration pathway, there are many externalities in this transition. When transitioning from fossil fuels to electricity as an energy carrier, it affects several actors. The supply-chain for construction companies is massively disrupted, thus altering market structures and power structures. As a result of changing structures in the construction industry, suppliers of e.g., fossil fuels, may be seeing a reduced demand for their products. Others, such as companies within renewable energy, sees trajectories for increased demand for their products.

The construction companies could – if they are willing to reorient themselves – survive, they either win or lose. Often, this transition is a case of exactly this: winners and losers.

If a company were to change their entire machine park from conventional excavators, to electrical excavators, several structural changes would occur (Geels & Schot, 2011). One of these changes, in the perspective of electrification, is infrastructure. Grid infrastructure, charging infrastructure, accessibility of both enough energy and sufficient power outtake. As a result, the list of suppliers – the chain of suppliers – are altered. Some gain access through the changes, other lose their position. To avoid ending up on the losing side of the transition, the companies need to predict the development and adjust accordingly.

The extent of impact

Changes in criteria and transitioning to emission-free sources of energy does not just affect the companies bidding for the tenders. In fact, the companies bidding also need to procure the materials and equipment necessary to carry out the work. The changes made by public procurers can thus alter the behavior of suppliers far back in the supply chain. The actors in the supply chain can be regarded as regime actors as well and are essential for the delivery of products and services in many industries. Electrification of the construction industry thus have an impact far beyond construction itself. As we are still early on in a complex transition, the scope of the impact is not easy to measure.

The scope of the impact also determines the path which this transition takes. At this point, it is not possible to point at one of the transition pathways in the MLP to describe it. The extent of disturbance and alterations in regime actors' involvement decides whether it can be regarded a transformation path or reconfiguration path. However, both imply that the transition and the measures made are sufficient to cope with the overarching problem, which is a changing climate (Geels et al., 2016; Geels & Schot, 2007, 2011). As time goes, this may prove to not be the case. If the measures made fail to fulfill the need for changes in the way of conducting business, the path may be of a mixed sort. In such case, it follows a sequence of pathways, eventually leading to a collapse of the regime. This may be the most dramatic outcome of this transition.

6.3 The big picture

The research nexus of policy, market and innovation represent dynamics which affects each other in the transition. The interplay between these three dynamics serves as a foundation to

analyze the wider context of this thesis. Shifts and changes in one of the dynamics, may cause change in the other two. How do these dynamics affect one another, and which dynamic is the most influential? In this sub-chapter, these questions will be attempted answered.

Policy

Policy represents the public and intermediate actors, who attempts to fulfill governmental targets. A change in policy have different consequences for innovation than it has for the market and vice versa. In this thesis, policy is mainly represented through public procurement as a policy tool. Requirements and criteria in tenders are decisive for determining who can submit bids, thus it can be both inclusive and exclusive – dependent on each case and which side you are on. For construction companies, represented in the market, the public sector is an important customer. Procurement is an economical tool which can shift the demand for certain products and services in a significant manner. Due to its majority in construction companies' turnover, procurement has got a firm grip on construction companies.

When such a dominant customer demands new solutions, the construction companies must change to survive. This, of course, have to be coordinated across municipalities, counties and national entities. As described by informant 7, a lack of coordination may be a major challenge. According to the informant, Bergen Kommune was making the same mistakes as Oslo Kommune did a year before them – which indicates a communication problem. Why reinvent the wheel in each municipality? For construction companies to adjust to just one municipality's criterion, would probably not be attractive. However, if they are coordinated, the change in criteria can happen across the board. Market actors would then have to be innovative themselves in the way they go about their work or cooperate with actors in the innovation dynamic. Thus, procurement does not only push market actors to change, but it may also facilitate and incentivize communication between market actors and innovation actors.

Procurement can also be used directed towards the innovation actors. Immature, or semi-mature, innovations may not be competitive with the existing, established market actors, but a shift in demand could create momentum for these niche actors in gaining access to the market. Public Procurement of Innovation (PPI) is one way for procurers to provide this helping hand to the technologies who, in the long run, might become crucial to achieve governmental targets. As these innovations develop, this may put more pressure on the established market actors, who eventually needs to change to keep their position. In this perspective as well, there are incentives

for both market and innovation actors to communicate and cooperate in their development. The interactions of the dynamics and the effects of changes in policy can be regarded both as a support-scheme for niche innovations and a reorientation by regime actors.

Market

Representing established companies, norms, and structures, the market is the arena for many private actors. Companies which over time has established as customers for the public sector, while using the mainstream technologies, can be found in the market. The structures are strong, and change does not come about rapidly. To know where we are going, the policymakers have to know where we are – and the market is the best indicator to get a grip on the current standings.

In relation to policy, the market can operate as a voice of realism. The market could show the policymakers the limits of current technologies and have a voice in saying what is realistic expectations for future development. In this perspective, the market can be regarded as conservative of technologies, routines, and structures of today. As the skepticism of informant 9A indicates, overly ambitious plans, criteria and targets could make the market actors lose faith in the actors within policy, thus potentially thwarting the progress of the transition.

Actors in the innovation dynamics struggle to access the market – which usually is the main objective for such actors. The market can, if willing to, provide necessary assistance for these innovations and facilitate opportunities. This can be especially relevant if the market actors predict large changes coming up ahead and they themselves are unable to come up with solutions in time. Internal innovation in the market is often incremental development and adjustments to existing products. Taking in radical innovations can be necessary to keep their market position – or simply an opportunity to invest in technologies which they foresee as a contribution to the development. Thus, market actors may benefit from being proactive rather than reactive.

Innovation

The actors in the innovation dynamic represent the arena which shows both market and policy the possibilities of the future. Innovative actors may be small and swift in their movement. New actors emerge frequently, as well as ideas and concepts fail maybe just as frequently. For the policy actors, the innovation dynamic represents the ones thinking outside the box. Radical innovations, technological development, and long-term opportunities is the name of the game

for innovation actors. This can serve as a guide of what to expect regarding development and progress. Providing this sneak-peak into the future, innovative actors may be important for policymakers in their planning.

Innovations may also serve as a problem solver for established market actors with their out-of-the-box thinking. As the innovative technologies mature, they become more competitive, and could also be push market actors to adjust their behavior. Depending on the situation, these actors could either in a harmonic relationship, or in a competitive one – described as symbiotic and competitive in the MLP. The project in Olav Vs gate shows a harmonic relationship between all the three dynamics, where actors from each of them benefit from each other. With innovative technologies opening the doors for new opportunities, both policy and market can benefit from this.

6.4 Analytical implications

When discussing the topic of public procurement and the energy transition, a common view among the informants can be summarized as such: however uncertain the development and transition may be, there has to be some predictability. Collaboration and communication are crucial factors in the dynamics, and may hold the key for a successful, deliberate transition. To provide such predictability, the coherence between spoken goals – such as climate mitigation goals – and action – such as procurement and other policies – must be clear to all involved parties. If clear, the market actors are given a chance to reorient themselves.

Innovative technologies have a hard time competing with the established regime actors, thus they must be nurtured and given access to the market. Through procurement, the public entities may open the doors for such innovations – and close the door for what is considered outdated technologies. Other ways to provide access is through setting criteria and requirements – related to the spoken goals – to push the regime actors towards reorienting themselves, which could provide the necessary opening for niche innovations to access the market. Thus, there are several ways to create windows of opportunities through deliberate fluctuations among regime actors.

With great market power comes great opportunity. In industries where the public sector is a large or dominant market actor, a lot of power is placed in their hands. For suppliers to survive, they must adjust to changes in demand. In the case of the construction industry, where the public

entities have a significant market share, the ability to adjust is critical. Changes in demand for the construction industry is not an isolated change for the industry. The indirect consequences for actors in the construction companies' supply chain are also significant. Thus, the ripple effects may be significant.

Conclusion

Related to the first research question, the most important aspects of transitioning to emission-free construction machines in Norway are collaboration between public and private actors, increased cost, infrastructural challenges, and the current availability of emission-free construction machines. These aspects, and the interplay between them, represent the most crucial dynamics in this transition. In particular, the predictability of development, criteria in public tenders and economic incentives can be the decisive factors in whether this transition in Norway can be accelerated or not. There is a general belief in the technological development of electrical machines and engines for the time ahead. And, if given sufficient time and market access, these technologies will gradually become more attractive. Through cooperation between private and public actors, in addition to overcoming the question of how to finance the increased cost, the transition could prove to be both fruitful and efficient.

As a part of a larger context, and related to the second research question, this transition is affected by the rate of innovation and development of the energy transition in other industries as well. This development requires a demand for innovative technology and a will to invest, as well as available technology and supply of necessary products. Thus, setting criteria in public tenders could provide the necessary demand for innovations, and predictability for the suppliers. The aspect of collaboration between procurers and suppliers is a crucial and decisive factor in achieving an efficient and feasible energy transition. It is important for the public entities – and procurers – to be aware of their market power, and their ability to facilitate innovations.

Reducing greenhouse gas emissions in the construction industry is a complex case and requires adjustments and changes on several levels. One of these levels are the energy consumption by construction machines. Due to this complexity, this thesis has a narrow focus and excludes several other aspects of the transition for the industry. Other aspects, such as emissions from material use, heating and drying of buildings, and waste management from construction sites, are also key to ensuring a sustainable construction industry. In addition, the economic models to justify and make green and innovative procurement possible is also relevant. In a practical sense, in the context of the ongoing Covid-19 pandemic, there were some limitations in gathering data through the research period. I was not able to meet with any of the informants in person, which may have affected the contents of the interviews, and the interaction between the

informants and me. However, as digital meetings have become more relevant than ever the past year, this did not hinder me in connecting with the informants.

For further research, I suggest that other aspects of the construction industry are studied. In particular, the use of materials and management of waste from construction. For more complex and thorough research, looking beyond the construction industry itself, and how changes affect the supply chain of different products is of great relevance. Public procurement, used as a strategic tool, should be researched in other industries and contexts as well. It is especially relevant to research the potential for innovative procurement.

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