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Are Plus Houses the Future? A Model for Guiding Decision Makers based on Current Standards for Sustainable Buildings and Plus House Projects

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PROBLEM DESCRIPTION

The purpose of this study is to achieve a better understanding of plus houses in society today, what is required to construct plus houses (technology and other smart solutions) and finally, how to make the decision to build plus houses more straightforward. The main content of the study are the following:

- Introduction to issues and background for the study
- Outline of the construction industry and relevant areas to the construction industry
- Outline of relevant legislation and standards for sustainable buildings
- Use strategic tools to review the research issues
- Develop a model for decision makers that will make the decision to construct plus houses more straightforward
- Give recommendations for decision makers and other relevant actors

PREFACE

This thesis is the result of an MSc in Industrial Ecology at the Norwegian University of Science and Technology. The thesis was completed in the spring of 2016 at the Department of Industrial Economics and Technology Management with the supervision from John Eilif Hermansen. The thesis is a multidisciplinary and integrated study with tools and ideas derived from the different courses I have attended throughout the MSc in Industrial Ecology. The ideas are based in systems thinking, where you study a holistic system and then focus the research on the main parts of the system.

The interest in buildings originated when I was writing my project thesis in fall 2015. The project thesis made me aware of the massive potential buildings have to reduce their environmental impact, the possibilities that exist in for example becoming BREEAM-certified and by being introduced to Powerhouse Kjørbo it made me realise that this is possible also in Norway. Thus, I wanted to explore the concept of plus houses, what measures are required and why the expansion of plus houses like Powerhouse has not exploded.

Special thanks are extended to Øyvind Mork (Powerhouse and Asplan Viak), Arild Gustavsen (The Research Centre on Zero Emission Buildings) and Thomas Haugen (Veidekke) for their contribution to the study. I would also like to thank John Eilif Hermansen, Associate Professor at IØT, NTNU, for his helpful supervision, and genuine support and interest this past year.

Thanks to my classmates for the company and support these last two years. To be very cheesy: we wouldn't have made it without each other! A significant thanks is extended to Wenche for always being there and letting me switch living rooms when I wanted to. Lastly, thanks to friends and family for the support and encouragement throughout this process.

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ABSTRACT

Buildings have a massive environmental impact, both in terms of energy use and GHG emissions. However, the improvement potential is substantial. With the SDGs and the Paris Agreement, the construction sector must contribute to reach the set goals and requirements and utilize its full potential. Plus houses are one alternative to reducing the environmental impact of the construction industry.

This study provides a qualitative analysis of plus houses and other sustainable buildings and the possibilities for its expansion in Norway. Special focus is given to construction policy and existing standards for sustainable buildings. By reviewing existing research, conducting interviews and case studies, and putting the study in the context of strategic analysis, a model is created to guide decision makers on whether to construct plus houses or not. The model contains the most important factors found in this study that can influence the decision towards constructing more plus houses.

The study has indicated several important factors that are vital to consider when constructing a plus house. These include more focus on the cooperation process, setting BHAGs and budgetary restrictions and exceeding the prevailing regulations. Also, exploiting the current technology, being committed and ambitious, and using BREEAM as a basis. In addition, it can be a good idea to consider the environmental savings that can come from renovating instead of constructing new buildings. Further, the building policies in Norway are lagging behind. This is at the core of the development in the construction industry. If regulations are tightened, the construction industry must follow and the industry as a whole will reduce its environmental impact and see an increasing development.

The study has produced several recommendations, both on policy level and decision maker level. The main recommendation to policy makers are to tighten regulations today and be more ambitious when setting demands. For the decision makers, the main recommendation is to have a stronger focus on the early stages of the cooperation process and include all relevant actors in the earliest possible stage.

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ACRONYMS

BAE	Bygge-, anleggs- og eiendomsnæringen
BHAG	Big, Hairy, Audacious Goal
BREEAM	Building Research Establishment Environmental Assessment Method
DIBK	Direktoratet for byggkvalitet
EOL	End of life
EPD	Environmental product declaration
EU	European Union
IEA	International Energy Agency
KMD	Kommunal- og moderniseringsdepartementet
KRD	Kommunal- og regionaldepartementet
LCA	Life Cycle Analysis
NGBC	Norwegian Green Building Council
NetNEB	Net Zero Energy Building
nNEB	Nearly Zero Energy Building
NEB	Zero Energy Building
NS 3700	Criteria for passive houses and low energy buildings. Residential buildings
NS 3701	Criteria for passive houses and low energy buildings. Non-residential buildings
PBL	Plan- og bygningsloven
PESTLE	Political, Economic, Social, Technological, Legal, Environmental
PV	Photovoltaic
PVPC	Photovoltaic Power Systems Programme
SDG	Sustainable Development Goals
SWOT	Strengths, Weaknesses, Opportunities, Threats
TEK	Regulation for technical requirements for buildings (Byggteknisk Forskrift)
TEK10	Byggteknisk Forskrift from 2010 (the current regulation for construction techniques)
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
ZEB	Zero Emission Building

1 INTRODUCTION

Are plus houses the future? Passive houses and BREEAM-certified buildings are today’s most common alternatives to conventional buildings. Plus houses are receiving growing interest, but there seems to be some barriers to the expansion of this type of building. This study will look at current standards for sustainable buildings in Norway and concrete examples of plus houses to review what is really required to construct plus houses and how this should be done. The results will show a model that can be used for decision making related to constructing buildings, and how plus houses can be the best alternative.

The following presents motivation and background for the study, the research model and questions, the methods used and the structure of study.

1.1 Motivation

The motivation for conducting this study about plus houses came in fall 2015. I conducted a study on choice of materials and environmental product declarations (EPDs) and discovered the large impact the choice of materials can have on the life cycle impacts of a building. In addition, I was introduced to the office building Powerhouse Kjørbo in Sandvika. The interest for choice of materials and the potential to be more sustainable that is inherent in buildings are the main motivations for focusing on plus houses. What is stopping the expanding growth of plus houses? Are there any key characteristics or similarities that plus houses have in common? How can the decision to construct plus houses be made more straightforward? The following study will try to answer these questions.

1.2 Background

Buildings are responsible for up to 40% of the world’s energy use (Lucon O. et al., 2014, UNEP, 2009) and up to 30% of greenhouse gas (GHG) emissions (UNEP, 2015, Lucon O. et al., 2014, UNEP, 2009). This sector plays a very large role in our society today, and it is a sector that has the potential of mitigation and should be mitigated. Figure 1 displays how buildings interact with the environment before the operation phase, during the operation phase and after the operation phase. Sustainable buildings have an increasing amount of attention around the world, and in Norway since Powerhouse (2016d) with Powerhouse Kjørbo has proven that it does not require new and revolutionary technology to create buildings that are sustainable, this subject has received much attention.

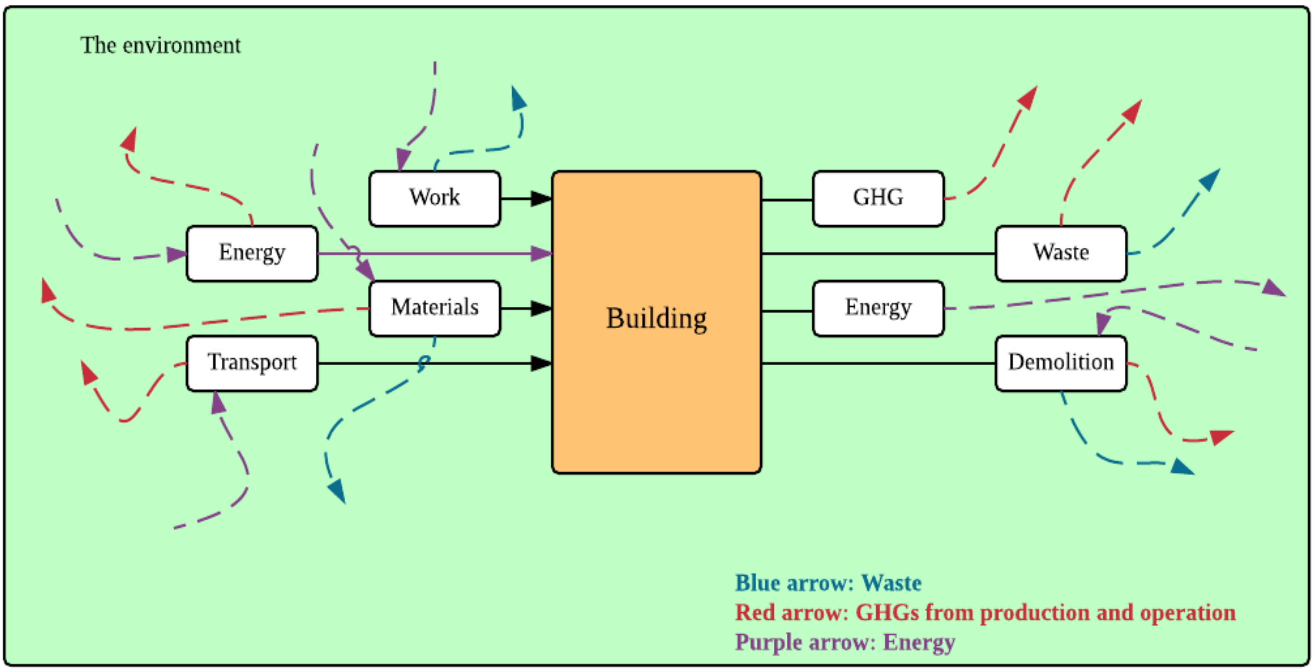

Figure 1: Illustration of how buildings interact with the environment

Sustainability has a large influence on the world today, and this influence will become larger and more important in the future. This is due to an ever-increasing focus on the environment and the impact we as a society has on the environment surrounding us. In December 2015, the Paris Conference of the Parties (COP21) resulted in 195 countries signing the first legally binding global climate deal. The Paris Agreement under the United Nations framework Convention on Climate Change (UNFCCC) is a result of understanding the importance of climate change and the commitment countries must have to stop it. The Paris Agreement is the first global climate agreement where all countries has agreed to work together to mitigate climate change and agreed to contribute together. The main goal of the Paris Agreement is to limit the increase of global average temperature to below 1,5° above pre-industrial levels which is more ambitious than the 2° target that has been a goal earlier (UNFCCC, 2015). All countries must set goals for themselves, these are to be revised every five years and the goals must become more ambitious for each revision (FN-sambandet, 2016). In addition to the Paris-agreement, UNs Sustainable Development Goals (SDG) was set in September of last year. These goals are to ensure sustainable development by ending poverty, protecting the planet and ensuring prosperity for all. Each goal has several sub-goals that are to be reached within the next 15 years (UN, 2016). Thus, the focus on sustainable development will influence all parts of our built environment and buildings can be a large contributor to sustainable development.

In addition to the Paris Agreement and SDG, Norway have its own goals for its climate policy. The climate settlement was agreed to in 2008 and 2012. Norway is to take responsibility for reducing GHG emissions through an active national policy. The goals concerning reducing GHG emissions are the following: By 2020, Norway is to cut the global emissions by 30% compared to 1990-levels. By 2050, Norway is to be carbon neutral. Other relevant measures include phasing out central heating based on oil, tightening the energy demands in the construction sector, expanding research on the climate and carry out a climate and technology commitment. In fact, when mentioning only nine measures, tightened energy demands in the construction sector is third on the list (Klima- og miljødepartementet, 2014).

The construction sector has a large potential and must take advantage of this potential to help achieve both the goals set in the Paris Agreement and the SDGs. This is due to the large impact buildings have today, and the potential the sector has to improve. Sustainable construction can be defined as:

> "…how the construction industry together with its product the 'built environment', among many sectors of the economy and human activity, can contribute to the sustainability of the earth including its human and non-human inhabitants" (Kibert, 2007, 595)

Another definition that is closely related to this is the definition of green or high-performance buildings:

> "A green building is one that considers and then reduces its impact on the environment. A green building uses considerably less energy and water than a conventional building… It also accounts for some measure of the life-cycle impact of building materials…" (Yudelson, 2009, 19)

Sustainable construction must consider all aspects of the construction of a building, before, during and after construction and all the involved actors must participate in this shift towards a more sustainable society. Both energy and materials used for construction purposes have a large potential to becoming greener and more sustainable.

Today, we see that buildings are becoming more sustainable, with passive houses and BREEAM-certified buildings being the most widespread alternatives to conventional buildings. These can be called high performance green buildings. These buildings shall consume less energy, materials and water and improve the quality of the built environment (Kibert, 2007). Plus house concepts that focus on energy and Zero Emission buildings (ZEB) that focus on emissions are expanding and are growing in interest. There is no plus house standard today, and according to Lexow (2016), there is no immediate plan for a standard.

1.3 Research model

A research model is a helpful tool to illustrate the route from the observation of issue(s) to the conclusion and possible recommendations. This type of model helps to organize the thoughts and see the connections between the larger and smaller issues.

Figure 2 displays the research model of this study. The dotted lines show where two connections influence each other both ways, while the whole lines show where one connection influences the other, but not the other way around.

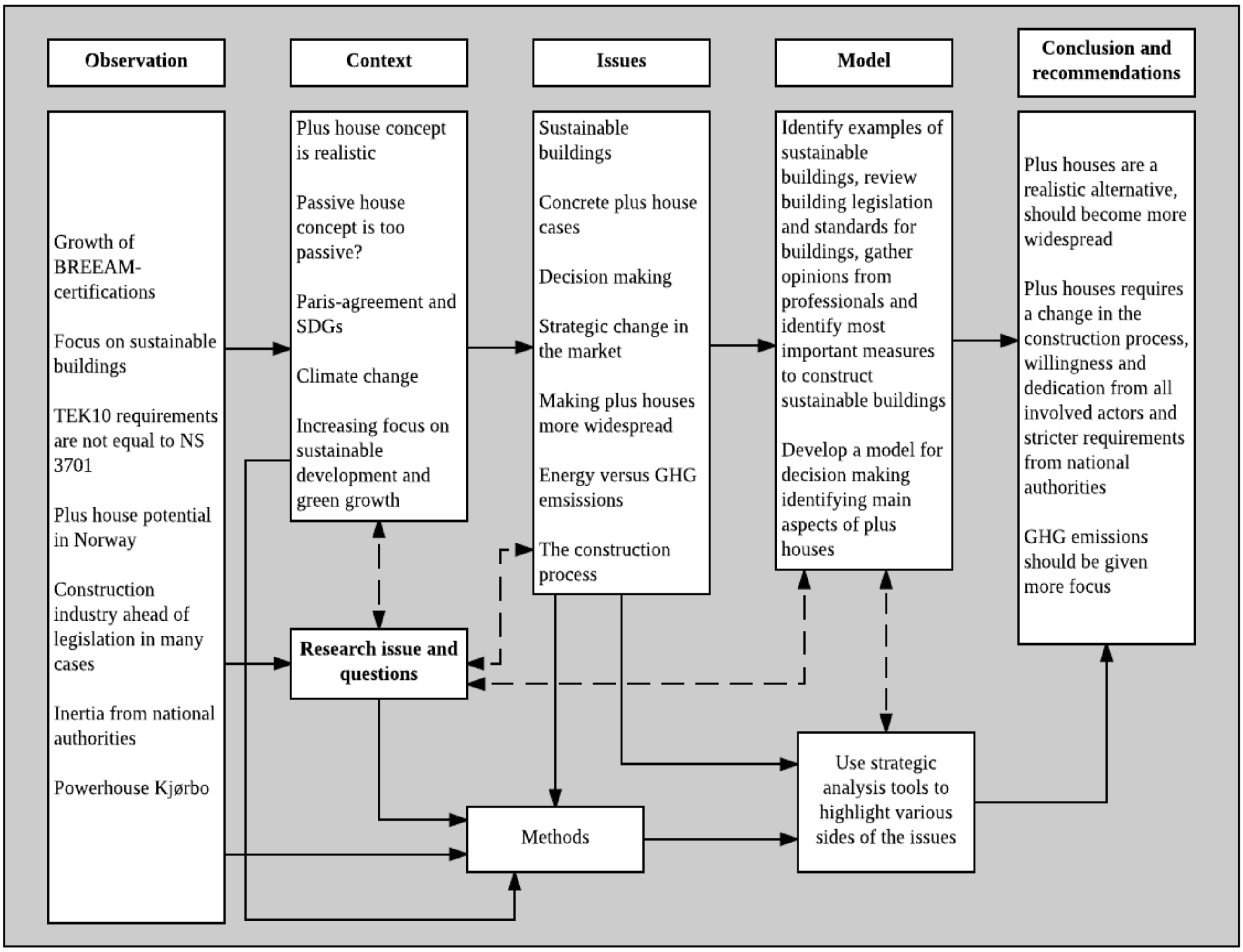

Figure 2: Research model based on Davis (1996)

The research model can also shows the system boundary of the study. In other words, the research model shows the delimitations of the study. It has been necessary to exclude other certification schemes for sustainable buildings, such as LEED. The main reason for this is that LEED is an American certification scheme, and to the author's knowledge, it is not used in Norway.

Economic implications and factors of plus houses will be mentioned, but not considered in depth. Specific technological and other restrictions and challenges to building plus houses and other sustainable buildings will not be considered. This study is rather an optimistic view on the opportunities that exist within the construction industry and the existing potential to be better and more advantageous.

Lean-process is not a focus, as this way of working mainly focuses on waste reduction. This study focuses on energy and materials. However, the idea of Lean is also based in creating more value while using fewer resources. Therefore, future research on the cooperation process should include Lean-manufacturing into the research process, as this is closely related to reducing the unnecessary use of materials.

1.4 Issue and research question

ISSUE AND CONTRIBUTION

The issue of this study is the considerable environmental impacts the construction industry has and the possible reduction of these impacts. The potential for improvement is substantial, but the progress to fulfil this potential is relatively stagnant. By constructing plus houses or other sustainable buildings, the environmental impact of buildings will be limited.

In 2015, two major measures were adopted to promote sustainable development and limit the global temperature from rising above unsustainable levels: the SDGs and the Paris Agreement. These measures will influence all parts of our society and the industrial sectors that contribute to climate change will have to adapt to the future of stricter requirements. This study will try to make the decision making process towards constructing plus houses clearer and see how this decision can preferred.

Plus houses are the main subjects for research in this study. Anda and Bjelland (2013) have been used extensively as inspiration and resource, as this book focuses on the process of transforming a passive house to a plus house. The cooperation process as a basis for constructing sustainable buildings has proven to be an essential factor in this study. Previous work on this has been carried out by Anda and Bjelland (2013), Yudelson (2009) and Throndsen et al. (2015) and this has formed the basis for this part of the study.

RESEARCH QUESTIONS

This study will develop a model for guiding decision makers to choose to construct plus houses. In addition, focus will be put on the outlook for plus houses, current legislation and the solutions required to construct a plus house. The research questions for this study is the following:

- How can the decision to construct plus houses be more straightforward?

This first research question is the main question to be answered in this study. In addition, the question in the title: “Are plus houses the future?” is an underlying question throughout this study. The following questions are more supportive questions that need to be addressed to be able to answer the main question:

- How are the prospects for plus houses in Norway today?
- Is current legislation facilitating and promoting sustainable buildings?
- Is a plus house standard necessary today? If so, what should it contain?
- What should be the focus areas before constructing a plus house and what are the main measures needed to construct plus houses?

1.5 Methods

This study will use three different methods to reach a conclusion, namely document analysis, case study and interviews. The reason for using mainly these three methods was to achieve a clearer understanding of the issue of sustainable buildings, and more specifically plus houses. Seeing as plus houses are not so widespread today, the literature on the subject is rather scarce. Thus, the choice to use three different methods provides a broader way of collecting data.

Firstly, document analysis is used to research the current state of standardization of buildings today. Governmental documents, relevant Internet sources and other relevant information is used to create a theoretical framework. Standards for conventional and more sustainable buildings will be analysed.

Secondly, interviews will be conducted to gather facts and opinions from professionals and researchers. The analysis of the interviews will contribute to the development of a model for guiding decision makers.

Thirdly, case study will be used as a tool to gather extensive information on the main case, Powerhouse Kjørbo, and how this renovation was turned into a plus house. In addition, other smaller cases will be reviewed to get an idea of how other projects have reached the plus house level and also lower levels of sustainable buildings.

The results from these three methods will be tied together by applying strategic analysis tools and further develop a model for guiding decision makers.

1.6 Structure of study

The research issue and research questions are examined in this study. Chapter 2 will present an introduction to the construction industry and the main areas within this sector that will be of focus. Chapter 3 introduces and outlines the methods used to answer the research questions. The theoretical framework is presented in Chapter 4. This chapter elaborates on relevant legislation and regulations, standards, the different types of building categories there are and the decision making process is discussed.

Chapter 5 presents the empirical data obtained for this study, such as information on the cases and the interviews. The analysis is presented in Chapter 6. The analysis of the interviews and the document analysis are outlined. The information gathered here is collected in a PESTLE-analysis and the main aspects are highlighted in a SWOT-analysis. Chapter 7 presents the results in a proposed model for decision makers. Chapter 8 discusses the analysis and the results, and an evaluation of the study is carried out. Recommendations are presented in Chapter 9 and Chapter 10 gives a conclusion of the study.

2 THE CONSTRUCTION SECTOR

The construction sector is a complex sector that includes a range of actors from construction workers to Governmental authorities. Buildings are responsible for a large amount of material and energy consumption. Due to the complexity of the sector, is necessary to take a closer look at the main aspects of the sector and relevant projects for sustainable buildings.

2.1 The construction sector and the construction process

The construction sector creates the built environment surrounding us within the limits set by authorities and the market (Bygg21, 2014). In 2012, there were over 4 million buildings in Norway. The building, construction and real estate (BAE: Bygge-, anleggs- og eiendomsnæringen) industry is the largest industry when measuring number of companies. 33% of all companies in Norway are BAE-industries. The BAE-industry is the second largest industry when measuring value creation and number of employees working in the industry. Around 13% of the population work within the BAE-industry (KRD, 2012). New buildings constitute around 1-2% of the building stock each year. The current trend predicts that the impact of buildings might double or triple by the end of this century. Much of this increase is due to the growth of wealth in developing countries, migration to cities and in general the population growth will affect the impact of buildings (Lucon O. et al., 2014). The main superior trends that will impact the design and shaping of new buildings and regulations for rehabilitation and new buildings are climate change, resource scarcity, increased urbanisation, globalization and migration, public safety and digitalization of society (Bygg21, 2014).

KRD describes the construction sector as a "*system of actors that are mutually interdependent*" (KRD, 2012, p. 21). Actors will be used as a term that describes someone who is involved and has a role in the construction process and sector. The most relevant actors in the development and implementation of construction policy outlined by KRD (2012) are public authorities, the construction sector, users and tenants and actors involved in knowledge and competence. The actors in the construction sector will be further discussed in chapter 4.6.

Figure 3 shows the simple route of a building process, from planning to end of life (EOL). In some cases, the phases are more or less straightforward, but in other cases, the building is a renovation project and then the EOL is reduced or minimized. Figure 4 is more detailed description of the life cycle stages of a construction process.

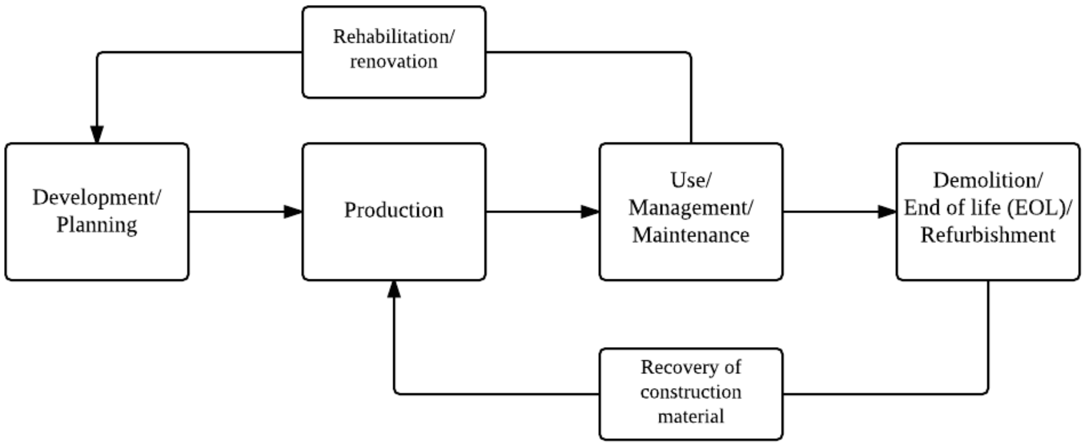

Figure 3: Simplified illustration of the construction process from KRD (2012, 21)

NS 15978, Sustainability of construction works, looks at the process of constructing a building. This standard divides the life cycle of a building into four stages, namely (A) product stage and construction, (B) use stage, (C) end of life and (D) benefits and loads beyond the system boundary and this is displayed in Figure 4.

Both Figure 3 and Figure 4 depict the same phases of a construction project. What is perhaps more interesting about this, is that both figures have a streamlined view of the construction process, where you construct a building, use it, demolish it and perhaps reuse some aspects of the building. However, another way of looking at the construction process is to view the whole process as rehabilitation. Thus, the building already exists and it is an opportunity to reuse and recover the structure, various components and materials. In this case, energy savings and GHG emission reduction is already done before the construction process is started because the starting point is an old building that will be fixed and used over again. In fact, by rehabilitating old buildings instead of constructing new buildings, the energy use can be halved (Bergesen, 2016a).

Stages of the life cycle of a building															**Supplementary information beyond the building lifecycle**
A 1-3			A 4-5		B 1-5					C 1-4					D
PRODUCT stage			**CONSTRUCTION**		**USE stage**					**END OF LIFE**					**Benefits and loads beyond the system boundary**
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4		D
Raw material supply	Transport	Manufacturing	Transport	Construction installation process	Use (B6 Operational energy use and B7 Operational water use)	Maintenance	Repair	Replacement	Refurbishment	De-construction/ Demolition	Transport	Waste processing	Disposal		Reuse potential Recovery potential Recycling potential

Figure 4: Complex figure of the life cycle stages (Standard Norge, 2011)

2.2 Energy

According to UNEP (2009), approximately 80% of the GHG emissions related to buildings, occur during the operational phase. This is due to using energy for different purposes, and this energy is largely based on fossil fuels. The energy demand in a building is mainly used for the following purposes: heating demand, tap water demand and technical installations and lighting (Killingdal et al., 2013). As will be more explained below, energy in Norway is primarily derived from hydropower. However, this is not guaranteed, because this depends on the availability of hydropower that in some cases can be lower than the demand, thus energy must come from the Nordic or European electricity grid. However, it is assumed here that most of the energy used in Norway comes from hydropower, making the energy very clean.

Approximately 80-90% of the life cycle energy use occurs during the use phase (Risholt et al., 2015, Khasreen et al., 2009). It is necessary, however, to have a life cycle approach to buildings due to the energy used and emissions emitted during all phases of a building: production, construction, use, maintenance and demolition.

Buildings in Norway are responsible for 40% of all energy use (Olje- og energidepartementet, 2016). According to the Government there is a very large potential for reducing the energy demand (DiBK, 2015). A step was taken towards a more environmentally friendly building stock in January this year, when the energy demands in TEK10 were tightened to be more similar to the passive house level (KMD, 2010). According to Miljøverndepartementet (2011), however, the Government wanted to have a passive house level by 2015 and nearly zero energy level by 2020. It remains to see whether the goal for 2020 is reached better than the goal for 2015.

The power sector is close to emission free, but use of energy in transport, industry, oil and gas extraction and heating leads to emissions of GHGs (Olje- og energidepartementet, 2016). Between 95-99% of energy production in Norway comes from hydropower. Hydropower is renewable, reliable, clean, flexible and a cheap energy source (Statkraft, 2009, Enova et al., 2016c). The main part of energy use in buildings in Norway comes from electrical power, and mainly hydropower (KRD, 2012, SINTEF and NTNU, 2007). A stated by SINTEF and NTNU (2007), hydropower development is not complete in Norway, and theoretically it is possible to provide all buildings in Norway with energy from hydropower. However, this should not lead to contentment with the situation we have today.

Heating constitutes a large part of energy use in buildings in Norway. For residential homes, around 78% of energy use is related to heating of buildings and hot water. The electricity share in this energy is between 70-80%. The rest has previously been covered by oil heating and wood heating. However, there has been a shift in the energy use in buildings in the later years, and electricity, district heating and heat pumps have become more common. In fact, the sale of oil heating has dropped 60% since 1990.

2.3 Materials

The construction industry is one of the biggest consumers of materials, water and energy, thus the sector is a significant contributor to pollution and waste generation. Also, the construction sector is often the largest sector in any country (Horvath, 2004). The largest amount of GHG emissions related to materials is dominated by production of steel, cement, plastic, paper and aluminium (Allwood et al., 2010). By far, the most important and widespread materials are steel and concrete. Concrete is the second most used material after water and is used for all parts of the built environment (WBCSD, 2009, Horvath, 2004). Out of all steel produced globally, 50% is used for construction (Worldsteel, 2015). In addition, buildings account for one-sixth of freshwater withdrawals and two-fifths of the material and energy flows (Guggemos and Horvath, 2005). To summarize, the construction materials and the energy used over the lifetime of a building are the most important factors when determining the environmental performance of a building (Asplan Viak, 2016).

When speaking of buildings, the embodied emissions are the GHGs released to the atmosphere when producing the materials used for constructing a building. This includes all faces of producing the materials: raw material extraction, transport and the actual production. It includes all emissions related to the building materials, both as a result of energy use and the production that can cause other emissions (Kristjansdottir et al., 2014). Greenhouse gas account (Klimagassregnskap) is a tool that can optimize the environmental performance of a building. If this tool is used early in the planning phase, the most important measures that need to be done will become clear and the planning can revolve around this (Asplan Viak, 2016). For example, whether to construct a new building or rehabilitate an old building can be decided by the greenhouse gas account. This was in fact the reason for why Powerhouse Kjørbo rehabilitated an old office building. If new steel and concrete for the structure had to be produced once more, the greenhouse gas account would have been over “budget” (Mork, 2016).

Bygg21 is long-term and broad cooperation between the construction industry and governmental authorities. The goal of the cooperation is to work together to better solve the challenges within sustainability, productivity and the cost evolution. Bygg21 has developed a strategy focusing on building the future together. A suggested goal for material and resource use is that by 2020, all construction projects shall prefer construction materials and installations that are documented by Environmental Product Declarations (EPD) (Bygg21, 2014).

EPD is an externally verified document that discloses the environmental impact of a product. Quantified environmental data based in life cycle analysis (LCA) must be collected to create an EPD (EPD-International, 2015). Zabalza Bribián et al. (2011) views EPDs as a tool that can help to adjust and harmonize the inventory databases of materials in the construction sector. Public institutions must put pressure on manufacturers to produce EPDs for their products. By doing this, products with EPDs will both become more attractive for customers and manufacturers will become more aware of the environmental impact of their products. EPDs can help in choosing the most environmentally friendly products. Two products can be compared, and if environmental concerns are the most important, the decision is made easier by having documentation that shows environmental impacts.

2.4 Projects for more sustainable buildings

Today there is an ever-increasing focus on making buildings more sustainable. This thesis will put focus on two Norwegian projects that are working to make the building sector more sustainable in both similar and differing ways.

Powerhouse is a collaboration between the contractor Skanska, advisor company Asplan Viak, architect office Snøhetta, property owner Entra Eiendom, aluminium profile company Sapa, aluminium producer Hydro and environmental organization Zero. Powerhouse is a collaboration revolving around building plus houses. Powerhouse Kjørbo is already finished and Powerhouse Brattørkaia in Trondheim is in progress, but is lacking a tenant. Powerhouse aims to demonstrate that building plus houses is also possible in Norway, and are doing so by exploiting each others strengths and being innovative (Powerhouse, 2016a).

The Research Centre on Zero Emission Building (ZEB) aims to eliminate GHG emissions caused by buildings. ZEB is working to develop products and solutions that can be applied in the construction industry to create buildings with zero GHG emissions from production, operation and demolition. The main objective is to:

> "…develop competitive solutions and products for existing and new buildings that will lead to market penetration of buildings that have zero emissions of greenhouse gases related to their production, operation and demolition" (ZEB, 2016).

3 METHODS

The following chapter presents the methods used in this study. It is a combination of analysing various documents, analysing cases and analysing interviews. These methods are combined to provide the reader with a holistic impression of the underlying issue of the study.

3.1 Document analysis

Document analysis has been a large part of this study. Plus houses are not widespread today, compared to other building categories. Thus, information on the subject has in a great deal been gathered from the Internet. TEK10, BREEAM-NOR and NS 3701 have been used as resources for the purpose of this study.

The study will use different examples of plus houses, BREEAM-houses, ZEB and passive houses to gather an understanding of the different concepts. Thus, the concept of cases has a strong role in the analysis. The sources that back up the cases are mainly gathered from respective companies that have been involved in the construction of the buildings.

3.1.1 INTERNET SOURCES

According to Bryman (2008), there are three main problems with using websites as sources of information. Firstly, the authenticity of websites can be a problem. Any person can set up any website. Secondly, credibility cannot be guaranteed on all websites. Thirdly, it is difficult to be certain on whether the information presented is in fact representative for the topic one is interested in. Nonetheless, websites have been used extensively as sources in this study. The main reason for the extensive use of websites is due to the fact that plus houses are a relatively new subject, and there is little scientific articles and books written about the subject. For example, the cases provided in chapter 5.2 are only found on different websites. Newer information regarding the development of plus houses and solar energy is too new to be in books yet.

Consequently, the reliance on websites as sources might be regarded as a weakness of the study. However, the author has been careful to use websites that are either connected to businesses or some known name/brand, or to some degree there is a third party that is responsible for the website.

3.1.2 DOCUMENTS FROM NATIONAL AUTHORITIES

The state is a good source both statistical information and textual material of possible interest (Bryman, 2008). In addition to the documents outlined below, White Papers, propositions, regulations, laws, directives and other official material has also been used as helpful sources.

TEK10

Byggteknisk Forskrift (TEK) is the Norwegian regulation for construction techniques further outlining and detailing the decisions set in the Plan and Building Law. TEK10 is the current regulation for construction techniques. It is the minimum demands the construction sector must abide to be able to construct buildings. TEK10 was updated January 1st of this year with stricter demands for energy, such as energy use and energy sources.

NS 3701:2012

NS 3701: 2012 Criteria for passive houses and low energy buildings. Non-residential buildings (NS 3701) (Standard Norge, 2012) is a Norwegian standard that sets the requirements for passive houses and low energy buildings that are not residential houses. *NS 3700: 2013 Criteria for passive houses and low energy buildings. Residential buildings* (NS 3700) (Standard Norge, 2013) is the same standard for residential houses. This study will mostly focus on non-residential buildings; therefore NS 3701 will be used as the main reference in the following study.

BREEAM-NOR

BREEAM is not technically a state document, but the Building Research Establishment, which established it, was previously a UK Government establishment. Thus, it goes under this category for this purpose.

There are many types of rating systems for buildings. DGNB (Germany), Green Star (Australia), CASBEE (Japan), Minergie (Switzerland), LEED (USA) and BREEAM (Great Britain) are the most well known today (Bauer et al., 2010). However, this study will focus on BREEAM, and more specifically BREEAM-NOR, as this rating system has been translated and modified to comply with Norwegian rules and regulations. BREEAM is an integrated classification system for buildings and real estate that focuses on the environment and health. It is the most common environmental classification system for buildings. BREEAM-NOR is the Norwegian adaption of BREEAM, including relevant standards within the areas of energy and environment (NGBC, 2012).

3.1.3 CASES

According to Ringdal (2007), a case study should capture the complexity of a case and focus on the unique aspects, rather than the general. The object should not be to tie a case up to theory, but rather attempt to understand the individual aspects of the case. Powerhouse Kjørbo is an example of a plus house in Norway and can be seen as the unique and extreme case of the study. A unique case according to Bryman (2008), is a case that is in fact unique and of particular interest of the study. In other words, the case stands out. The purpose is to see the unique qualities of this building and attempt to make this more understandable for decision makers.

For the purpose of this study, 17 cases are chosen in addition to Powerhouse Kjørbo. These cases can be labelled as exemplifying cases, as they exemplify "*a broader category of which it is a member*" (Bryman, 2008, 56), The broader category here is buildings that perform better than conventional buildings. These cases are not studied in depth like Powerhouse Kjørbo, but rather used as examples of different building categories and the main measures to achieve the given building category is outlined. Powerhouse Kjørbo will be used as the main case study in this study.

3.2 Analysing interviews

The following will present how the interview process was handled, the benefit of the interviews, how the analysis process was managed and the reliability and validity of the process.

3.2.1 THE INTERVIEW PROCESS

A qualitative interview is a helpful method that limits the interviewers role as a guide in the interview. The reason for conducting qualitative interviews is to acquire the interviewee's viewpoints from their own perspective. Thus, it is imperative that the interviewee guides the interview process (Holme and Solvang, 1996). However, the interviewer must have some notion as to what subjects are to be touched upon during the interview. In a semi-structured interview the interviewer will have a list of questions or topics that are of relevance to the study. However, the interview is still very flexible in terms of what response is given. Thus, the questions might not be asked in the same order and extra questions can be added during the interview (Bryman, 2008). Therefore, an interview guide with set questions is a helpful tool. The interview guides used in this study can be found in Appendix B, D and F in Norwegian. There is a separate interview guide for each interview object because some questions were excluded for some interviews and additional questions were included for some interviews.

The interviews were conducted in Norwegian, and the author has translated the quotes and summaries of the interviews to English. Each interview lasted around 20 minutes and this amounted to 12 pages of text. The most important content from the interviews are shown in Appendix C, E and G where the interview are analysed thematically. All the interviewees were asked if it was okay that I recorded. They all approved. All the interviewees were asked if they or their employer should be made anonymous. It was okay for all of them that I used both their names and their company names. However, some companies and projects have been made anonymous in the interview with Thomas Haugen. This is because he at times gave an example as an answer to a question where he would talk about a subcontractor or a developer, and this has not been cleared with the respective companies.

3.2.2 Objective

According to Holme and Solvang (1996), the objective of conducting qualitative interviews is to increase information and create a basis for a more complete understanding of the phenomena of the study. Bryman (2008) proposes purposive sampling of interview objects, as this will provide interview objects that are of relevance and can contribute to the study. The phenomenon under scrutiny for this study is plus houses. To achieve a more complete understanding of plus houses, it is important to interview people with some relation to this. The interviewees chosen for this study are professionals that hold a high level of knowledge about plus houses and the construction process. In addition, the interviewees are all a part of the construction industry, but they have different roles in this sector.

The interviews will mainly be used in Analysis chapter, but some information will also be used in Chapter 4. This information is gathered from the interviews and provides factual knowledge from the interviewees.

It is important to point out that no governmental officials have been interviewed in this thesis. DiBK (Direktoratet for byggkvalitet) has been contacted, but the attempt was unsuccessful. Thus, only professionals have answered the questions regarding the authorities expected demands for 2020.

The subjects for the interviews were carefully selected to represent different aspects for the research issue. The following people were interviewed:

Øyvind Mork is the chairman of the Powerhouse board and the chief executive in Asplan Viak. Asplan Viak is both the tenant of Powerhouse Kjørbo and they are one of the cooperating companies in the Powerhouse project.

Arild Gustavsen is the centre director for the Research Centre on Zero Emission Buildings. The aspect of GHG emissions is often ignored or put less focus on compared to energy. The Research Centre on Zero Emission Buildings focuses on finding solutions to how buildings can emit less GHG.

Thomas Haugen is a former NTNU-student of Civil and Environmental Engineering and he now works in Veidekke as a managing engineer for the subcontractors working at Kunsthøyskolen in Bergen. His experience with cooperation between different actors in the construction process is very valuable.

3.2.3 Coding and analysis

Bryman (2008) states "*Coding is the starting point for most forms of qualitative data analysis*". Important steps to consider when coding is to do it as soon as possible, do it more than once, review the codes and not to think of coding as the analysis. The coding of these interviews are shown in Appendix C, E and G and the colour coding is used to distinguish between different types of quotes and whether the quotes from the different interviewees coincides. The colour coding is as follows:

Red quote: Important statement, but not mentioned by the others
Blue quote: Similar opinions
Green quote: same topic, but differing opinions

The purpose of the interviews in this study is to gather information and viewpoints. Thus, *how* a quote is said is not of importance, rather the content of the quote is the essential part. For this reason, the coding has been simplified into whether the interviewees agree, disagree or else say unrelated important facts. In addition, the quotes have been categorized into themes.

A thematic analysis of qualitative material focuses on what is being said rather than how it is being said (Bryman, 2008). As mentioned in 3.2.2, the purpose of conducting interviews in this study was to gain knowledge about the topics for the interview. Hence, a thematic analysis is the most reasonable way to conduct the analysis.

According to Bryman (2008), thematic analysis is a framework to categorize the most important themes and what is said about the themes in an orderly manner. It is suggested that is should be indicated where in the transcript the quotes appear, the language is to be kept as far as this is possible, the quotes should be kept short and to use abbreviations in the table cells. The selected themes are then a result of reading and rereading of the transcripts. The quotes are marked as (QX) as to which question the quote is in answer to, where the X represent the question number given in the interview guides.

Semi-structured interviews were used as the interview method in this study. Thus, the main themes were already decided beforehand and the questions were shaped around these. There are four main themes that were covered in the interviews, namely (1) Powerhouse Kjørbo and plus houses, (2) passive house as demand from authorities, (3) standardization as a tool and (4) focus on energy versus GHG emissions. The full tables of the thematic analysis are available in Appendix C, E and G. The method is also exemplified in Table 1.

Table 1: Thematic analysis of the interviews

Plus house					
	Powerhouse and plus houses	**Passive house as demand from authorities**	**Standardization as a tool**	**Focus on energy vs. GHG emissions**	**Other important aspects**
Øyvind Mork	Quote	Quote	Quote	Quote	Quote
	Quote	Quote	Quote	Quote	Quote
Arild Gustavsen	Quote	Quote	Quote	Quote	Quote
	Quote	Quote	Quote	Quote	Quote
Thomas Haugen	Quote	Quote	Quote	Quote	Quote
	Quote	Quote	Quote	Quote	Quote

3.2.3 Reliability and validity

According to Holme and Solvang (1996), the question of reliability and validity is especially important in quantitative approaches. Quantitative approaches must be representative, the measures done must be reliable and the data must be valid. In qualitative approaches, the goal is not always to present data that is representative, but rather reach a thorough understanding of an issue. However, reliability and validity are important factors to consider when reviewing the obtained data, which in this case are the interviews. For example, were the interviews helpful for the study? Did the interviewer ask relevant questions? Did the interviewees understand the purpose of the interview? Thus, there are many factors that will impact the reliability and validity of the interview, and the following will give a critical review of these factors.

Reliability is defined as "*the degree to which a measure of a concept is stable*" (Bryman, 2008, 715). This means that if something is measured several times, the results will be the same. Validity is the degree to which a an indicator devised to measure a concept really measures that concept (Bryman, 2008). These two concepts are interconnected, as a result cannot be valid if it is not reliable.

The interview subjects were chosen based on their differing experience in the construction industry. Thus, the interview guides are not exactly the same for all three, and the answers they gave are not comparable. However, the purpose of the interviews was to achieve a better understanding on the issues in this study and to hear different perspectives on these issues. As such, it is difficult to say whether the interviews are reliable, as the purpose was not to ask the exact questions. When it comes to validity, all the answers in the interviews are not used in the study. Hence, some questions can be said to be superfluous. However, the interviews proved to be of great importance in the development of the model and added aspects that the author had not considered. Thus, the outcome of the interviews can be said to be valid for this study.

3.3 Literature search

The literature search for this study has been focused around plus houses and other sustainable buildings. The searches have resulted in the conclusion that plus houses are not widespread around the world.

Examples of search words in Scopus:

1. Plus w/1 house
2. Plus w/1 energy w/1 house
3. Plus w/1 house w/1 standard
4. Plus w/1 house w/1 definition

Both “Plus w/1 house w/1 definition” and “plus w/1 house definition” gave zero results on Scopus.

The idea of using strategic management tools as means to better analyse the future of plus houses appeared during the study. While searching for PESTEL analysis, one article attracted attention: “Target-oriented obstacle analysis by PESTEL modelling of energy efficiency retrofit for existing residential buildings in China’s northern heating region” by Shilei and Yong (2009). The search for “PESTEL w/1 analysis” gave 9 results on Scopus and 15 others had cited this article.

“Plus house standard” gave 17 results on Google and seven results on Google Scholar. “Plus house definition” gave one result on Google and zero results on Google Scholar. These searches did not result in any useful information. Thus, Appendix A is mainly based on Norwegian search words and definitions.

Oria was used as a search engine. When searching for “plusshus”, this resulted in two highly relevant and much used sources. “Plusshus”, a Zero-report by Nordby (2009) and “Fra passivhus til plusshus” by Anda and Bjelland (2013) have been used extensively as sources.

4 THEORETICAL FRAMEWORK

This chapter gives an overview of relevant laws for the building sector; outline of building categories and relevant standards for sustainable buildings today. In addition, the chapter outlines the decision making process, what factors are important to this in relation to plus houses and helpful tools for decision making.

4.1 Building policy and relevant laws in Norway

"*Gode bygg for eit betre samfunn*" (KRD, 2012) – "*Good buildings for a better society*" is the name of White Paper number 28 from the Ministry of Local Government and Modernisation *(Kommunal- og regionaldepartementet - KRD)* from 2012. This paper outlines the Government's building policy. The main emphasis is put on the actual buildings and the tools the state has to promote sustainable buildings that function well for the people who use them over a long time perspective and with as low resource consumption as possible. This is the first White Paper on building policy laid out to the Norwegian Parliament. The White Paper has been made in cooperation with the construction industry, thus it also represents the position of this industry. The most relevant goal put forward by the Government in this report is the goal to reduce energy use in buildings substantially by 2020 and according to KRD (2012), several studies show that there is a large potential for more energy efficiency.

There are two possible ways to make the building stock in Norway more sustainable. One option is to construct new buildings according to the given regulations by law, to construct new buildings according to NS 3701 or BREEAM-NOR or to go beyond these and construct buildings that perform better than the current standards. However, with the current pace of new construction, it will take 50 years to replace the existing building stock in Norway (Haugland, 2016). The other option is to rehabilitate and renovate old buildings so that they conform to the standards mentioned above. According to Haugland (2016), rehabilitation of the building stock in Norway can halve the energy use of buildings. According to Olje- og energidepartementet (2016), there is a large potential for making older buildings more energy efficient, but this is very challenging. However, it is not mentioned why this is challenging. Thus, as stated by Bergesen (2016a), there is a large CO_2-profit to gain from rehabilitating old buildings. This is caused by the fact that when rehabilitating old buildings, the building structure is normally retained and this avoids the production of new concrete and steel. It is merely necessary to repair and upgrade the existing structure rather than producing it all over again. Though this will demand extensive investments, it is still more reasonable both in terms of cost and resource use, compared to constructing new buildings (Haugland, 2016). According to Jon-Viking Thunes from Sweco (2016a), by rehabilitating old buildings to be more energy efficient, 25% of energy can be saved. In fact, Enova has measures to rehabilitate older buildings and making them more energy efficient (Olje- og energidepartementet, 2016).

4.1.1 Planning and Building Act

The Planning and Building Act of 2008 applies to all land-use management and building operations in Norway. The law was passed in 2008. The purpose of the law is to promote sustainable development as laid out by the Brundtland-commission, coordinate public tasks that relates to the scope of the law, ensure that measures are made according to the law and ensure universal design (KMD, 2008).

4.1.2 TEK10

Byggteknisk forskrift (TEK10) is the minimum requirements for buildings set by law. The authorities set this regulation and all parts of the construction sector must abide by this law when constructing buildings. TEK10 is a regulation for the Plan and Building Act and it came into operation in 2010. This regulation is a more detailed and elaborate report on the regulations and requirements that are expected of the construction sector than the Plan and Building Act. According to KRD (2012), the energy demands in TEK were to be tightened to passive house level in 2015 and nearly zero energy level in 2020.

4.1.3 New energy demands in TEK10 and TEK15

The new energy demands laid out in TEK10 from 01.01.2016 means that new buildings can become 20-25% more energy efficient compared to the old demands (KMD, 2015a). The current demands state that the energy demand shall not exceed 100 kWh/m^2/year + correction for surface area (1600/m^2 heated useful area) for residential homes, 95 kWh/m^2/year for apartment buildings and 115 kWh/m^2/year for office buildings. For comparison, the average energy demand for Norwegian dwellings is 185 kWh/m^2/year (Olje- og energidepartementet, 2016, KMD, 2010).

According to the Government, the new energy demands are to “provide environmentally friendly buildings that spares the environment and the nature for future generations” (DiBK, 2015). The new demands are a result of the climate settlement from 2012 and tighten the demands for energy in TEK10 (KMD, 2015b). The goal of the climate settlements was to have demand of passive house level in 2015 and nearly zero energy level in 2020 (Miljøverndepartementet, 2011), thus according to KMD (2015b) and Olje- og energidepartementet (2016), the new demands are in accordance with the demands of a passive house level and the climate settlements. However, Table 2 demonstrates otherwise.

The specific demands are shown in Table 2. Other changes include prohibition against installing fossil energy, more opportunities for exceptions (for example a building producing renewable energy can get some other exceptions), smaller houses must be built with chimney to take advantage of bio energy and more energy efficient technical installations (KMD, 2015a). In addition, some demands have been removed to make the process easier and to open for using electricity for heating (KMD, 2010). This is a measure to make the construction sector more electrified. According to Jon-

Viking Thunes from Sweco, this is a wrong step to take now. Instead, space heating that contributes to GHG emissions should be replaced by renewable energy, such as solar energy, heat pumps, bioenergy or district heating (Bergesen, 2016b).

Another important factor in the new demand is to retain net energy demand as the measure for energy efficiency. Thunes and Elin Skjerven Talhaug from Sweco disagree with this. Instead, the measure should be delivered energy (Bergesen, 2016b). Net energy demand is the calculated energy a building needs according to its technical qualities. Delivered energy is the amount of energy that is required to be delivered to the building to fulfil the net energy demand. This includes losses in the heating system and does not include local energy sources. According to Thunes and Talhaug (2016b), this shift will lead to a stronger focus on energy supply, which will in turn direct the attention to reducing the energy supply and consequently the GHG emissions from the energy supply.

Table 2 shows the difference between the new energy demands in TEK 10 and the energy demands in NS 3700 and NS 3701. The numbers for TEK10 that are not in parentheses is the minimum demand for new buildings, while the numbers in parentheses are suggestions to demands for achieving the total net energy demand.

It is clear from Table 2 that though KMD (2015b) claims these new demands are in accordance with passive house levels, most of the demands are lower than what is required by the two passive house standards.

TEK15 was the new TEK10-regulation planned for 2015. This has been postponed until 2016 or 2017. It is unclear whether the updated TEK10 is indeed the planned TEK15. However, it is clear from Table 2 that the planned TEK15 demands are very similar to the new TEK10 demands. TEK15 was meant to follow the goal of having demands equal to passive house level in 2015, and further on having nearly zero energy levels in 2020. However, we see from Table 2 that the proposed demands are not the level of the passive house standard.

Table 2: Comparison of new demands in TEK10, the previously planned demand in TEK15 and NS3700/NS3701

Area	New demands in TEK10 (1)	TEK15 (2)	NS 3700/NS 3701 (3)
U-value outer wall [W/m² K]	≤ (0,18) – 0,22	–	0,10 – 0,12
U-value ceiling [W/m² K]	≤ (0,13) – 0,18	–	0,08 – 0,09
U-value floor [W/m² K]	≤ (0,10) – 0,18	0,10	0,08
U-value windows and doors [W/m² K]	≤ (0,80) – 1,2	≤ 0,80 – 1,2	≤ 0,80
Yearly average temperature efficiency for heat recovery in ventilation installation (%)	≥ 80%	≥ 80-85%	≥ 80%
Specific fan effect in ventilation installation [kW/(m³/s)]	≤ 1,5	≤ 1,5	≤ 1,5
Air leakage number	≤ (0,6) – 1,5	≤ 0,6	≤ 0,6
Normalized thermal bridge values [W/m² K]	≤ 0,05-0,07	0,03	≤ 0,03

(1): (KMD, 2010)
(2): (Lavenergiprogrammet, 2015c)
(3): (Standard Norge, 2012) and (Standard Norge, 2013)

4.1.4 Public Procurement Act

The current Public Procurement Act (Anskaffelsesloven) includes certain basic principals and demands for procedures that must be followed when performing public procurement. These sets of rules shall promote efficient use of resources and provide confidence to public procurement. EU has adopted three new directives regarding public procurement, thus Norway must revise its set of rules in the area that relates to EEA. In addition, there is a need for simplification of the law, as this is often viewed as too complicated, rigid and not efficient enough. EU's reason for revision is simplification, flexibility, reduce administrative burdens, make it easier for smaller businesses to compete and to handle environmental and societal concerns and innovation in a better manner. It is a tool to reach the goals in the Europe 2020-strategy, which will be more discussed in 4.2. Prop. 51 L is the Norwegian proposition for the new Public procurement law. The most relevant propositions are a new provision that takes care of environmental concerns and the environmental consequences of procurement (Nærings- og fiskeridepartementet, 2016). However, the environmental consequences of procurement is already included in the original law in §6 (Nærings- og fiskeridepartementet, 1999).

From the new proposition, societal concerns such as bettering the environment and reducing climatic challenges are seen as concerns that are outside of the scope of the law. More specifically, it is seen as outside of the law's objective to have an efficient use of resources. The minority of the commission proposing this new law are in favour of including these societal concerns, as public authorities should be ahead in taking social responsibilities and ensuring that national environmental goals being fulfilled. The final decision on how environmental concerns are viewed in the new proposition is that this is up to the delegating authority. Environmental demands are to be put weight on in the whole procurement practice of the relevant authority. §6 is no longer valid; instead §5 shall be an efficient tool for realizing the Government's environmental goals (Nærings- og fiskeridepartementet, 2016). The new proposed §5 declares that:

> "…state, county municipal and municipal authorities … shall arrange their procurement practice in a way that contributes to reducing harmful environmental impacts and promote environmental friendly solutions where this is relevant" (Nærings- og fiskeridepartementet, 2016, 91)

ENVIRONMENTAL PRODUCT DECLARATIONS

EPDs are not mentioned in the proposition for the new Public Procurement Act. It is nonetheless important to consider the impact EPDs can have in the construction industry. KRD (2012) explicitly states in their White Paper that the Government shall consider whether there should be demands for documentation of EPDs or other official environmental labelling in the next revision of Byggteknisk Forskrift (TEK). In addition, the Government was going to contribute to intensifying the work with EPDs. Bygg21 (2014) proposes that by 2020, materials and products with EPDs are to be preferred in all construction projects. According to KRD (2012), there are few construction components with EPDs and this leads to a low demand for it. Statsbygg is a frontrunner in the work towards expanding EPD demand: they demand that five to ten of the most used materials in new buildings and rehabilitation projects must be documented with EPDs.

THE PUBLIC SECTOR AS A LEADER AND EXAMPLE

The national authorities propose and implement the regulations that apply to the construction sector. Often these regulations are made in cooperation with the industry and this adds credibility to what the national authorities can expect from the industry. However, the public sector can add more credibility by being a pioneer or a leader when constructing public and official buildings. As pointed out by Bygg21 (2014, 21), "*the public sector can to a larger extent use its position in the market as a tenant and a real estate actor to serve as an example of sustainable innovation and environment*". The main areas for improvement are commission competence, early phase investigation and cooperation (Bygg21, 2014).

KRD (2012) also points to the immense influence the public sector has had and can have. Official developers and property managers can be a driving force and serve as an example for smaller official government agencies and municipalities. In addition, by setting higher requirements official developers and property managers can contribute to better and more cost efficient buildings, and suppliers can be encouraged and challenged to be more innovative. Cooperation between the public, the industry and researchers can lead to new solutions (KRD, 2012).

4.1.5 Subsidies from Enova

Enova offers subsidies for a range of areas within the construction and property sector. The following examples are the most relevant subsidies: subsidies for concept development, subsidies for existing buildings, subsidies for new technology in buildings of the future, subsidies for energy measures in construction and subsidies for municipalities. Subsidies for concept development relates to the planning process, where the inquiry of innovative solutions for the benefit of the environment and solutions that aim further are studied. This process is then subsidized which in turn can lead to these solutions being implemented (Enova, 2016b). According to KRD (2012), Enova shall contribute to reducing energy use in buildings and industries, encourage heat from renewable energy sources and demonstrate the potential in new energy technologies and energy solutions. As mentioned, Enova offers subsidies for a range of different purposes. However, Enova is not allowed to give subsidies to measures that are according to national regulations. Thus, Enova encourages developers to construct buildings that are more ambitious than the national regulations (Enova, 2016b).

4.2 European Union and the construction sector

The European Union (EU) has an ambitious target they have named 20/20/20. This is a goal to cut 20% in GHG emissions, 20% of energy in the EU is to come from renewable energy sources and to have a 20% improvement in energy efficiency. All these goals are to be reached by 2020. This is often referred to as Europe 2020-strategy. The targets were set in 2007, and implemented in legislation in 2009. They are the main targets for EUs 2020 strategy for smart, sustainable and inclusive growth (European Commission, 2016). According to Hermelink et al. (2013), the building sector is on of the key sectors to achieve the 20/20/20 target. In 2010, the European Union adopted a directive on the energy performance of buildings to strengthen the energy requirements set for the member states. The largest ambitions are that by 2020, all new buildings have to be nearly zero-energy buildings and by 2018 and all new buildings occupied and owned by public authorities are nearly zero-energy buildings (The European Parliament and the Council of the European Union, 2010).

In addition to the 20/20/20 goal, EU has set a goal that by 2020, 70% of construction materials from the construction industry are to be recovered. This number was 60% in

2013. The 60% considers all material from new construction, refurbishment and demolition (SSB, 2013).

4.3 Current building standards

The following will present a short introduction to standardization as a tool, NS 3701 and BREEAM-NOR.

STANDARDIZATION

Standardization is used for a wide variety of areas and situations in society. Standards are a tool for efficiency and simplification for both complicated and not complicated tasks. A standard can be defined as:

> "A standard document for common and repeated use, emerged by consensus and approved by a recognized body which provides rules, guidelines or characteristics for activities or results of activities to achieve optimal order in a given context" (Standard Norge, 2015).

The work of standardization is divided into three levels: national, European and international. The standards are divided into 14 different fields, where buildings, construction and real estate (BAE) are its own field with a large variety of different standards.

NS 3701: CRITERIA FOR PASSIVE HOUSES AND LOW ENERGY BUILDINGS – NON-RESIDENTIAL BUILDINGS

NS 3701 is a Norwegian standard outlining the criteria for passive houses and low energy buildings in Norway. This standard applies to non-residential buildings. NS 3701 focuses primarily on energy and reducing energy demand. The standard is the Norwegian adaption of passive house definitions due to climatic differences, differences in construction solutions and building traditions (Standard Norge, 2012).

BREEAM- NOR VER. 1.1

BREEAM is an environmental classification system for buildings. It is the leading and most commonly used system for environmental classification and has become the scale to which buildings are measured up against. BREEAM-NOR is the Norwegian adaption of BREEAM. The Norwegian Green Building Council (NGBC) developed this together with cooperating businesses. Thus, BREEAM-NOR is adapted to relevant Norwegian standards and rules within the energy and environmental areas. BREEAM-NOR is not a Norwegian standard on the same level as NS 3701, but it is still a recognized tool for measuring a building's classification.

The goals of BREEAM is to reduce building's impact on the environment, to stimulate the demand for sustainable buildings, to make it possible to recognize buildings from an environmental standard and to offer trustworthy environmental classification and certification.

Buildings that are to be classified according to BREEAM are awarded points according to their performance. There are ten environmental areas that are assessed and awarded points, and the points are then summarized. This leads to a classification in one of these classifications: *Pass* (≥30%), *Good* (≥45%), *Very Good* (≥55%), *Excellent* (≥70%) and *Outstanding* (≥85%), where the percentage numbers are out of a 100% (NGBC, 2012).

BREEAM-NOR can be used to classify new buildings, renovations and rebuilding, additions to existing buildings and a combination of new buildings and larger renovations. Office buildings, industrial buildings, retail buildings and educational buildings are all building categories that can be assessed by BREEAM-NOR (NGBC, 2012).

4.4 Energy and emission efficient buildings

Today there are many alternatives to constructing conventional buildings. The following will present the categories that are most widespread and other categories that are more ambitious, not so widespread, but realistic alternatives. In general, all of these categories can be classified as a type of green building. Green buildings uses design and construction methods that reduce or remove the negative impacts buildings can have on the environment as a whole and the people who will live in the buildings (Yudelson, 2009).

ZEB is a term that is used for two purposes: Zero Energy Building and Zero Emission Building. To avoid misunderstandings, this study will use ZEB when speaking of emissions: Zero Emission Buildings. Zero Energy Buildings will be referred to as NEB, where N is the Norwegian word for zero – “null”.

4.4.1 PASSIVE HOUSE

The Passive House Institute (2015) defines a passive house a building standard that is simultaneously energy efficient, comfortable and affordable. It is not the name of a brand, but rather a well tested construction concept that can apply anywhere. According to Bolig ENØK (2016), a passive house will have an energy demand that is up to 75% lower than a conventional building. The reason for calling it a passive house, is that the measures made to lower the energy demand is done through passive measures. These measures include extra thermal insulation, good density and heat recovery. More specifically, the measures are that outer walls, roofs, floors and windows are better insulated and the better density leads to less air leakage (Lavenergiprogrammet, 2015a). The challenge with having this type of heightened insulation and limiting air leakage to this extent is to achieve good air quality and a good indoor climate. This can be done through a ventilation system that has the possibility of heat recovery (Lavenergiprogrammet, 2015a).

4.4.2 Nearly zero-energy building

Nearly zero-energy building (nNEB) is defined as a building that has a very high energy performance, where the additional required energy, which is nearly zero or very low, is to a large extent covered by energy from renewable sources either on-site or nearby (The European Parliament and the Council of the European Union, 2010). The definition does not imply that the building must have its own renewable energy production on the building, but the definition has a focus on locally produced energy (Killingdal et al., 2013). For Norway, the author has found one suggested definition for nNEB: the energy use shall be 70% lower than TEK (Killingdal et al., 2013). This may not be too illustrative, so an example is given: an office building in Oslo-climate will have net delivered energy of 30 kWh/m^2/year. However, there is no official definition and no Norwegian standard for nNEB.

4.4.3 Net Zero energy building and Zero energy building

A net zero energy building (netNEB) is a building with very high energy efficiency where the energy demand over the year is covered by it sown production of renewable energy. The building is connected to the grid and may get delivered primary energy from the grid when necessary. However, when conditions allow for it, the building will deliver excessive produced energy back to the grid or to energy storage. This relationship will be zero over the year (Killingdal et al., 2013).

A zero energy building (NEB) produces enough energy on-site to cover its own annual energy demand. This building is not connected to the grid (Killingdal et al., 2013).

4.4.4 Zero emission building

A zero emission building (ZEB) focuses more on the GHG emissions than the energy use. By producing renewable energy, the building is able to compensate for the emissions related to either the whole life cycle or some parts of the life cycle. This depends on what characterization the building is to achieve out of the levels laid out by ZEB, which are illustrated in Table 3.

Table 3: Levels of ZEB

Levels of ZEB	Renewable energy compensates for:
ZEB – O ÷ EQ	Operation minus energy use for equipment
ZEB – O	Operation
ZEB – OM	Operation and production of construction materials
ZEB – COM	Construction, operation and production of construction materials
ZEB - COMPLETE	Production of construction materials, construction, operation and demolition/recycling

Arild Gustavsen (2016) explained that the goal is not necessarily to construct a building that lives up to the ZEB – COMPLETE level instantly. The different levels laid out in Table 3 can rather be used as a ladder where you want to climb to a higher level consecutive. Thus, the ambition level might be ZEB – COM, but that does not necessarily mean it will be this level straight away, but rather it is an on going process where the building is improved and can eventually reach ZEB – COM, or maybe ZEB – COMPLETE.

4.4.5 BREEAM-NOR

BREEAM-NOR is the Norwegian adaption of the British BREEAM-standard and certification. BREEAM is both a standard and a rating system. BREEAM-NOR is holistic rating system that focuses on all parts and phases of a building. There are five possible levels of a BREEAM-classification: *Pass*, *Good*, *Very Good*, *Excellent* and *Outstanding*. BREEAM will be further explained in chapter 6.2.3.

4.5 Plus houses

A plus house, energy plus house or plus energy house has no one standard definition at present. Appendix A shows various definitions of a plus house, mainly from Norwegian sources. It has been difficult to find international definitions of plus houses. The reason for this is not known. For the purpose of this study, the definition from Powerhouse will be used. This definition states that:

> "A plus house is a building that throughout the operating phase generates more energy than what was used for production of construction materials, construction, operation and demolition of the building" (Powerhouse, 2016b)

The reason for choosing this definition is because it is a very ambitious definition, it covers all processes of a building and it is proven to work in real life through Powerhouse Kjørbo. Figure 5 is an illustration of the relationship between nearly zero energy building, zero energy building and a plus house. From Figure 5 we see that a Nearly Net ZEB has a larger energy demand than the production can cover, whilst the Net plus house has a production larger than the demand. In other words, this is focused on *energy*. However, this figure can also be applied to *emissions*. Though the plus house definition from Powerhouse focuses on energy, it can be thought that the energy can be replaced by emissions. This is related to chapter 4.4.5, where the focus is ZEB. However, as mentioned earlier, the concept of ZEB is extremely ambitious and it is perhaps unlikely that renewable energy will be able to compensate for more than ZEB COMPLETE. Thus, Figure 5, if applied to emissions, would probably not include the level of plus houses for now.

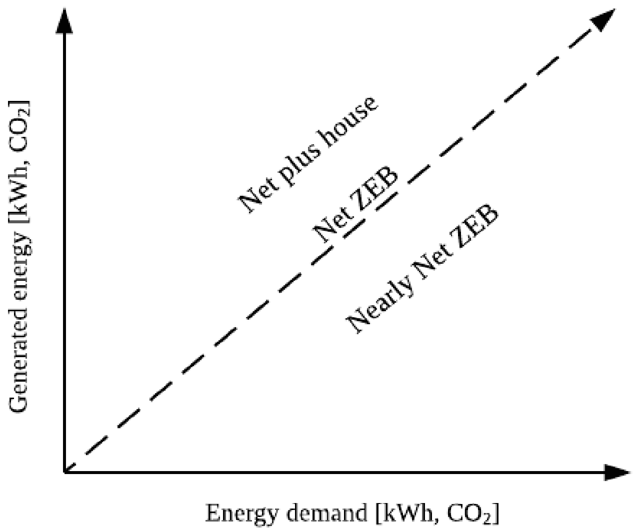

Figure 5: Simplified figure from Voss et al. (2012) explaining the relationship between nearly ZEB, ZEB and plus house

All energy used in the building is produced by the building itself, and the surplus produced is delivered to the electricity grid (Anda and Bjelland, 2013). By being able to produce more energy than it needs through its life cycle, a building becomes a part of the solution rather than being a large part of energy problem (Powerhouse, 2016b).

A plus energy house can be a passive house that also produces energy needed for space heating, tap water, energy for lighting and other electric appliances. In addition, the house will deliver the surplus energy for the electric grid. This energy is usually supposed to compensate for energy in all or some of the phases in a construction process (Anda and Bjelland, 2013).

According to Yudelson (2009), the main barrier against building green buildings today is the perception that it will add extra cost. Yudelson (2009) found that even though: *"…senior executives representing architectural/engineering firms, consultants, developers, building owners, corporate owner-occupants and educational institutions have held positive attitudes about the benefits and costs of green construction"* (Yudelson, 2009, 97), the leading obstacle is still the perceived higher costs and lack of knowledge about the benefits of building green. His book, "Green Building Through Integrated Design" focuses on LEED Rating System, and he also found that the complexity of LEED and added cost of certification and documentation was a large barrier to building green.

4.6 The construction process

As shown in chapter 2.1, in the most general terms the process of constructing a building includes four sub-processes as shown in Figure 6: development/project planning, production/construction, use/management/ maintenance and demolition/ EOL/refurbishment.

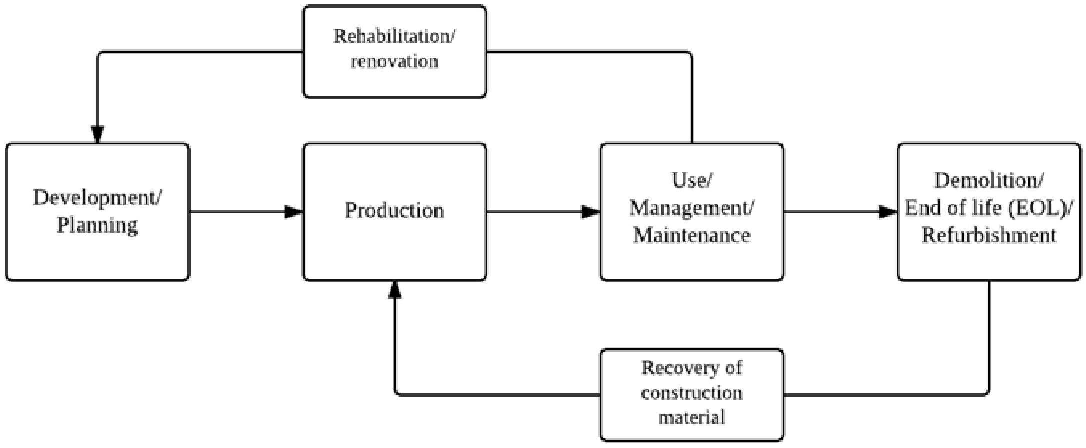

Figure 6: Simplified figure of the construction process

The construction process involves many actors over the lifetime of the process, and there is no general answer as to how and when these actors participate in the process. Figure 7 displays the actors that are normally involved in a construction process. However, we can make some general conclusions about which actors are indispensible in each phase.

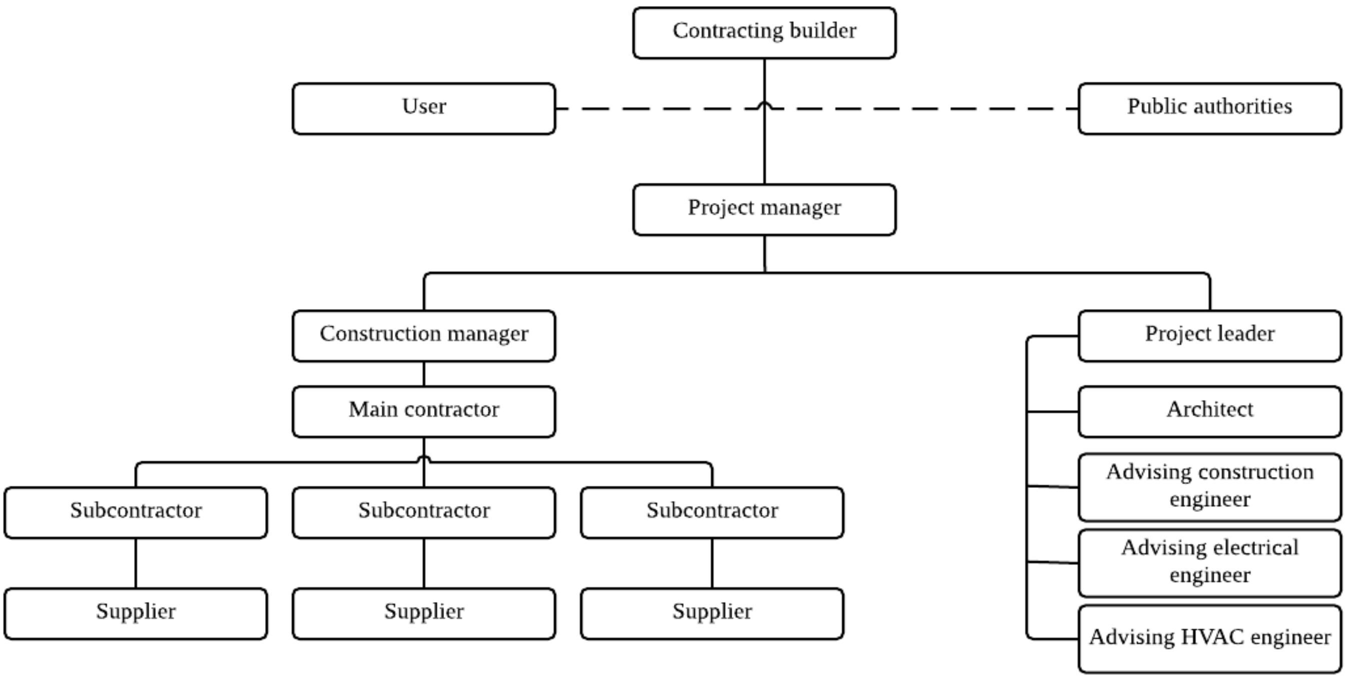

Figure 7: Modified model from SINTEF and NTNU (2007) displaying actors involved in the construction process

As pointed out by Throndsen et al. (2015), construction processes are usually managed in a logical order. What this means, is that the owner of a building start the process with architects included early. After a while, engineers and main contractors are included to take care of technical solutions and overall planning. Subcontractors are eventually involved to actually construct the building and suppliers are hired to supply their goods. Thus, the two first phases as shown in Figure 6 are upheld and kept divided. Anda and Bjelland (2013, 25) agree with this view on the conventional construction process:

> "The traditional design process is characterized by professionals participating in the development of a project, joins consecutively in the planning. The architect shapes the building first, and different engineers and consultants add their solutions consecutively".

According to Bygg21 (2014), one of the main challenges in the construction industry today is that the production processes are characterized by poor cooperation. The extensive use of detailed contracts and choosing suppliers based on the lowest price combined with procurements that are split up, results in many changes, additions and conflicts. This in turn creates poor cooperation and lack of confidence. Thus, Figure 8 presents some alternative to the conventional construction process.

Figure 8 present four different perspectives on how the cooperation in the construction process currently is and how it can be. In process 1, the architects, engineers and contractor are a part of the project planning and the suppliers and distributors enters the process in the construction phase. Process 2 on the other hand, shows an integrated design process where all the above mentioned actors participate in both the project planning phase and the construction phase. Process 3 shows the reality of the construction process according to Meland (2000). The projecting group, project manager, developer and user make out the project planning phase. In the construction phase, the projecting group participate in the beginning of the phase; the project manager, developer and user participate throughout the phase; the contractor and the construction manager enter in the middle of the phase, whilst the suppliers join later in the phase. Process 4 shows how the Powerhouse consortium arranged their way of working. The property owner, developer, contractor, architect, advisor, user, provider of aluminium, aluminium solutions and the company working with the environmental profile all participated in both the project planning phase and the construction phase.

Process 1, 2 and 3 are not examples of actual cooperation processes, but rather examples of how this cooperation process can be viewed. Process 4 on the other hand is an example of how the Powerhouse cooperation was actually carried out. This particular example will be further analysed in chapter 5.1.

The integrated design process is explained by Anda and Bjelland (2013) and their definition is directly related to plus houses. Integrated design is a way of working that includes all the different professionals and experts from day one. The reason for this is the understanding that all aspects of a building design are interconnected. With this attitude, all the involved actors will see the building as a system consisting of different systems within the whole interconnected system. The building is always considered as an integrated system where all subparts are a part of the whole and mutually dependent. The process of integrated design is more time consuming, but it is proven that this is essential for constructing buildings that are both energy efficient and environmentally friendly (Anda and Bjelland, 2013).

Anda and Bjelland (2013) found that the main barrier to working in integrated design is the impression that this process will be more costly than a conventional construction process. The reason for this impression is the fact that integrated design requires whole days of workshops between the involved professionals and experts. Anda and Bjelland (2013) argue that this might be true. The integrated design and integrated projecting phase will probably be more costly than a conventional process. However, the results of the initial integrated process can lead to reductions in construction costs, a building with higher quality and a more energy efficient building. In addition, the integrated process will be a earning process for the participating actors, and they will benefit in terms of learning from each other that can lead to mutual respect for each others professions and the integrated design process will become less complicated the next time it is done (Anda and Bjelland, 2013).

Integrated design is also explained by Yudelson (2009) and this way of working is also in this case related to green building. Integrated design emphasises commitment to the process, including the right people at the right time and using a collaborative approach that focuses on the whole building system instead of individual components. The key elements of an integrated design process according to Yudelson (2009, 45) is:

- Commit to integrated design and hire a design team that are willing to work with this approach
- Set “stretch” goals or BHAGs (will be explained in chapter 4.7.2)
- Create a realistic budget and get the design team to commit to a zero cost increase. Alternative and innovative solutions might come from this strict commitment to no cost increase.
- Throw environmental charrettes[1] in the initial design process.
- Allow time for feedback and revision before deciding on the design
- Everyone in the design team must participate without considering just their own interest in the project

[1] A public meeting or workshop devoted to a concerted effort to solve a problem or plan the design of something

Yudelson (2009) emphasises the importance of having charrettes in the design process that includes all the actors involved in the building process. The charrettes are both a tool for cultivating interdisciplinary solutions and to change the rigid “business-as-usual”-way of working that is inherent for many actors in the construction process. The key here is change in the process. The actors and clients must be willing to work differently on integrative design projects, especially in the design phase of the building.

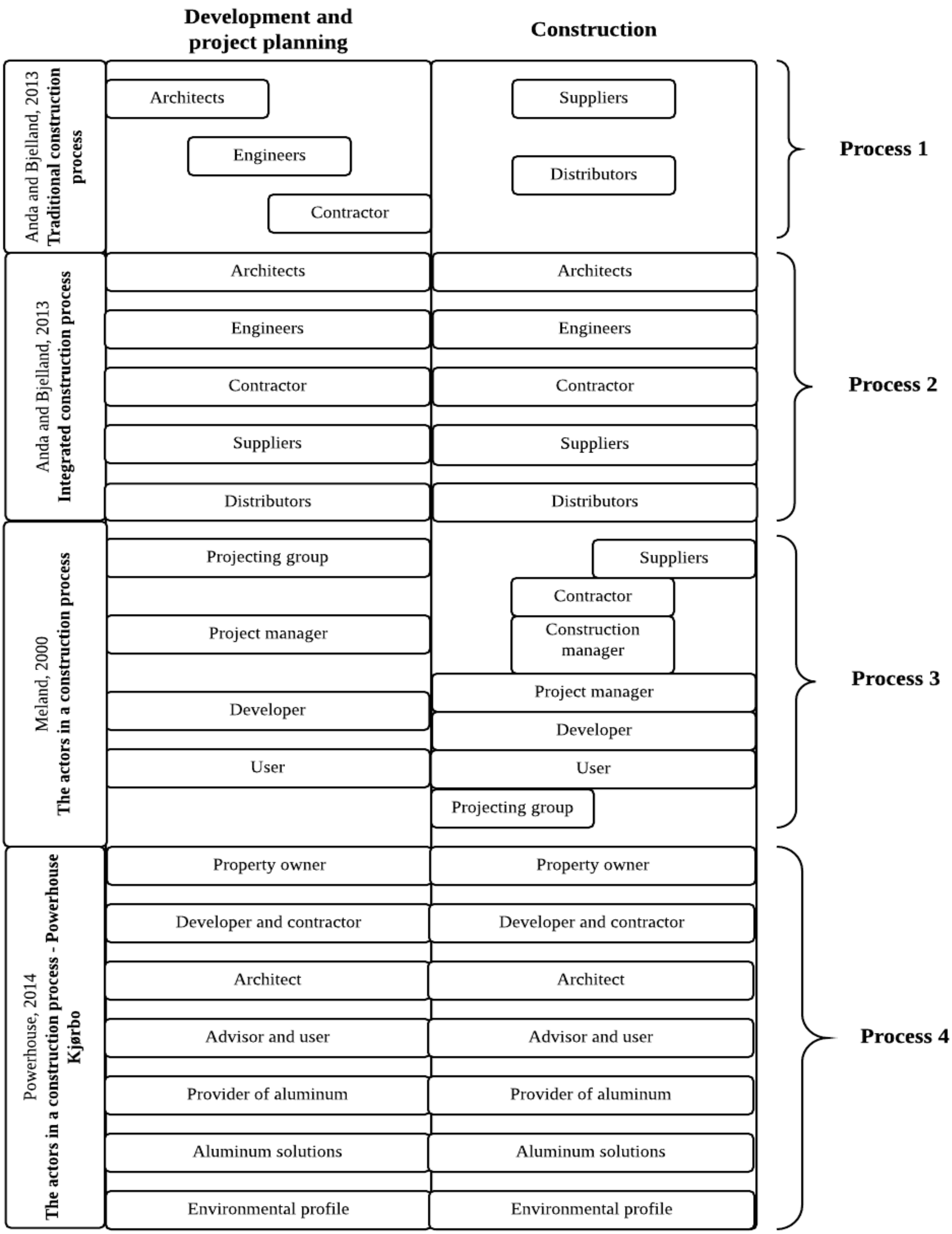

Figure 8: Four perspectives on actors in the construction process (from Anda and Bjelland (2013), Meland (2000) and Powerhouse (2014))

4.7 Decision making

Decision making in the context of this study is related to the decision to build a plus house or not. Accordingly, the decision makers are the company or individuals who make this decision. This can be developers, property owners, governmental authorities, or as in the case of Powerhouse Kjørbo: a consortium of ambitious companies. However, it is not necessarily optimal for one single company to make this decision alone. The optimal might be to include several actors, e.g. advisors, to see if the decision to construct a plus house is indeed feasible.

According to Mintzberg and Westley (2001), decision making has to be based on defining a problem, finding reasons for why it is a problem, find possible solutions to the problem, finding the best solution and finally implementing the best solution. This decision making process is the way Mintzberg and Westley (2001) sees a decision normally being made. It is not, however, necessarily the optimal way. The decision making process is illustrates in Figure 9 and this example shows a linear decision making process that does not allow for revision.

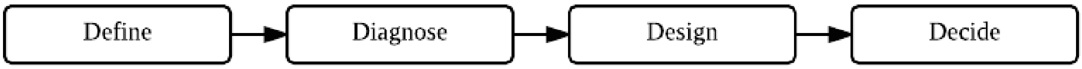

Figure 9: Simplified process of decision making visualized

Davis (1996) has a similar approach to the decision making process. The process according to Davis consists of problem recognition, information search, problem analysis, alternative evaluation and decision and it is visualized in Figure 10. This process is more comprehensive, as the different subprocesses are interconnected and influence each other. This process is non-linear, and e.g. the problem analysis might affect both the information search and the problem recognition. This non-linear process makes more sense than the linear process shown in Figure 9. When recognizing a problem, all the facts are not necessarily all clear from the start. Thus, when information is gathered, this might shed different lights on the problem and change the problem or some aspects of the problem. An alternative evaluation which is based on more extensive information and analysis will lead to a better decision, as more aspects of the issue is considered.

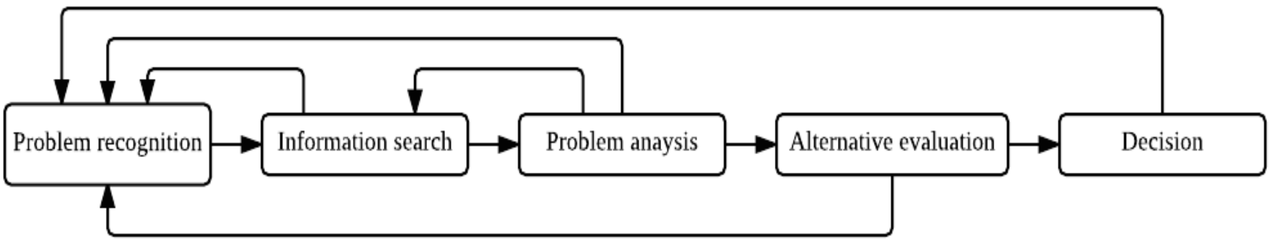

Figure 10: Decision making process according to Davis (1996)

The decision to construct a plus house is a process that requires extensive information search. For the given decision maker, this means cooperating with others that can aid the decision with background information as to what is necessary in terms of budgetary resources and technological knowledge. Thus, process 2 and process 4 in Figure 8 might be the preferred way of cooperating. These options are both models of integrated design. They include the relevant actors at an early stage and consequently, problems or other issues can be tackled at an early stage. As is shown in Figure 10, the information search can influence the initial problem and requires an analysis of the problem. An alternative evaluation where all previous factors are included will lead to a preferred decision. Thus, the decision is not merely a yes or no question, but needs extensive background information and evaluations.

4.7.1 Change and industry evolution

The concept of plus houses is a fairly known idea, but it is yet to be mainstream. This process requires a change in both attitude and action. Wit and Meyer (2010) differentiates between two types of change, namely revolution and evolution. Though this theory is meant for managers and strategic change, it can also be applied to this case. Revolutionary change refers to change that is disruptive or radical within a short period of time, that can lead to a clear break with how things were previously. Evolutionary change refers to change that is incremental and gradual where continuity is held high and moderate changes are gradually implemented over a longer period of time (Wit and Meyer, 2010). Plus houses can be seen as a result of evolutionary change, as presented in Figure 11.

Figure 11 is an exemplification of how the evolutionary change of buildings can be seen. This is also a summary of the buildings focusing on energy in chapter 4.4. It is a depiction of how the higher energy requirements have evolved in terms of building categories. The broken line shows that a conventional building can reach all the other levels of energy requirements through e.g. renovation. As explained above, evolutionary change happens over a longer period of time, continuity is valued and moderate changes are implemented. In addition, aspects already functioning are kept and non-functioning aspects are disposed of. For plus houses, the core of low energy buildings and passive houses are kept. For example, low u-values are essential in all the building categories Figure 11. New aspects, such as for example solar panels and energy wells, are added as a value to the technological solutions to be able to call it plus houses.

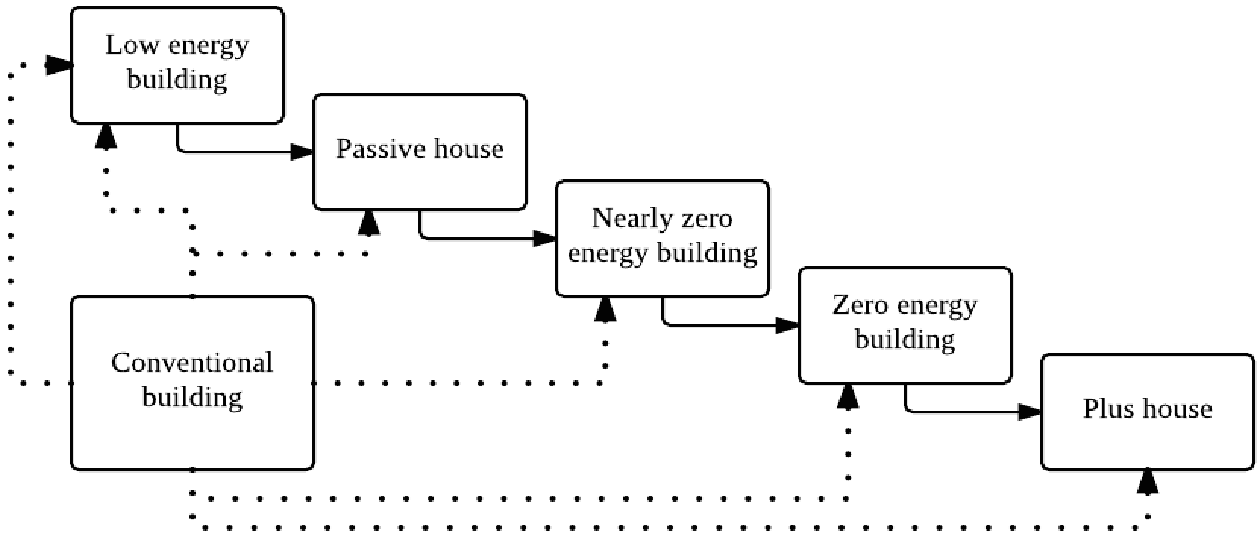

Figure 11: Evolutionary change of buildings

As shown in chapter 4.4, there are many alternatives to constructing sustainable buildings. Low energy buildings, passive houses, nearly zero energy buildings, zero energy buildings, zero emission buildings, BREEAM-buildings and plus houses are all viable and realistic alternatives in the market today. The demand for sustainable buildings is growing rapidly and it is possible to see this as an industry evolution.

The construction industry is not one entity, like a firm or business, but rather a very large sector comprising many actors or entities of firms. Thus, the aspect of changing the entire mind-set of the sector seems unlikely, or at least very challenging.

4.7.2 Big, Hairy, Audacious Goal

A Big, Hairy, Audacious Goal (BHAG) is seen as a bold and daunting challenge that might seem impossible, especially to outsiders. The BHAG is a helpful tool to envision how the future will be and gives a company or organization the drive to progress. When the BHAG is correctly used, it will become a unifying point for the workers and launch a specific type of team spirit around the BHAG. The BHAG must be highly focused, tangible, challenging and easy to comprehend (Wit and Meyer, 2010). According to (Yudelson, 2009), establishing ‘stretch’ goals in the design team are essential to create high-performance or green buildings. This ‘stretch’ goal can be seen as a BHAG. A crucial part of the BHAG is that it poses challenges for those the goal is set for (Yudelson, 2009). According to Wit and Meyer (2010), BHAGs are a good approach to engage and energize the involved parties.

4.7.3 Tools

Business analysis tools are well known in the sphere for strategic management. Such tools can be helpful when decisions are to be made, as the tools will often help seeing a bigger picture. PESTLE and SWOT are both tools that can help decision makers to map out different sides of the problem or opportunity they are facing. The PESTLE-analysis forms the basis of what is included in the SWOT-analysis, in addition to the interview and document analysis. Though this study is not an analysis of one specific business, but rather a concept, the PESTLE- and SWOT-analysis can be transferred to the case of plus houses.

PESTLE

A PESTLE-analysis is a tool for analysing business decisions. It is a tool for analysing the environment around where a business is operating or intending to launch new projects. PESTLE stands for Political, Economic, Social, Technology, Legal and Environment (PestleAnalysis, 2016). The original analysis was only PEST, but the increasing focus on the environment and the impact businesses has on the environment, this and legal has been added as separate factors. The PESTLE-analysis looks at more specific factors surrounding the decision to be made.

The different external factors of a PESTLE-analysis will be presented in the following paragraphs where the information is gathered from PestleAnalysis (2016) and Professional Academy (2016):

POLITICAL

Political factors examine to what extent governmental authorities can influence a certain industry or business and how the business environment can be affected by these influences. This can for example taxes, legislation or environmental regulations that will affect the industry.

ECONOMIC

Economic factors examine how an organisation does business and how profitable they are. It can be economic growth, inflation or the demand in an industry to name a few factors.

SOCIAL

Social factors focuses on the social environment. This includes shared beliefs, attitudes and cultural trends. In general, the factors are either a result of how society influences businesses or industries or how businesses and industries influence the society.

TECHNOLOGY

Technological factors looks at the technology market and changes in this that can affect the industry. New technological solutions, innovation in technology and current research and development are important factors.

LEGAL

Legal factors focuses on legality of an industry or business. It is necessary to have knowledge of the policies and regulations in both a specific country and the industry one is operating in. The legal factors include both internal and external sides. This can be safety standards, labour laws, health and safety and product safety.

ENVIRONMENT

Environmental factors have become more important the last years. The environmental factors include both demands from the environment, demands from consumers and governmental demands.

Many of the above mentioned factors are made specifically for business-use. Therefore it is necessary to adjust some aspects so that they are compatible to use for an industry (construction industry) and for a product (plus houses).

SWOT

A SWOT-analysis maps out Strengths, Weaknesses, Opportunities and Threats of a case or project. SWOT-analysis is a methodological tool designed to help "*optimize performance, maximize potential, manage competition and minimize risk*" (Gomer and Hille, 2016). By looking at both the internal and external factors, the people who utilize the SWOT will achieve a better and broader understanding of the environment surrounding the problem or opportunity. The SWOT-analysis looks at more general factors either for or against going for the decision. Below is a short explanation of the aspects of a SWOT-analysis and examples of these aspects.

The strengths are internal to the project and can be particular talents within the project or resources. The weaknesses are also internal to the project. These can be disagreements or lack of resources. Opportunities lie externally to the project. These can be natural resources, incentives or eager partners that are willing to invest. The threats are also external factors, such as laws or other actions from authorities that could jeopardize the project (Yudelson, 2009).

5 EMPIRICAL DATA

The following chapter will present empirical data about Powerhouse Kjørbo and other cases relevant for this study. The most frequently applied technical solutions to build sustainable buildings will be presented, and the content of the interviews will be laid out.

5.1 Powerhouse Kjørbo

> "An old office building in Sandvika is transformed into "the construction industry's Tesla"
>
> (Bjørkeng, 2014)

One can be hopeful at the prospect that buildings will see the revolution that has been seen in the automobile industry, see Tesla. The renovated office building Powerhouse Kjørbo in Sandvika is the first Powerhouse plus house in Norway. This plus house was finished in 2014, and it is seen as a revolutionary building. The reasons for this will be presented below. The building has received a great deal of attention, and this March the Research Centre on Zero Emission buildings published a report evaluating the construction process and the early use phase called "*Powerhouse Kjørbo. Evaluation of construction process and early use phase*" (Throndsen et al., 2015). This report will be used as a critical source in the following chapter.

The term plus house implies that throughout the operation phase of the building, the building has to generate more renewable energy than what it requires through production of construction materials, construction, operation and demolition. The lifetime of this building is 60 years. In addition to being the first Norwegian Powerhouse plus house, the building is also the first renovated office building that has earned the title of a plus house. Powerhouse Kjørbo has the largest solar cell installation in Norway which produces approximately 220 000 kWh in a normal year. In addition to the building being termed as a plus house, the building also received "Outstanding" certificate from BREEAM- NOR (Powerhouse, 2014).

Figure 12 is a summary of the main technical measures done for constructing Powerhouse Kjørbo. In addition to these, Powerhouse Kjørbo has used materials that are either recovered or recoverable. In fact, 95% of the materials are recovered or recoverable. In addition, the carrying construction in concrete was maintained from the old building. This was a measure that saved the project of much energy and GHG emissions (Mork, 2016). As outlined in 4.1.3, the new energy demands in TEK10 for office buildings is 115 kWh/m^2/year. As a result of the rehabilitation, Powerhouse Kjørbo on the other hand uses 32 kWh/m^2/year (Skanska Norge, 2014).

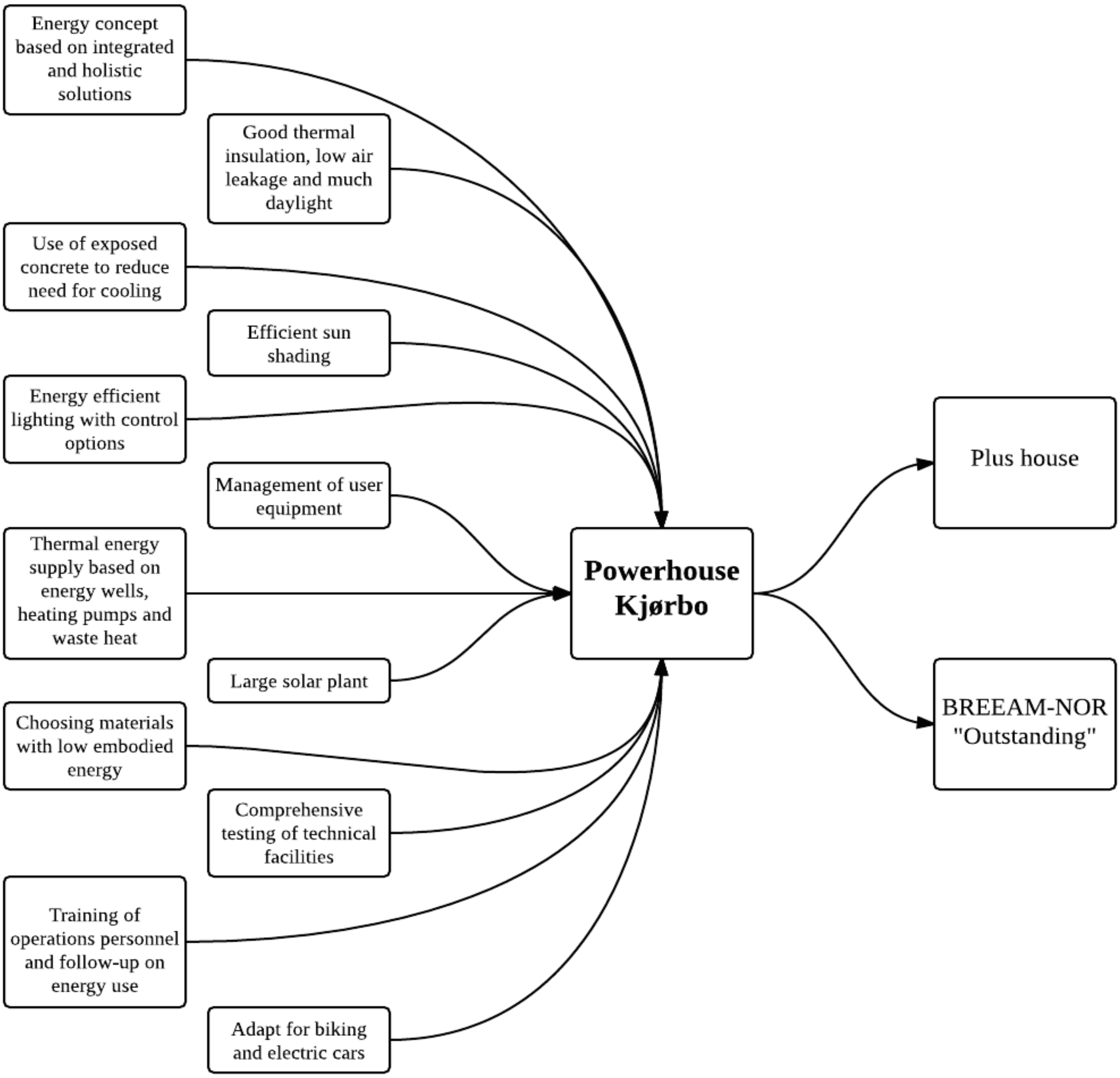

Figure 12: Model displaying measures to achieve plus house level based on Entra (2014), Powerhouse (2014) and Powerhouse (2016e)

Energy calculations are the basis and foundation of this Powerhouse project and for the Powerhouse concept in general. Thus, the energy of all relevant processes had to be counted, accounted for and made sure it did not exceed the set goal. This complicated and demanding process had to consider all phases of the building and all that was done and built had to be compensated for by renewable energy production. This also included a large focus on the materials chosen for the project. The production of materials would have an impact on the total energy account, thus the producers of materials had to provide detailed information concerning the energy costs of their products. The material choice was then done based on these numbers. For many producers, this is not the usual practice and they did not have these numbers prepared beforehand in EPDs for example. Thus, much material information was based on generic values and assumptions (Throndsen et al., 2015).

THE COOPERATION PROCESS

Powerhouse is a Norwegian collaboration between companies that can contribute in the development of, realization of and creating demand for plus houses in Norway. The collaboration consists of Entra Eiendom, Skanska, ZERO, Snøhetta Asplan Viak, Hydro and Sapa (Powerhouse, 2014). Table 4 shows the actors in the collaboration and their function in the collaboration.

Table 4: Roles in the Powerhouse collaboration

Company	Function in Powerhouse
Asplan Viak	Advisor to Powerhouse and tenant of Kjørbo
Entra Eiendom	Owner of property
Hydro	Aluminium producer
Sapa	Profiler of aluminium solutions
Skanska	Project developer and entrepreneur
Snøhetta	Architect
ZERO	Environmental profile

An important criteria to make an ambitious project like the Powerhouse projects to work is according to them to start a close collaboration between all involved parties from day one. Interaction, teamwork, expertise, and comprehensive and holistic thinking are some of the keywords that are used to describe the keys to succeeding in projects like this. SkanskaGroup (2015) states in their promotional video of Powerhouse Kjørbo: "*Central to the success of the project was an open collaboration between the partners in the early stages to achieve synergies from different technologies to create a Powerhouse*". According to Throndsen et al. (2015), many interviewed informants emphasized the importance of the interdisciplinary effort. This effort created the innovative environment that realised the project.

The Powerhouse concept and collaboration is unique both in its form and in its ambitions. The concept of Powerhouse Kjørbo is creating a plus house with refurbishing an old office building. As far as the author knows of, and according to Powerhouse (2014), this is the only rehabilitated plus house in the world. Thus, the idea was completely new and there was no basis for receiving exact information from similar projects. Consequently, the project started as a goal to do something never done before and the ambitions were extremely high and seemed nearly impossible to reach (Throndsen et al., 2015). This can be called a "Big, Hairy, Audacious Goal" (BHAG) (Wit and Meyer, 2010). This can be the unifying factor a company needs to move forward and the goal is very clear as to when the goal is reached. Thus, a team can see a clear finish line in the future. As explained by Skanska Norge (2014):

> "The consortium aims to demonstrate that it is possible to create energy-plus buildings in colder climates such as in Norway, and that developing such buildings makes commercial and environmental sense to all parties involved"

Thus, the BHAG of Powerhouse was to create a plus house where it might previously have been thought this was not impossible. The Powerhouse project and collaboration has received much attention nationwide and internationally. One might assume that the reason for the success of Powerhouse Kjørbo is due to technology and solutions that are entirely new and ground breaking. However, most of the solutions used in Kjørbo is indeed well known and commonly used solutions.

According to Powerhouse (2014), the approach for a project like Powerhouse is different from other construction projects. Constructing a plus house requires a combination of extreme energy performance, low environmental impact and robust solutions. Thus, a project of this sort is dependent on collaboration from the very beginning. The key lies in achieving more with less and the correct solutions (Powerhouse, 2014). Normally, the different processes of a construction project are managed in order, where the relevant actors are only involved in their own field and eventually finished when their work is done. The unique collaboration style of Powerhouse Kjørbo involved all the actors in the design phase simultaneously and many were also participatory in the following phases. Workshops were used as a starting point, to get the collaboration rolling. This interdisciplinary work made the involved actors realize that everyone was working towards the same BHAG and created a mutual respect and more understanding for each others discipline (Throndsen et al., 2015).

The energy account was a very large part in the process of constructing Powerhouse Kjørbo and every single choice made had to be seen in the context of the energy account and how the choice would affect the energy account. In fact, the energy account can be seen as the centre of the collaboration (Throndsen et al., 2015), as it was the energy account that measured if the BHAG was reached and the energy account was something every person involved in the collaboration had to relate to and work with and towards. The energy account created a BHAG and all decisions had to be made with concern of the energy account. This created a cooperation that can be seen as a competition to create the most energy-efficient solutions. Everyone wanted to fulfil the goal and the goal created an environment that brought about the best solutions. As mentioned before, the solutions already existed – they were used in new ways and the full potential is taken advantage of. As one executive officer explains: “It’s mostly known solutions which have been put together and which have been dimensioned optimally” (Throndsen et al., 2015).

Despite the success of the realization of Powerhouse Kjørbo and the unique teamwork that contributed to this success, there were some problems especially in the detailing phase. The collaboration between the initial actors had worked very well, but problems arose when new people, such as subcontractors, were brought into the process. The main problem seemed to be that people brought in later in the process did not fully understand the commitment to the BHAG and did not fully commit to the concept of Powerhouse. In addition, the people brought in later did not embrace the energy account with the same enthusiasm and understanding of its importance. In fact, several subcontractors declined to deliver the requested products because they did not believe in the concept of Powerhouse and that it would actually work. It is believed that a the reason for this was that the subcontractors were not included in the planning process, thus they were not a part of the start of the project and lacked knowledge of the opportunities that were decided earlier. This led to the project resembling a conventional construction process in the construction phase. The subcontractors were included late in the project and consequently did not embrace the idea of the BHAG. The construction phase was characterized by difficult cooperation between the initial actors and the new actors, and the subcontractors were reluctant to changes and new solutions, as this would cost them more money compared to a conventional construction project (Throndsen et al., 2015).

5.2 Other examples of energy efficient buildings

Table 5: Example of buildings with different standards

Project	Category	Type of building	Location	Source	Status
Maison Air et Lumiere	Plus energy house	Residential	France	(Velux, 2016b)	Finished
Multikomfort Larvik	Plus house	Residential	Larvik, Norway	(Multikomfort, 2016)	Finished
Powerhouse Brattørkaia	Plus house	Office	Trondheim, Norway	(Powerhouse, 2016c)	Planned
Powerhouse Kjørbo	Plus house and BREEAM	Office	Sandvika, Norway	(Powerhouse, 2016e)	Finished
Private house Larvik	Plus house	Residential	Larvik, Norway	(Nilsen, 2015)	In progress
Settlement Freiburg	Plus house	Residential houses	Freiburg, Germany	(International Energy Agency, 2009)	Finished
The Home for Life Denmark	Plus house and carbon neutral	Residential	Denmark	(Velux, 2016a)	Finished
Tvedestrand VGS	Plus house	School	Tvedestrand, Norway	(Ekern, 2015)	Planned
Wicona Test Center	Plus house and carbon neutral	Office	Germany	(Wicona, 2010)	Finished
Campus Evenstad	Zero Emission Building – COM	School	Hedmark, Norway	(Statsbygg, 2015)	Planned
Forsvarets logistikk-organisasjon	Zero Energy Building	Office	Bergen, Norway	(Byggeindustrien, 2015)	Finished
Skarpnes boligfelt	Zero Energy and Zero Emission Building – O	Residential	Arendal, Norway	(Skjævestad and Husbanken, 2014)	Finished
Haukåsen barnehage	Passive and BREEAM	Kindergarten	Trondheim, Norwy	(NCC, 2016)	Finished
Heimdal VGS	Passive house	School	Trondheim, Norway	(Kreative Trøndelag, 2015)	Planned
Nesttunbrekka 99	Passive house and BREEAM	Office	Bergen, Norway	(Multiconsult, 2016)	Finished
Office and commodities Fantoft	Passive house and BREEAM	Office	Bergen, Norway	(Sweco, 2016)	In progress
Sandstuveien	Passive house and BREEAM Excellent	Office	Oslo, Norway	(Hårvik, 2016)	Finished
Veritas-senteret	Passive house and BREEAM	Office	Oslo, Norway	(VVSForum, 2015)	Planned

5.2.1 Technical solutions

The most important technical solutions of the buildings described in Table 5 can be found in Appendix E. Figure 13 is a summary of these technical solutions and shows how frequently they were used in the cases from Table 5.

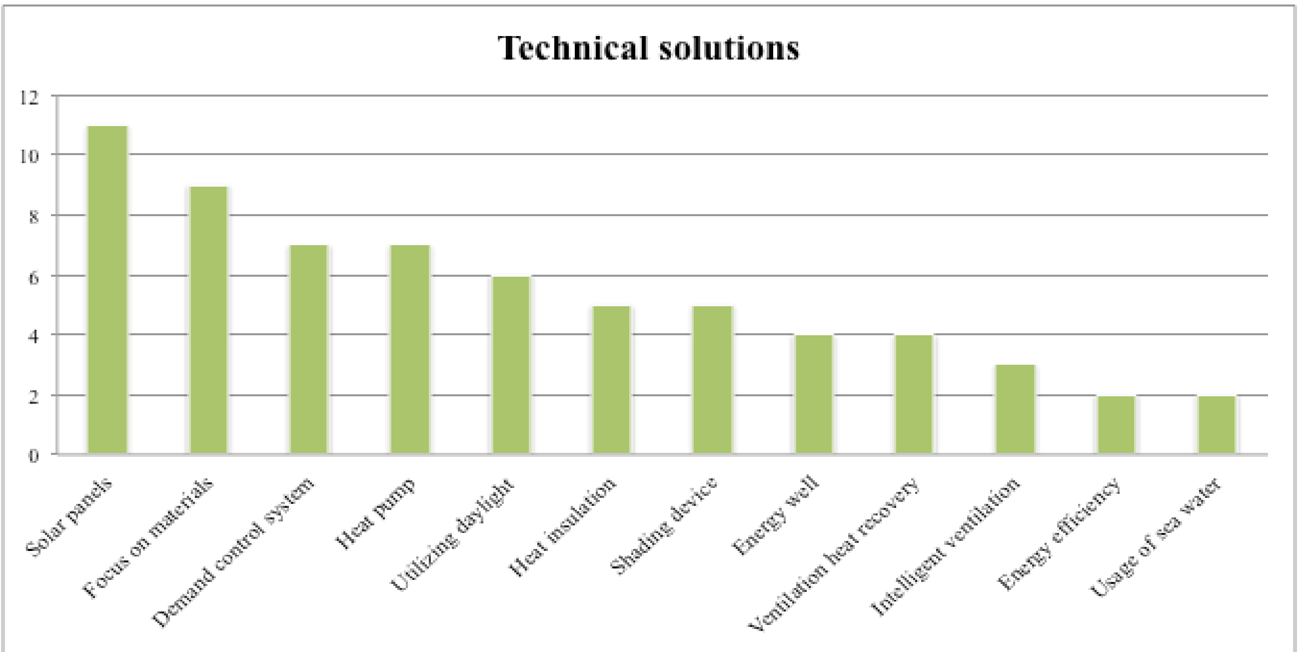

Figure 13: Summary of technical solutions

SOLAR ENERGY

Solar energy comes in many different forms and shapes. Solar energy can be used directly via solar collectors for electricity and heat generation. Solar energy can be thermal solar collectors, used for heating water, ranging from pool water to tap water depending on the given temperature. Thermal solar collectors can also be used as a process heater for industry purposes. A photovoltaic (PV) collector turns sunlight into electricity (Bauer et al., 2010). As stated in SINTEF and NTNU (2007), thermal solar collectors are common in the most sunny countries in the world. PV is expected to have the capacity of covering half of the US's energy demand in 30-40 years time. 90% of PV installations are in Japan, Germany and USA (SINTEF and NTNU, 2007). However, these numbers are from 2007, thus there can have been changes as to their accuracy today.

International Energy Agency Photovoltaic Power Systems Programme (IEA PVPS) is an organisation that produces reports on the development of photovoltaic (PV) around the world. 2015 was a record breaking year in the development of PV. The PV market experienced a 25% growth in 2015, and this happened because nearly all regions in the world participated in this massive expansion (IEA PVPS, 2016). According to San Francisco Insider, the cost of solar energy has dropped by 56% the last eight years (Nilsen, 2016). According to Solar Energy Industries Association (2016), the cost to install solar energy has dropped 73% in the US. Bloomberg New Energy Finance states the cost of solar energy has dropped 65% since 2009 (Ryan, 2016).

Insolation in Norway varies according to geography. The optimal places for insolation are found in the south and east and in mid-Norway, and the areas with worst conditions are found along the northwest coast and in the northern part of Norway. Though the climatic conditions in Norway might seem less than optimal, the potential for useful solar energy is prominent (Enova et al., 2016b).

In 2014, 2,2 MW solar cells were installed in Norway. This was seen as a turning point for solar power in Norway, as this was three times as much as the year before (Enova et al., 2016a). In addition, Enova (2016b) has made a support mechanism that gives up to 35% of total costs back to households that produce energy from renewable energy sources. San Francisco is the first large city to introduce a demand to have a solar power installation on all new buildings under ten floors. San Francisco already has demanded that all new buildings must have 15% of roof space for solar power. This demand applies both to residential and non-residential buildings (Nilsen, 2016).

MATERIALS

Material choice in a construction process is a very important process that is given too little attention. Materials are normally included in the embodied emissions of a building. The embodied emissions are the GHG emissions released to the atmosphere when producing the materials (Kristjansdottir et al., 2014). This means that the extraction, processing, transport and manufacturing of materials are all embodied emissions. These GHG emissions occur elsewhere and beforehand. According to Kristjansdottir et al. (2014), a large percentage of the overall impact of buildings over the lifetime can be attributed to the embodied emissions in materials. When discussing energy use in buildings, it is mostly the energy used by the building. However, the production of materials and components also require energy.

EPD is a helpful tool to see the environmental impact of materials and components. An EPD will normally display both the energy use required in production and the GHG emissions that are emitted through the life cycle of a product. There is an increase in available EPDs in Norway (Kristjansdottir et al., 2014), but the demand for EPDs is still relatively low in the construction industry. In addition, EPDs are not required by law.

DEMAND CONTROL SYSTEM

Demand control system is the solution to make the electric and lighting more user friendly and make it work together with the user. For example, the lighting might be dependent on movement, the ventilation system is turned down afyter a certain time of day and other movement censors. Another option is to have the building set to different modes. For example, away-mode or night-mode, which will set lighting and ventilation according to the user needs. In other words, the electrical appliances will work together with the user. To sum it up, a demand control system controls all the other technical installations to minimize unnecessary energy use.

HEAT PUMP

A heat pump collects heat from our surroundings and increases the temperature of this heat so houses are warmed. All heat pumps work in the same manner, the difference lies in what energy source the heat pump collects the energy from. Air-to-air heat pump collects heat from outside and transforms this to warmer air inside. Air-to-water heat pump collects heat from outside and transforms the heat to water-borne heat through floor heating or radiators. Ground heating heat pump collects heat from the foundation and heats through a water-borne distribution system. Terrestrial heat pump takes advantage of the stored solar energy in the ground and heats through a water-borne distribution system. A seawater heat pump collects heat from seawater and heats through a water-borne distribution system. In a ground water heat pump system, ground water is pumped to a heat exchanger where the heat is collected (NOVAP, 2016). A heat pump uses significantly less power compared to a normal heater. Heat production from heat pumps has increased 0,4 TWh to 15 TWh from 1990 to 2014 (Olje- og energidepartementet, 2016).

UTILIZING DAYLIGHT

Utilizing sunlight is very obvious and available solution. This means having windows that maximize the daylight, larger windows and open areas that allows sunlight to come in. The maximum use of sunlight can give large energy savings during the day. In addition, concrete has the ability to absorb sunlight, transform it to heat and emit this heat during the night. It is a natural heat recovery that will have energy savings in addition to concrete being a good insulation material.

5.3 Interviews

The interviews were conducted in the order as shown below. There were some generic questions that all interview objects were asked and some questions were more specific for the individual and their professional role. The interview guides for the different interviewees can be found in Appendix B, D and F.

SUMMARY OF THE INTERVIEWS

Øyvind Mork is the chairman of the Powerhouse board and chief executive in the engineer and architectural consultancy firm Asplan Viak. Since Gustavsen is a part of the Powerhouse collaboration, his knowledge about the project and plus houses is very valuable.

- The importance of the cooperation process
- Passiveness from authorities regarding regulations
- The challenge and success of building Powerhouse Kjørbo
- The advantage of energy focus and the importance of material focus

Arild Gustavsen is the Centre Director of the Research Centre on Zero Emission Buildings (ZEB). Gustavsen is a good source for focusing on emissions rather than energy. Prior to starting this study, my impression was that there was a lacking focus on materials and emissions. Instead, the focus in much relevant literature, governmental documents and standards is that on energy. Gustavsen's interview underlined this initial idea. Important aspects from this interview were the following:

- No standard definition of plus houses
- Should have more focus on the origin of energy
- Should have more focus on material choice
- The data on impacts of materials are growing
- Standards are helpful tools

Thomas Haugen is a managing engineer in Veidekke. Veidekke is one of Norway's largest contracting companies. Haugen was chosen as an interview object due to his experience in the construction industry in the recent years, and more specifically, his experience in the construction process and dealing with the different actors in this process. On a daily basis, Haugen is the coordinator between the five to six subcontractors on Kunsthøyskolen in Bergen. He also coordinates with the projecting companies. Thus, Haugen was a very good source in regards to the construction process and the cooperation process. Important aspects from the interview were the following:

- The importance of the cooperation process
- The cooperation process would benefit from including subcontractors at an earlier stage
- EPDs are receiving more attention
- Focus should be given to both energy and materials
- BREEAM is a much discussed subject in the industry today

6 ANALYSIS

The following will analyse the interviews, the regulation and the different standards for sustainable buildings. A PESTLE-analysis will analyse different aspects of the issues and a SWOT-analysis will summarize the most important findings of the analysis.

6.1 Thematic analysis of interviews

The analysis of the interviews has been focused around four main themes. This way of analysing makes it easier to see similar and differing opinions between the interviewees and gives a clear view of the focus areas.

6.1.1 POWERHOUSE KJØRBO AND PLUS HOUSES

Øyvind Mork's opinions about the cooperation process confirm the theory laid out in 4.6. Mork explains: "*The biggest challenge was probably to get all the actors to work as integrated as we did. That was in a way the key to the whole success*" (Q3). When elaborating on the subject of cooperation, he points to that the process made the actor exploit their strengths:

> "Instead, it was more "how can we help each other to get this to work" and "if you need more from me, I'll be back in two days and have a solution". This attitude, instead of "it's not my job, it's your job"... I think if we hadn't got into that mode, we wouldn't have managed to pull it of" (Q3)

This way of cooperating, where all the main actors join from the beginning, which can be compared to the integrated design process explained in chapter 4.6, was for Powerhouse the reason for its success. It was a new experience, but will not be the last time Asplan Viak cooperates. Mork elaborates:

> "We haven't worked in that way before [like in Powerhouse], but I can say that we will assuredly work this way again. The philosophy is very close to how we want to work" (Q4)

Thus, for Mork, the process of planning Powerhouse Kjørbo would not have worked without the cooperation. Thomas Haugen, who works as managing engineer for the subcontractors, also has some thoughts on the construction process:

> "In a perfect world, we would have more time in advance… to involve our subcontractors. If they get involved it creates an ownership to the whole process… In a perfect world we would have better more time to involve the painter or other professions and they would be able to say: "I need two weeks, and this is how the work schedule should be set up"… But there is something in getting an ownership of the process and the planning, to actually be a part of it" (Q6)

Haugen, who works on a day-to-day basis with several of the different actors in the construction project also emphasises the importance of involving more actors early.

This will lead to a better relationship between the actors and the subcontractors will get an ownership to the project. As he goes on to explain "*This does not create goodwill with the subcontractor. You get off to a bad start from the beginning*" (Q6), where "this" is a situation where a developer says that a subcontractor has this given amount of time to finish a process without it being realistic for the subcontractor to finish within this amount of time. Thus, if the subcontractor had been a part of the planning process, they would be able to say how much time they would need in advance.

Mork adds that a big strength was the goal that was set: to build a Powerhouse. For many, this goal seemed impossible, but it made them reach further than they would have done normally:

> "What I think has been the most fun about this [Powerhouse] is that it is possible to sit down and just set this hairy goal and then have focus on what we are going to be able to manage. That is one of the things that have been the biggest trigger for myself and for most of the other people in the project. It is amazing what you can do if you just really want to. And most of the time it works out well, also economically. If you just put some good will into it" (Q13)

As Mork points out here, "…this hairy goal…" coincides with chapter 4.7.2, where BHAGs were explained and the importance of BHAGs in an ambitious project is emphasised. The BHAG, according to Mork, worked as a catalyst for the whole group and even though the goal seemed too ambitious for many, it worked well for this project. Mork mentions in the last part of this statement; it worked out well economically if "if you put some good will into it", he did not elaborate on whether this was in reference to overriding the original budget or whether the project was more expensive than a conventional building. However, Mork did have some comments about the cost of a Powerhouse:

> "...probably it costs somewhere around 10-15% more than if you had built a standard building…. But we have been willing to pay around 200NOK/m2 more to live in a Powerhouse. And most of that will be paid back by a reduced energy bill… in a long perspective this is pretty sure to be profitable. Also because it is planned in a life cycle perspective, so a lot of the materials that are used will hold for 60 years" (Q10)

As we see here, the project was around 10-15% higher than a conventional building would cost. But, and this is a significant but, the work laid down in producing a building with a life cycle perspective has its benefits, as this will lead to little or no refurbishment throughout the lifetime of the building. In addition, the reduced (or non-existing) energy bill will lead to large savings.

Though Arild Gustavsen did not have any specific additions to Powerhouse Kjørbo, he had more general thoughts around plus houses:

> “When it comes to measures, we see that many of our demonstration buildings end up with using a lot of photovoltaic. And in addition, heat pump and very energy efficient constructions. Passive house levels are often the basis, and often more than that, more insulation, even more airtight. And when it comes to GHG emissions, the GHG emissions from materials are extremely important” (Q14)

Gustavsen emphasises the importance of renewable energy production and heat pumps as the main measures to achieve plus house level. The construction is very energy efficient and the basis of the building is often better than passive house. And as expected, he highlights the importance of GHG emissions from materials.

Haugen, who currently works for a contractor, Veidekke, in the construction industry had these reflection son plus houses: “*Internally at Veidekke there isn’t much talk about plus houses actually. There has been more talk about BREEAM-certification*” (Q9). This is certainly a step in the right direction, and a more extensive use of BREEAM is a very positive step in the direction of sustainable buildings. In addition, he share an experience he had on a project:

> [The project leader from the developer] came up on the roof of a building project and said: “Crap, we should have installed solar panels here”… It’s positive that a developer would say that; it shows that they focus on it (Q9)

Here the project leader from the developer realised that solar panels would have been a good idea to put on the roof, but it was too late to do anything about it. This might mean that this will be done for a later project, as the project leader probably saw the potential in this investment. However, this should have been suggested and thought of of in the planning process.

6.1.2 PASSIVE HOUSE AS A DEMAND FROM AUTHORITIES

As seen earlier in this study, the concept of passive house is very popular today, and TEK10 was supposed to be passive house level by 2015. As this did not happen, it might be more realistic to expect passive house levels required by law in 2020. Hopefully this will happen before, and the authorities will stick to its goal to have nearly zero energy level in 2020. Gustavsen has some thoughts about this reality:

> “They originally planned to have passive house requirements from 2015. The requirements that were introduced are almost at passive house level. In 2020 the aim is nearly zero energy buildings. That is the ambition. But it is yet to be defined and to see whether the authorities actually introduces this as a requirement” (Q11)

As Gustavsen points out, the requirements are almost at passive house level. This is demonstrated in Table 2. Gustavsen also points out a crucial factor: the concept of nearly zero energy buildings must be defined. Today, there is no official or standardized definition of nearly zero energy buildings. As he later explains:

"…EU is saying this: from 2020 the requirement shall be nearly zero energy for new buildings. But nearly - what is nearly? It is too vague if you ask me. It will be enough to just have a little bit - and what is a little bit? It is both vague and imprecise" (Q11)

Thus, the need for a common decision is necessary before this can become a legal requirement. Mork was more explicit in his thoughts about passive houses:

"Passive house is too passive, to be a bit funny. It's obvious that you understand that there is more to a Powerhouse compared to a passive house. So the authorities should go considerably further when we reach 2020… And not least - if they don't get the regulations to follow along - they should at least build their own buildings with a standard that is much further than passive house" (Q6)

According to Mork, the passive house requirement is in fact too passive. He brings up another important issue: the public sector should be a leader for the whole construction industry. In fact, public authorities have also made this point (see chapter 4.1.4). If public and governmental buildings have a higher standard than the legal requirements, this might have a spill over effect to the rest of the construction industry. However, the situation today seems to be opposite: the construction industry is ahead of the public authorities. Haugen has this reflection about the issue:

"It is positive that they are pushing for more environmentally friendly buildings. That's the way we should go. And for the contractors it's more: as long as we get paid to construct a plus house, we will construct a plus house" (Q10)

The current development is positive, according to Haugen. Indeed, the development is positive, but it might be a little to slow. It seems as though the contractor has no say in the decision making process leading to constructing a plus house. If the contractor had been a part of the project planning, this would not be the case. He goes on to say: "*But [a governmental developer] should definitely go ahead and set an example on environmental issues, to push the development in the right direction because they are able to*" (Q8), where the governmental developer is an actual company. So Haugen and Mork agree that governmental developers and projects should set an example for the rest of the industry.

6.1.3 STANDARDIZATION AS A TOOL

TEK10 is a regulation, but also a standard of how buildings are to be constructed today. NS 3701 and BREEAM-NOR are voluntary standards for constructing more sustainable buildings than they would have been if TEK10 were to be followed. Does standardization hinder innovation or is it a helpful tool in the construction process? Mork emphasises the problems with standardization:

"Standardization is a very interesting topic, because if we go beyond just energy, there has been talk about standardization for 20-30 years. Consequently, one commercial building is not very different from the other… To find new solutions and draw up every detail every time instead of standardizing, I think this has been a weakness in the construction sector in a way. Because it has contributed to low industrialization... and that again has made the efficiency or the productivity of the construction sector to fall in the last ten years" (Q7)

According to Mork, standardization leads to buildings being very similar to each other. However, this is not necessarily a problem. He goes on to say:

"And then you try to compensate and improve the efficiency with BREEAM, for example, and with more model planning and standardization. I think that the question has at least two answers: one being that there is nothing wrong with standardizing some things, as long as you standardize good elements... But if you want innovation, you can't base everything on standard solutions. So it has to be a combination of these" (Q7)

Standardization is necessary, especially if the correct elements or processes are standardized. His main argument is that standardization may slow down the development of the construction industry, as everybody will just follow the standards without thinking outside the box. However, he also sees the value of standardization. Gustavsen focuses more on the importance of standardization:

"I think it is important. It is important to ensure that the different actors use the same methodology. And when you have calculated a building's energy demand, you can say: "I used that calculation method". So, yes, I think it is an important tool in the development of the future's buildings" (Q12)

For Gustavsen, the issue is more concerned around the comparability of buildings and processes. Without standardization, buildings could not be comparable as the route to constructing a building would then maybe be different for each building. Haugen agrees with this point:

"I think it is very positive to standardize it, to put a label on it. Then you are able to distinguish buildings from each other. If you can market it as a plus house, then that's positive. If you didn't have standardization, then you wouldn't have a scale, a name on it…And I think e.g. BREEAM is very positive and to construct a BREEAM Excellent is highly valued. Simultaneously it is cost benefit. What do they get back from constructing a BREEAM Excellent building?" (Q11)

Haugen also points out the comparability aspect standardization offers. In addition, the ranking of buildings is emphasised. Without standards, it would be hard to distinguish houses into different categories and say that one is better than the other.

Gustavsen goes on to explain the coming standard for calculating GHG emissions, where ZEB is participating in the development. This standard would be the basis for ranking buildings according to their GHG emissions:

> "ZEB is contributing in the development of a standard for calculating GHG emissions for buildings. Another standard is also needed, on definition of the different levels. What is a zero energy building, what is a nearly zero energy building, what is a zero emission building and with the different levels also. When a calculation standard is ready, then it is possible to calculate the level of the buildings" (Q12)

6.1.4 FOCUS ON ENERGY VERSUS GHG EMISSIONS

The focus on energy is much larger than the focus on GHG emissions. This might be a paradox, as when we are talking about the global warming, the reason is increasing GHG emissions in the atmosphere. These two are of course connected, as it is often the production of energy that is the main problem, as it is produced with non-renewable sources.

Mork explains why energy was chosen as the main measure tool for Powerhouse Kjørbo:

> "The advantage of focusing on energy is that it is very easy to communicate, you can measure the energy use. So there is really no discussion around that. But it is clear that what means something to the climate in the world, it is the GHG emissions. So I actually think that one should consider both" (Q8)

Energy is easy to measure and communicate to outsiders. However, it should be said that the Powerhouse Kjørbo project had a very large focus on GHG emissions as well. For example, the concrete structure was kept to not exceed the GHG emission balance sheet and 95% of the materials used are either recovered or recoverable (Mork, 2016). He goes on to explain that the two are interconnected:

> "Energy is a part of the GHG account, the energy can be produced in different ways, which gives different GHG emissions, right. Materials can be collected in different ways, a lot of different GHG impact. So I think both, but you can say that Powerhouse has primarily focused on the energy side. And that is to a large degree to have something that is easy to communicate" (Q8)

Mork makes an important point here that is often overlooked: energy is produced in different ways. Gustavsen is the director of the Research Centre on *Zero Emission* Buildings. Thus, it was not surprising that he finds GHG emissions important:

> "I've been thinking a bit about that lately actually… When you say zero energy building, you don't say anything about how the energy is produced, whether it is coal power, hydropower or based on other sources. It is implicit here that you compensate with renewable energy. When you focus on emissions, you get a more integrated handling of the problem where you look at the quality of the energy you use and how the energy is converted" (Q8)

An important point here is the same as Mork made in the previous quote: the production of the energy. If you construct e.g. a zero energy building, the focus is how much energy used and this has to be compensated by producing renewable energy. There is no focus on the GHG emissions that occur when this energy (that is to be compensated for) is produced. With ZEB, the emissions are in focus, and renewable energy production is compensating for the emissions from the energy production and other phases of the building, not the amount of energy produced. Gustavsen goes on to say:

> "For me zero emission building is becoming more and more correct. It is more directly connected to the climate crisis, since it is connected directly to CO_2 that is the main problem. But of course, it is ambitious, and it is still a bit difficult to find good documentation, for example on materials…We see that approximately half of GHG emissions related to buildings come before you start to use the building. It is therefore also important to focus on GHG emissions from the construction process and material production, even though there is a bit poor documentation on the material side" (Q8)

As Gustavsen points out here, the discussion around the climate crisis is concerned around CO_2, so the focus on emissions in a construction project should be more extensive. He also brings up GHG emissions from material production, which is a large contributor to the total of emissions from construction projects. He continues:

> AG: "[But it's getting better with EPDs?] Yes, and when we are focusing on it in our demonstration buildings, we are pushing the development. And even though it doesn't exist for all materials, there is a lot of generic data you can use, like from Ecoinvent or other international databases. So there are opportunities for it" (Q9)

ZEB is pushing for growth and progress on the EPD area. Though the optimal EPD shows the exact environmental impacts of a product, Gustavsen sees the potential in using generic data as well. Haugen also has some experience with EPDs:

> "…[a developer] is demanding EPD on paint. We go to the subcontractor and told them that they must deliver EPD. They have gone to the producer and said that they need and EPD. Then the producer says they don't have an EPD on the product. Then we have to go back to [the developer] and say we weren't able to provide and EPD… The way I interpret this is that [the developer] is pushing the industry to go ahead… and maybe the industry needs it too. You need someone who is a driving force, I think that's positive" (Q13)

Here he explains a situation where a developer is pushing the producers to have an EPD for their product. As explained in chapter 4.1.4, EPDs are useful tools to compare products and then choose the product that has the least amount of environmental impacts, if that is the objective of the user of the EPD. In this case, however, the developer is demanding EPDs from the already chosen producer. Thus, the point of the EPD disappears. Nonetheless, as Haugen says, its positive to have a driving force for making EPDs more common.

6.2 Document analysis

The following document analysis focuses on the three relevant standards and regulations for buildings and sustainable buildings today. Firstly, the mandatory minimum standard TEK10 is presented. Secondly, the voluntary NS 3701 is presented. Finally, the voluntary BREEAM-NOR is laid out.

6.2.1 TEK10

TEK10 is a national regulation that lays out the minimum requirements to construct and refurbish buildings today. It is a comprehensive regulation that covers many aspects of the life cycle of a building and it has many specific requirements (and many not so specific). TEK10 is divided into four parts, namely (1) general regulations, (2) natural strains, outdoor area and outer environment, (3) demands for construction and (4) various regulations (KMD, 2010). Table 6 gives an overview of the chapters and the main content in these chapters. TEK10 is a regulation for new buildings and large renovations. New buildings represent approximately 1-2% of the building stock per year (KMD, 2015a). For the purpose of this study, chapter 9: "Outer environment" from part two and chapter 14: "Energy" from part three are the most relevant.

Chapter 9 deals with the outer environment, toxic substances, pollution in the ground and management of waste. There are very specific demands to some of the aspects mentioned and there are other general demands. An example of the most general demand to the outer environment is the following: "*Buildings shall be projected, constructed, operated and demolished, and waste shall be managed, in a manner that causes the least amount of burden on natural resources and the outer environment*" (KMD, 2010). The part about waste aims to limit the amount of waste throughout the lifetime and to choose products that are reusable and materials that can be recovered. Though there are specific demands for toxic substances, pollution in the ground and waste, the demands for the rest of the environment affected by construction is not specified.

Chapter 14 concerns energy use, energy efficiency and energy supply. There are specific demands to energy demands according to type of building, u-value, air leakage and thermal bridge values. As stated in KRD (2012), the Government was supposed to tighten the energy demands to passive house level in 2015 in TEK10. Instead, the energy demands have recently been updated and the demands were implemented 01.01.16. The new demands are shown in Table 2.

Table 6: Content in TEK10

	Chapter	Content
Part 1	**1. Common decisions**	• The use of the regulation on special actions
	2. Documentation of completing demands	• Verification of functional demands and performance • Documentation of solutions
	3. Documentation of products	• General demands regarding products for buildings
	4. Documentation for management, operation and maintenance	• Documentation of operation phase
	5. Degree of utilization	• Developed area • Utilized area
	6. Calculation and measurement regulations	• Area
Part 2	**7. Safety for strain on nature**	• Safety for flooding and storm surge • Safety for landslides
	8. Outdoor area and positioning of buildings	• Outdoor area • Positioning of buildings
	9. Outer environment	• Waste • Waste plan • Final report of waste disposal • Emission demands for stove
Part 3	**10. Construction safety**	• Personal and material safety
	11. Fire safety	• Carrying capacity and stability • Quality of material and products during fire • Technical installations
	12. Floor plan and building components	• General demands • Waste system
	13. Environment and health	• General demands for ventilation • Thermal indoor climate • Room acoustics • Light and view • General demands on humidity
	14. Energy	• General demands • Demands for energy efficiency • Minimum demands for energy efficiency • Demands for solutions for energy supply
	15. Installations and plant	• Heat and cold installations, central heat, heat pump
Part 4	**16. Security check of elevators**	–

6.2.2 NS 3701

NS 3701: 2012 Criteria for passive houses and low energy buildings. Non-residential buildings set requirements for non-residential buildings that can be defined as passive houses or low energy buildings. This is a Norwegian standard that is adapted to the Norwegian climate and conditions. The standard is based on *NS 3031: Calculation of energy performance of buildings – Method and data.* The NS 3701 standard includes demands for heat loss, cooling demands, energy demand of lighting and energy supply and minimum demands for some subassemblies. In addition, demands are set for leakage numbers, measuring methods, and the energy performance of completed buildings (Standard Norge, 2012). The standard consists of three main chapters:

4. Superior criteria
5. Minimum demands for subassemblies, components, systems and leakage numbers
6. Report, documentation and certification

Table 7 summarizes the main content of NS 3701. It is clear that the main focus in this standard is energy demands, reducing loss of energy and minimum requirements for certain building components. As explained in 4.4.1, a passive house can have a 75% lower energy demand than a conventional building This is due passive measures, such as thermal insulation in building components, heat recovery and less air leakage.

Table 7: Content in NS 3701

Chapter		**Description**
4.	Superior criteria	
4.1	Heat loss numbers for transmission and infiltration heat loss	Measure of a building's heat loss to the environment
4.2	Heating demand	Heating for space heating and ventilation heating
4.3	Cooling demand	Thermal comfort shall be reached with a very low need for cooling
4.4	Energy demand for lighting	Numbers given for highest allowed net specific energy demand for lighting
4.5	Energy supply	Comply with demands in TEK10
5.	Minimum demands for subassemblies, components, systems and leakage numbers	
• U-value for windows, doors, outer walls, roof and floors • Normalized thermal bridge value • Yearly average temperature efficiency for regenerator • SFP-factor ventilation installation • Leakage numbers at 50 Pa		
6.	Report, documentation and certification	
6.1 – 6.4	The energy calculation, documentation on selected components and documentation for the finished building will determine if the building can be classified as a passive house or a low energy building	

6.2.3 BREEAM-NOR

BREEAM-NOR is the most comprehensive standard out of these three examples. Table 8 gives an overview of the different categories in BREEAM-NOR and the main content in these categories. The categories range from health and indoor environment to innovation, where the different categories are weighted differently according to how important the category is viewed. This weighting is shown in Table 9. As explained in **Error! Reference source not found.**, there are five possible levels of a BREEAM-classification: *Pass*, *Good*, *Very Good*, *Excellent* and *Outstanding*. Each of these levels has some minimum requirements that must be fulfilled to achieve the wanted level. For the purpose of this study, the most relevant are:

- Material 1: Materials specification
- Health 8: Ventilation solution to ensure indoor air quality
- Energy 1: Energy efficiency
- Energy 2: Sub-metering of substantial energy uses
- Energy 5: Energy supply with low GHG emissions
- Energy 23: Energy performance of building structure
- Management 3: Construction site impacts

There are other minimum requirements that must be fulfilled as well, but these will not be taken into account here, as they are not relevant. It is clear from the list above that the energy minimum requirements are very important. For example for Energy 1: Energy efficiency the maximum points that can be rewarded is 13 points. If the building is to achieve *Excellent* level, this category must have 7 points and if the building is to achieve *Outstanding* level, this category must have 9 points (NGBC, 2012).

Table 9 shows how the different categories are weighted. All the categories except Innovation add up to 100%. Innovation is seen as an extra measure that will give extra points in addition to the other categories. It is possible to see this table as a ranking of the most important categories. It is clear from Table 9 that *Energy* is the most important category and *Health and indoor environment* is the second most important category. These two categories are closely related, as the energy requirements will affect the indoor environment, especially thermal comfort and indoor air quality. *Materials* is the third most important category. The following will present the two categories *Energy* and *Materials* in more detail, as these are the two topics that are of focus in this study.

Table 8: Overview of categories in BREEAM-NOR

Category	Content
Management and administration	• Start-up • Impact on site • User manual for buildings • LCC
Health and indoor environment	• Daylight • Thermal comfort • Acoustic • Indoor air and water quality • Lighting
Energy use	• Energy demand • Low or zero carbon solutions • Part measures of energy • Energy efficient installations
Transport	• Proximity to public transport • Arrangement for pedestrians and cyclists • Proximity to facilities • Travel plans and information
Water	• Water use • Leakage detection • Reuse and recycling of water
Materials	• Life cycle evaluations of materials • Reuse of materials • Responsible purchasing • Robustness • EPDs
Waste	• Construction waste • Recycled aggregates • Recycling plant
Land use and ecology	• Choice of site • Protection of ecological functions • Lessen/strengthen ecological values
Pollution	• Use and discharge of coolant • Risk for flood • NO_x-emissions • Pollution of water system • External light and noise pollution
Innovation	• Exemplary performance level

Table 9: Weighting of categories

Categories	Weighting (%)	Number of goals in category
Management and administration	12	14
Health and indoor environment	15	15
Energy	19	14
Transport	10	8
Water	5	7
Materials	13,5	5
Waste	7,5	6
Land use and ecology	10	6
Pollution	8	8
Innovation	10	1

ENERGY

The Energy category in BREEAM-NOR has 14 subchapters. The following will present the most relevant subchapters for this study and these are chosen as most relevant due to the fact that these requirements are also the minimum requirements to be able to get a BREEAM-certification as shown above. *Energy Efficiency, Sub-metering of Substantial Energy Uses, Energy supply with low greenhouse gas emissions* and *Energy performance of building structure* are the most relevant subchapters for this category. All of these subchapters are relevant for all types of buildings. Many of the other subchapters are for example only relevant for one building category, thus these four subchapters are chosen as focus points. In addition, these subchapters are all related to TEK10 and NS 3701.

Energy Efficiency is the subchapter in the Energy-category that awards most credits, namely 13 credits. The goal is to recognise and encourage buildings that are able to minimise the operational energy consumption. This is measured in percentage improvement: if a new building has an improvement of e.g. 100% compared to energy character C in the Norwegian energy labelling system, the building is awarded 13 credits. In other words, the improvement is calculated based on the standard C in the energy labelling system (168 kWh/m^2) and the amount of delivered energy required in the new building. Powerhouse Kjørbo can give a concrete example:

$$\frac{E_{ref} - E_{lev}}{E_{ref}} = \frac{168\ kWh/m^2 - 32kWh/m^2}{168\ kWh/m^2} = 81\%$$

Where E_{ref} is the current standard in Energy label C and E_{lev} is the delivered energy for the building.

Powerhouse Kjørbo had an improvement of 81%, which provide this building with 11 credits out of 13 possible credits.

Sub-metering of Substantial Energy Uses encourages the installation of separate sub-metering of energy in different systems, e.g. space heating, cooling and lighting. This will hopefully lead to a stronger awareness of energy consumption. The goal of *Energy supply with low greenhouse gas emissions* is to reduce GHG emissions from the energy sources. This subchapter can give three credits and promotes the potential of using local renewable energy sources. It is not a demand that the whole energy demand is to be covered by local renewable energy sources, but it is encouraged that a significant amount of the energy demand is generated by local renewable energy sources. Two credits are awarded if the GHG emissions are reduced by 35%. In addition, if 50% reduction is proven, one innovation credit can be awarded and if the reduction is 100%, two innovation credits are awarded in addition to the first mentioned credits. *Energy performance of building structure* encourages constructing buildings that minimize the need for energy for cooling and heating. This subchapter is directly linked to NS 3701. The requirements for net energy demand for heating and cooling given in NS 3701 are the same for BREEAM-NOR, but it is encouraged that the net energy demand shall be lower than that of NS 3701. In addition, the air leakage numbers should be according to the *passive house requirements*, meaning it is lower than *low energy building requirements* (NGBC, 2012).

MATERIALS

The chapter about materials focuses on the life cycle of a material and the ability to reuse a material. More specifically, the subcategories include *Material Specification, Reuse of Facades, Reuse of Structure, Responsible Sourcing of Materials* and *Designing for Robustness*.

We see that *Materials Specifications* is also one of the minimum requirements to achieve any level of BREEAM-certification. Within this subcategory, Climate gas calculations, LCA and EPD are three of the main areas required. By fulfilling these three areas, five out of seven credits are awarded. All of these three areas are related and can possibly overlap. The climate gas calculations are a tool to reduce the GHG emissions from materials. By reducing 80%, one credit is awarded, 60% reduction gives two credits and 50% reduction gives three credits. By using LCA for at least two material options and proof that his result has influenced the choice of design gives one credit. At least ten EPDs for different building products must be documented to achieve one credit.

Reuse of Facades and *Reuse of Structure* encourages the reuse of existing façade and structure. The points are awarded a given percentage of the above is reused. BREEAM-NOR is currently being revised and one important suggested addition is a subchapter in *Materials*: "*Mat 06: Design for easy disassembly and reuse*". The purpose of this addition is to encourage thinking of reuse in new construction. The idea is that buildings are to be easy to disassemble and easy to reuse (Nohre-Walldén, 2015). *Responsible Sourcing of Materials* focuses on the legality of purchasing materials and for example that a supplier has an approved environmental management system. Designing for Robustness presents the importance of using design that will withstand protect exposed parts of a building and that will lead to a low grade of replacing materials (NGBC, 2012).

6.4 PESTLE-analysis of plus houses

By applying PESTLE-analysis to the case of plus houses, one achieves a more integrated picture of the issue. It is a helpful tool that, in this case, summarizes the theoretical framework, empirical data and the analysis chapters into six different categories that all relate to plus houses either on a micro or macro level. PESTLE is a tool for decision makers to highlight the important aspects related to the issue in question.

6.3.1 POLITICAL

The most important factors to mention here is governmental decisions regarding buildings. This includes governmental goals, such as White Papers, regulations, such as TEK10 and governmental acts, such as the Plan and Building Act and the Public Procurement Act. All of these mentioned factors will influence the construction industry and how they work.

White papers set the goals of the Government, and for the construction industry both construction-specific White Papers and more general White Papers concerning the environmental goals of Norway will influence the industry and its scope of action. Chapter 4.1 outlines the current building legislation in Norway. White paper 28 (KRD, 2012) is very relevant here, as this is the first White Paper concerning only buildings, their impact on society and goals for making the construction industry more sustainable. The main goal of this White Paper is that the buildings of the future shall be well-developed, secure, energy efficient and healthy.

For the purpose of this study, the main legal regulation is TEK10. As explained in 4.1.3, the revision of TEK10 was supposed to set the demands at passive house level according to NS 3701. All new and refurbished buildings must comply by the demands set in TEK10. However, the revision of TEK10 did not comply with the set goal of passive house level. Thus, all new and refurbished buildings must not comply by passive house level. With that said, the construction industry can be said to be ahead of legislation, and many new buildings today are indeed passive house level or better.

Another important act is the Public Procurement Act. The revised act states that all public procurement practices shall reduce their impact on the environment. However, the act does not mention EPDs. Including EPDs could be a measure to make producers and public consumers of these products more aware of the environmental impacts. In addition, this would make it easier in public procurement to choose the products that have the least amount of environmental impact.

It is clear that political factors have a large influence on the construction industry today. The development in the requirements set by national authorities is moving in the right direction. The revised TEK10-requirements are more demanding than the previous requirements. The next time it is revised, the requirements will probably be passive house level or maybe higher. This development will probably continue. Higher requirements will emerge, and eventually the requirements might be that buildings must be energy positive according to one of the definitions in Appendix A.

Governmental authorities could set other demands than merely focused on energy. For example, national authorities could impose that all new buildings and refurbished buildings must be BREEAM-NOR certified. This would lead to buildings in general becoming more sustainable, as even the lowest level of BREEAM-NOR certification, *Pass*, would lead to a higher awareness of the environmental impacts a building has and that the improvement of these impacts might not be too complex or costly.

6.3.2 ECONOMIC

Economic factors are not a large focus area in this study. However, it is worth mentioning the importance of economic factors when constructing buildings. As explained in chapter 4.7.4, economic factors can be e.g. economic growth, inflation or demand in an industry. For the purpose of this study, the focus will be on the cost of constructing plus houses and how the demand for sustainable buildings in society relates to this cost. Budgetary restrictions set in the early planning phase is the best measure to avoid that sustainable buildings are more costly than conventional buildings. Introducing the budgetary restrictions early makes it easier for all actors to relate to this and choose solutions that work around the restrictions.

For a concrete example, we can look to Powerhouse Kjørbo. According to Mork[2] "…probably it costs somewhere around 10-15% more than if you had built a standard building" and "…we [Asplan Viak] have been willing to pay around 200NOK/m2 more to live in a Powerhouse. And most of that will be paid back by reduced energy bill". In addition "…because it is planned in a life cycle perspective, so a lot of the materials that are used will hold for 60 years." Thus, the buyer or tenant must perhaps be willing to pay more than it would have done for a conventional building. In addition, Haugen also pointed out that the decision to construct plus houses is a question of cost. However, if a building produces all the energy it uses, the energy bill is negligible and if the materials used for construction are meant to last for the whole life cycle, this will save costs of refurbishment.

6.3.3 SOCIAL

This study is not a study of consumers and society's attitudes towards buildings. Thus, this section is merely a reflection of how the author perceives the public attitudes and trends in society. The author has very strong opinions regarding this subject, but understands that this cannot be generalized for the rest of society. In the context of plus houses, the social factors can be seen as social trends and attitudes in society. Sustainability is receiving increased attention in society as a whole and the

[2] See Appendix C

Paris-agreement and the SDGs are backing the importance of awareness around the impact society has on the environment surrounding us. There is no clear demand for plus houses by consumers today. Therefore it is more reasonable to look at sustainable buildings in general. This social factor is also affected by the political and legal situation. If building requirements were higher, the demand would probably be as well.

If the public sector would go ahead and set an example with their respective buildings, the demand might be higher. Also, if society was aware of the large impact buildings have, the demand for sustainable buildings would probably increase. In addition, the impression that sustainable buildings are much more expensive than conventional buildings must also be an important factor in keeping the demand low.

6.3.4 TECHNOLOGY

As mentioned several times in this study, constructing a plus house does not require a technological revolution. The solutions already exist, and by using these solutions in both conventional ways and innovative ways, the outlook for plus houses are impressive. The last years have especially made the outlook for plus houses blossom: the cost of solar technology is going down year by year, and seeing as this is the main technological solution to construct plus houses, this is a positive trend that favours sustainable buildings.

The Research Centre on ZEB is based at NTNU and is working closely with the industry to find new solutions, both technological and others, to promote ZEB and solutions to the market. Powerhouse Kjørbo used the planning process to use known technological solutions in new ways to create a plus house.

There is constant improvement in technological solutions, and the focus on sustainable buildings is increasing. If we look to Tesla, technological innovations are still being introduced to the market, and it is in constant improvement. This can be the future of buildings as well.

6.3.5 LEGAL

Legal factors are important tools to make the construction industry more sustainable. National authorities have a lot of power when it comes to making the construction industry more sustainable. For example, the TEK10 requirements are mandatory by law. The construction industry must abide by the requirements set in this regulation. Thus, if the requirements are made more ambitious, the new and refurbished buildings will also become more ambitious in terms of fulfilling these requirements.

EPDs can be a tool to regulate and limit environmental impacts for construction products. It will assist the consumers choose the most environmentally friendly products and it will also make producers aware of the environmental impacts of their products. In addition, if producers compare their own EPD with an EPD of a similar product and see that the other product has less environmental impact, the producer can learn from this product and make their respective product better. An EPD shows where in the life cycle the impacts occur, thus the producer will be able to see where there is room for improvement.

As mentioned in chapter 4.1.4, the Government was supposed to consider whether there should be demands for documentation like EPD in the revision of the next TEK. The revision was done in 2015, and EPDs are not mentioned in the revised TEK. If the Government made EPDs required by law, the producers of construction components would have to document their activities and the consumers of these components would have clearer incentives to choose products based on environmental concerns.

6.3.6 ENVIRONMENT

Environmental factors have been mentioned in all of the above categories. When talking about sustainable buildings and plus houses, everything is connected to environmental factors, as the purpose of making buildings more sustainable is to minimize the environmental impacts they have. Governmental requirements, consumer demands, technological innovations, legislation and economic factors are all tied together to the environmental factors. This is why the whole debate about buildings started and why it will continue in increasing volume in the future. Buildings will continue to impact the environment, and the environmental factors will constantly be there. If the cost of constructing sustainable buildings will become equal to constructing conventional buildings in all cases, the economic factors will no longer have an impact. If the next revision of TEK10 sets the requirement that all buildings must produce renewable energy that compensates for the GHG emissions of all the phases of a building, the political factors will be less important. However, the environmental factors will always be a factor, as this is the basis for why we need sustainable buildings.

6.5 SWOT-analysis of plus houses

The following SWOT-analysis is a summary of the preceding analysis. Positive and negative factors are placed according to if they are internal or external factors to plus houses. The positive factors include strengths and opportunities, while the negative factors include weaknesses and threats.

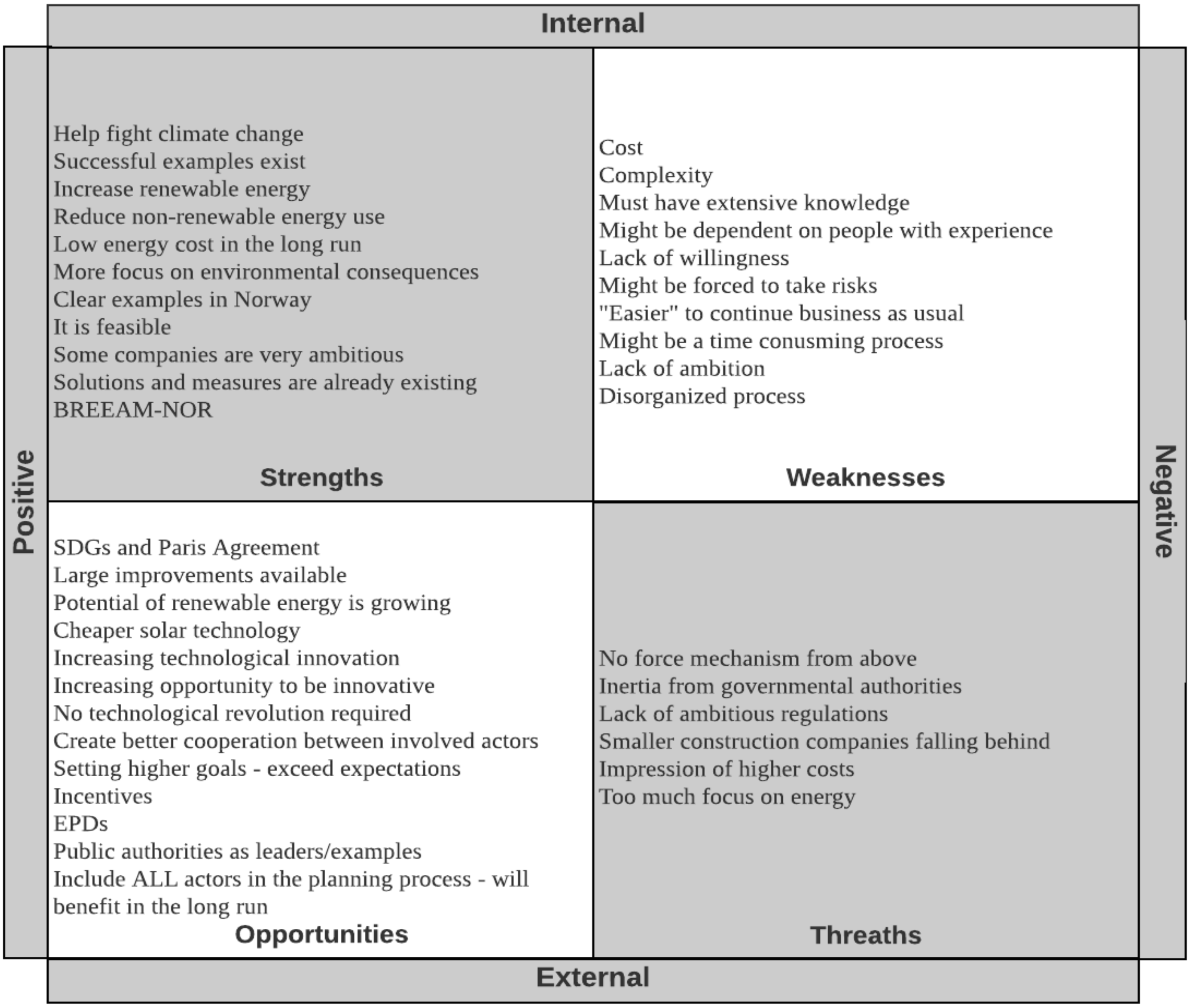

Figure 14: SWOT-analysis of plus houses

7 RESULTS

> "We have enough technology, knowledge and economy to solve the environmental challenge. What we are lacking is a common superior strategy and genuine willingness to implement it" – Jon-Viking Thunes (Bergesen, 2016a)

The proposed model for decision making is shown in Figure 15. This model presents the main aspects decision makers should consider when deciding whether to construct plus houses or not. However, the model can also be used when considering any of the sustainable building categories presented in chapter 4.4. The model is a result of the information presented in Chapters 4, 5 and 6 and has taken the key factors from the SWOT-analysis in Figure 14. The model can be divided into three separate parts. Firstly, the theoretical framework, empirical data and analysis represent the main chapters in this study. This leads to the second part, where the most significant parts from these three chapters are presented. The third part is the proposed model. Here the critical factors that can influence a decision on whether to construct a plus house or not are presented. The following will present the third part of the model – the proposed factors the decision makers should focus on when making the decision to construct a plus house or not.

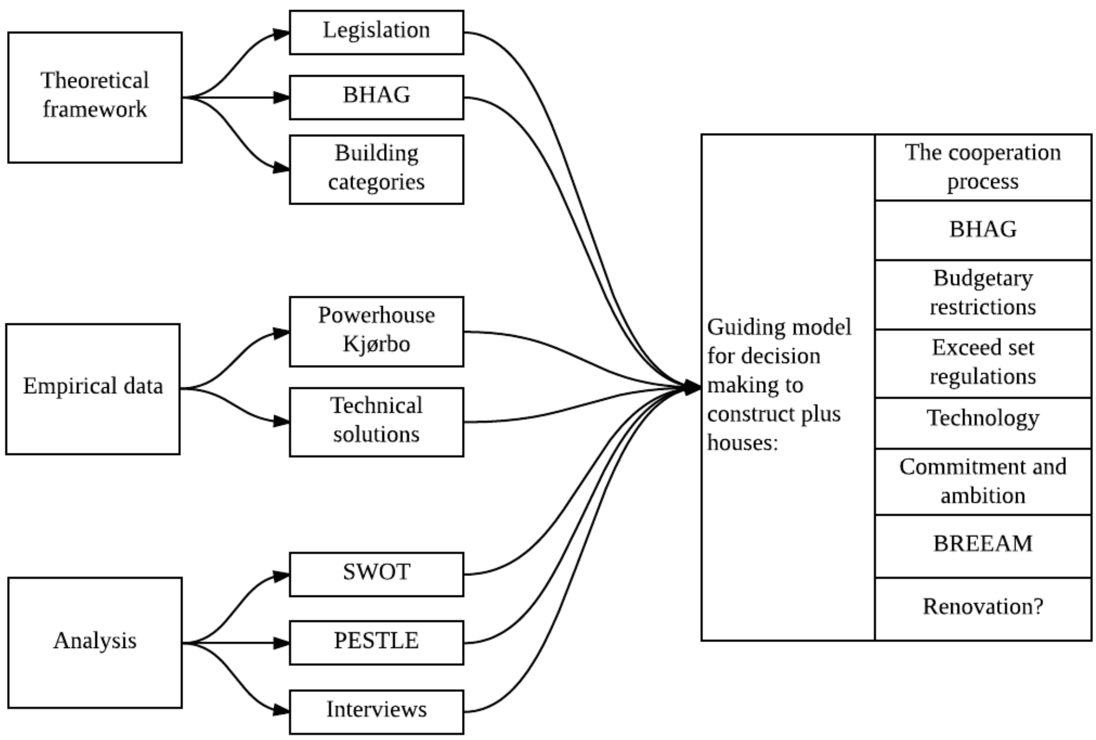

Figure 15: Proposed model for decision making

THE COOPERATION PROCESS

The cooperation process has proven to be crucial in the successful construction of plus houses. BHAG and budgetary restrictions are closely related to the cooperation process, as this is where these are defined. The cooperation process, and especially the planning and design process, will benefit from having all relevant actors included. This can be done by hosting workshops and charrettes that allows for free flows of ideas. When all relevant information is provided from the relevant actors, acting on the decision will be easier as the decision will be anchored in knowledge from several actors and professions. In the current construction climate in Norway, the decision to construct a plus house is quite radical and unusual. There is no standard for plus houses, the only predefined terms is that the building must produce more energy than it consumes. This may or may not include all the phases of the building, depending on how it is defined (see Appendix A). Thus, when the decision to construct a plus house is made, the BHAG must be set. This can be merely to build a plus house, it can be related to the budget or it can be both. Nonetheless, a BHAG must be set so the involved actors will have something to reach for and strive to complete together.

BUDGETARY RESTRICTIONS

A plus house is a large investment, and the impression is that the cost is higher than for a conventional building. This may be the case, but if a strict budget is set from the start, and the involved actors must relate to this budget throughout the project, innovative solutions may emerge as a result of the restrictions. In addition, it is important to remember the energy savings that will occur throughout the lifetime of the building when deciding to construct a plus house. The decision to construct a plus house must be based on knowledge, trust in the relevant actors, a set budget and a BHAG.

EXCEED REGULATIONS

The regulations for constructing buildings in Norway are set in TEK10. When it comes to energy, the regulations are set lower than passive house level. It is therefore obvious that the set regulations must be exceeded when constructing a plus house. The important factor here is to know that it is possible to be better than the set minimum requirements and that the tools required to do this are already existing, as will be shown in the next paragraph. The point here is to strive to be better than the minimum standard; to show the authorities that the construction industry is miles ahead of what is required from them. This might lead to the authorities setting higher requirements, plus houses becoming more commonplace and the perceived higher price will be lowered as the solutions, e.g. solar panels, will be more widespread.

TECHNOLOGY

As mentioned, the expansion of plus houses will make the technology used in plus house concepts more commonplace. However, as seen in the quote in the beginning of this section, the technology required is already here and available. As seen in Figure 12, which shows the solutions used to construct Powerhouse Kjørbo, the solutions are not revolutionary in any way. And as Figure 13 shows, the most common technical solutions are already commonplace or are expanding on a yearly basis.

COMMITMENT AND AMBITION

To be committed and ambitious are two factors that will determine the decision to constructing a plus house. One can say that constructing a plus house will not happen without commitment and ambitious behaviour, as the whole process will require sincere dedication to the concept. This aspect is closely related to both BHAG and budgetary restrictions.

BREEAM

Seeing as there is no standard for plus houses today, the decision to construct a plus house is not as straightforward as the decision to construct a passive house, for example. A plus house standard can have many possible formulations. For example, it can focus exclusively on energy, as NS 3701, or it can have a more holistic focus like BREEAM-NOR. There is currently no plan for a plus house standard today and there is currently no clear demand for it either. Thus, BREEAM-NOR can be a very useful tool for decision makers in deciding to construct a plus house. BREEAM offers step-by-step guidance on how to construct sustainable buildings, and if these steps are followed correctly it can potentially result in a plus house. As presented in chapter 5.1, Powerhouse Kjørbo is both a plus house and it has the highest level of BREEAM-certification: *Outstanding*. BREEAM focuses on all aspects of a building, and as energy requirements probably will become stricter in the future, other aspects will be more important, e.g. materials. Thus, when a prospective plus house standard will be relevant, energy requirements alone might not be sufficient. Hence, it is recommended that decision makers use BREEAM-NOR as a standard for their plus house and to look at other examples of plus houses, such as Powerhouse Kjørbo.

RENOVATION?

The last point in the model is “Renovation?”. This is an aspect that has had little focus earlier in the study, though it has been mentioned. The question of renovating or building a new building is more a logical question than anything else. If a building is to be constructed where a building already exists, the existing building should be examined to see if parts of it can be kept and perhaps upgraded to achieve the demanded standard. Reuse of building components will save energy, GHG emissions related to materials, extraction of raw materials and perhaps work.

8 DISCUSSION

The discussion is divided into two parts. Firstly, there is a discussion of the results. Throughout the study there has been discussion, assessment and evaluation of the overarching issue. However, this discussion is a discussion of the topics that have been found to be of most importance through the SWOT-analysis. Secondly, there is an evaluation and discussion of the study as a whole.

8.1 Discussion of the analysis and results

The following discussion will bring together the preceding chapters to form a holistic frame around the content of this study. The main topics that have emerged are based on the results in chapter 7. These are the cooperation process, technology and BREEAM. The cooperation process will cover BHAG, budget restrictions and commitment and ambition. BREEAM-NOR will cover the topic of renovation as BREEAM has a large focus on reuse and recovery. In addition, the topic of legislation will be discussed. Seeing as this is not a topic directly related to the decision making process in the same way as the other topics, this was excluded from the model in Figure 15. It is, however, a very important topic that can impact the decision making process in many ways. These topics cover more than just their name and these topics are all interconnected in some ways.

LEGISLATION

The current energy demands required by law in Norway in TEK10 are lower than passive house level even though the goal was to have passive house level by last year. By examples provided in Table 5, it is clear that the potential for buildings with higher energy standards than passive house are possible in Norway, and this should be more encouraged. As Mork points out, "*Passive house is too passive*". Thus, lower than passive house is indeed even more passive. NS 3700 came in 2010 and NS 3701 was made official in 2012. Thus, the definition of passive house in Norway is at least six years old. Still, the goal to have passive house level as requirement was not fulfilled.

Figure 11 is an illustration of the imagined evolution of buildings. This might translate to the requirements set by governmental authorities as well, and in the end the requirement might be plus house. However, for now the next goal for energy efficiency is to have requirements for nNEB in 2020. There is currently no standard definition for nNEB in Norway. The most official definition is from the EU where a nNEB is a building with a very high energy performance and the nearly zero extra energy required is to be covered to a significant extent from renewable energy sources (The European Parliament and the Council of the European Union, 2010). As pointed out by Gustavsen[3], the definition is very vague. What is nearly zero? It is not specified in more detail. The proposed Norwegian definition is that nNEB has an energy use 70% lower than TEK. It might seem unlikely that the goal of nNEB will be reached by 2020, as there is no standard definition for the concept yet.

[3] Arild Gustavsen, see chapter 6.1

The EU has the same goals as Norway: passive house level in 2015 and nNEB in 2020. In addition, the EU has a goal for 2018 where all new buildings occupied and owned by public authorities are nNEB. This demonstrates a leadership from public authorities that they are going ahead to set an example. Mork[4] and KRD (2012) agrees with this as shown in chapter 6.1.2.

Legislation has an immense potential in setting the standard for new buildings. The governmental authorities can set requirements regarding all phases of a building. We see that the energy demands are getting stricter, and they will probably increase in strictness. Thus, the focus should perhaps be put on other issues, such as materials. The construction industry is one of the biggest consumers of water, energy and materials. To illustrate this, out of the total production of steel, 50% is used for construction purposes. However, there are no specific regulations today related to the use of materials, other than it is encouraged to use materials that can be reused and recovered in TEK10. Bygg21 (2014), which is a collaboration between governmental institutions and the construction industry has proposed that by 2020, all construction projects shall prefer construction materials and components that have documented EPDs. This suggestion has not been discussed in any of the other relevant literature and has seemingly had no real influence in legislation. However, to prefer materials with documented EPDs is the wrong use of EPDs. EPDs are to be used for comparison reasons. An EPD documents the environmental impact of a product and then the consumer shall choose the product with the lowest environmental impact. As told by Haugen[5], a developer demanded and EPD from the producer, BUT the producer was already chosen. Thus, the EPD merely becomes a document without any actual influence in the positive direction of environmental benefits.

Legislation also has an immense potential in setting the standard for old buildings. Refurbishment of old buildings can halve the Norwegian energy use. Refurbishment has several environmental benefits, such as minimizing demolition, reducing raw material extraction and material production and the construction phase can be reduced due to the remaining elements of the building. For example, there could be some guidelines that regulate the demolition of old buildings. If some elements of a building are reusable, they must be reused or recovered.

Enova has subsidies for a range of different sustainable solutions and stages of a construction process. However, subsidies are only given when the measures are higher than the minimum requirements set in TEK. Thus, Enova is pushing for further development in the construction industry and the construction industry should work towards receiving such subsidies.

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[4] Øyvind Mork, see chapter 6.1
[5] Thomas Haugen, see chapter 6.1

TECHNOLOGY

Powerhouse Kjørbo makes it obvious that the technological solutions required to construct a plus house already exist. This is not to say that technological development should stop, but rather that applying current technological solutions in new manners is sufficient to have an expansion of plus houses and other sustainable buildings. Technology is closely tied to innovation, and further technological innovation will make the construction of sustainable buildings more accessible in the future. However, both Mork and Bygg21 (2014) agree that the efficiency and productivity is low in the construction sector. For Mork, standardization is understood to be an inhibitor to progress, as choosing standard solutions is seen as the opposite of innovating. That is not to say that he finds standard solutions useless. For Bygg21, the construction industry as a whole is reluctant to incorporating innovative solutions. Bygg21 wants a commercialization of innovation.

In the climate settlements, the Government is committed to focusing on further research on climate and technology, and there is constant development. In addition, this development leads to the cost of formerly expensive solutions to go down, such as solar energy. The cost of solar solutions has dropped dramatically the last 5-10 years; it has dropped at least 50% in cost as shown in chapter 5.2.1. The expansion of solar energy is clear in all parts of the world, and in Norway, 2014 was a record breaking year when three times more solar energy was installed compared to 2013. In addition, Enova offers subsidies for solar energy, where 35% of the cost is paid back to private households. San Francisco has made it a legal requirement that all new buildings must cover at 15% of the roof area with solar power. This measure shows a clear dedication to renewable energy, and could be translated to be legal requirements in Norway.

COOPERATION PROCESS

The cooperation process has proven to be an essential factor in constructing successful plus houses and other sustainable buildings. The integrated design process includes all the relevant actors in the early stages and arranges charrettes to have brainstorming sessions. This way of working creates an ownership to the project that the remaining phases of the project will benefit from. In addition, it creates an environment of aiding each other and thinking outside the box, as the actors can suggest solutions that might be outside of their profession and then the professionals within that area can judge whether it is feasible or not.

As Mork points out, the integrated cooperation process was "*the key to the whole success* [of Powerhouse Kjørbo]". However, as pointed out by Throndsen et al. (2015), problems ensued when involving the subcontractors. As these actors had not been a part of the initial planning process, they did not fully grasp the idea of a Powerhouse. Haugen also made this point. According to him a perfect cooperation process would include the subcontractors earlier in the process. The early inclusion will lead to better planning, the subcontractors will be able to express the time needed to finish their job and the subcontractors would get an ownership to the project.

BHAG, budget restrictions, commitment and ambition are all essential parts of the cooperation process. BHAG and budget restrictions should be set in the very early stages and if these two are set correctly, this will lead to both commitment and an ambitious mind-set, particularly if the budget restrictions are high. Then the solutions must be within these bounds and be ambitious.

BREEAM-NOR

BREEAM-NOR can be a very helpful tool on the route of constructing sustainable buildings. The categories in BREEAM-NOR cover all aspects of a building and the categories *Energy*, *Health and indoor environment* and *Materials* are given most importance. Thus, when a building is BREEAM-certified, the focus is on more than only energy. This is not to say that energy is not important, but rather that other areas should be given more attention as well. In BREEAM-NOR renewable energy is not a requirement. It is recommended parts of the energy supply is from renewable energy sources. If the BHAG of a construction project is to construct a plus house or a ZEB, renewable energy must be given more extensive attention.

In the category *Materials*, reuse and recovery of building materials is promoted. Reuse of structure and facades are especially advocated. In addition, a new subchapter is planned to be introduced in the new version of BREEAM-NOR, which promoted the design for reuse and reassembly. In other words, the advantage of reusing "old" building materials is given extensive importance. The reuse of "old" building materials has many environmental benefits, such as reducing raw material extraction, production and demolition. BREEAM-NOR is a standard both for new buildings and renovating old buildings. The weight BREEAM-NOR puts on reuse can be understood as a promotion of renovation in general. All the benefits of reuse can be translated to renovation, as the two are degrees of the same concept. In addition, by reusing and renovating, considerable amounts of GHG emissions can be avoided. Much of the GHG emissions aggregated in a construction process are embodied emissions in materials. If materials and components are reused, the GHG emissions from these are avoided. For example, ZEB use renewable energy as compensation for the GHG emissions from either the entire construction process or some phases of it. The aspect of renovation and reuse is therefore very relevant here. For the future of buildings, energy requirements will probably be higher than the current situation and then the focus might be on other aspects, such as materials and GHG emissions. Thus, it is clever to be prepared for this possibility in the future and start now.

8.2 Evaluation of the study

This study has produced interesting results that are relevant to the sustainability of the construction industry. The case studies, interviews, document analysis and the current literature has given new insight into how the decision to construct plus houses can be made more straightforward. In addition, the role of policy makers has become a crucial factor in this process. Answering the research question has been challenging, as there is no one correct answer to the question. Rather, the question can have many different answers. However, by answering the supporting research questions with the methods used, the answers to the questions emerged and a model for guiding decision makers was created.

The issue in this study, the construction industry as a whole, is a very broad and complex issue. Therefore, much of the study has consisted of attempts to make this issue more clear and understandable, and to highlight the complexities that underlie the industry. Its complexity stems from its size, the number of involved actors and the many regulations that are tied to the industry.

The concept of plus houses is not a very widespread issue today. Therefore, much information has been from Internet sources rather than scientific articles. The Internet sources are reliable sources, as they originate from companies in the industry, recognized newspapers or organizations. The documents that were analysed are constant, as they are official standards, and other researchers can replicate the results from this analysis. This is harder to say about the interviews.

The interviews were done to achieve a better understanding of the themes shown in chapter 6.1. Thus, the answers to the questions are not comparable, but rather used to show different perspectives of the themes. The question of reliability of the interviews is hard to determine. If the interviews had been conducted over again with the same interviewees, the answers would probably have been similar. But the answers from the different interviewees are not directly comparable. The answers give in the interviews led to interesting perspectives and gave broader viewpoints of the research issue. In addition, the interviewees are all professionals, either working in the construction industry or researching on the subject. The issues that were discussed in the interviews were not sensitive issues, so it did not seem as though the interviewees held back their opinions. Thus, the results gathered from the interviewees can be said to have a high validity.

The empirical data was mainly the case studies. Powerhouse Kjørbo was the main case and information of this was gathered from different sources, both positive and more critical sources. The other cases were mainly used to show the technical and other solutions these buildings had to achieve the given building category. However, These cases could have been further used in the research to back up the conclusions drawn. For example, it could have been helpful to look at the cooperation process of these construction processes. However, this would have been very time consuming, as this information is not available on the Internet. Thus this would probably have required several more interviews, and the issue would have been expanded too much.

Policy makers of construction policy have received much attention in this study, more than what was first anticipated. However, construction policy is a crucial tool for promoting the construction of plus houses. If regulations are stricter, the expansion of sustainable buildings will increase. In addition, the role of governmental actors in the construction industry as leaders and examples is also very important for the expansion, because this will give the rest of the construction industry incentive to be better or equally good as the governmental actors and make sustainable buildings more commonplace.

9 RECOMMENDATIONS

The following recommendations are drawn from Results and Discussion. They are divided into different categories, where the recipient of the recommendation is the headline of the section.

DECISION MAKERS IN THE CONSTRUCTION INDUSTRY

Seeing as there is no plus house standard today and no immediate plan to make one, BREEAM-NOR is a useful alternative. BREEAM-NOR has a more holistic approach to buildings than NS 3701, where only energy is considered. The future will hold stricter and stricter energy requirements, and therefore the focus in sustainable buildings will probably be on other environmental areas as well. Therefore, the recommendation is to focus on more aspects than only energy. Materials, for example, are large contributors to the life cycle GHG emissions of a building. ZEB focuses on the GHG emissions aggregated in the life cycle of a building and uses renewable energy to compensate for this. Thus, the understanding of buildings is more holistic, as the energy sources are accounted for, and the whole life cycle of materials and building components are taken into account. GHG emissions are the problem when global warming is discussed, thus this should receive more attention than it currently does. For inspiration and step-by-step guiding to how a plus house can be constructed, it can be a good idea to look at examples such as Powerhouse Kjørbo.

The role of the cooperation process has received much attention in this study and that is due to realisation that the cooperation process is an imperative part of constructing plus houses in particular and sustainable buildings in general. By focusing on the cooperation process and involving all the relevant actors in this process, especially in the early stages, the whole project will have an added holistic mind-set to it. The chosen solutions will work better together and better ideas will emerge from the cooperation. In addition, the inclusion in the project in the early stages creates an ownership to the project compared to merely doing what is required or what one is told to do. BHAGs or stretch goals are necessary to construct buildings that are better than conventional buildings, especially if there are tight budgetary restrictions. By setting a BHAG, the whole team of actors will commit to this, and the chosen solutions must be realistic both to complete the BHAG and within the bounds of the budget.

CONSTRUCTION INDUSTRY

The minimum requirements in TEK are not a hinder to be better than these. The goal should be to be better than the minimum, and by doing being better, the rest of the construction industry is challenged and might follow. By constructing plus houses and other sustainable buildings, the construction industry will move forward, and sustainable buildings will be more commonplace. The impression of extra cost when constructing sustainable buildings will be brought down when the concept the different sustainable buildings are more widespread.

GOVERNMENTAL ACTORS IN THE CONSTRUCTION SECTOR

By setting the goal of all buildings occupied or owned by public authorities to be nNEB by 2018, the EU shows a very ambitious side in its building policy. The public authorities will be leaders and set examples for the rest of the construction industry. The goal of having passive house level by 2015 was not reached, but the public authorities can still set higher ambitions for themselves. For Norway, the goal can simply be that public authorities are to hold a higher standard than the minimum requirements.

POLICY MAKERS

With the knowledge of the severe impact buildings have on both energy consumption and GHG emissions, it is crucial that the goals are upheld. As pointed out in chapter 1.2, Norway is to cut GHG emissions by 30% compared to 1990-levels by 2030, and one of the main measures mentioned to do this is to tighten the energy demands in the construction sector. Nevertheless, the goal was passive house level by 2015 and this goal was not fulfilled. To reach the set goals, the building policy must become more ambitious and demanding. The technology to construct sustainable building exist, it is merely a question of having the construction industry use these measures to its full extent.

SUMMARY

To sum up the recommendations, more plus houses and other sustainable buildings should be constructed. The technology already exists, Enova offers subsidies for measures that are more ambitious than the minimum requirements set by law and the concept is feasible in Norway. Learn from the Powerhouse consortium and concentrate on the early stages of the cooperation process by setting BHAGs to reach higher standards.

10 CONCLUSION

Norway has to relate to many different environmental goals: reduce GHG emissions by 30% compared to 1990-levels by 2030, limit the increase of global average temperature to below 1,5° above pre-industrial levels and the SDGs. Buildings are the "forgotten environmental hooligan" (Haugland, 2016) and the construction sector has the potential to be a massive contributor to reaching these goals. Buildings are responsible for up to 40% of the world's energy use and up to 30% of the world's GHG emissions. However, the construction sector is probably the sector that has the most potential to improve.

The Norwegian Government did not manage to implement its initial goal to set requirements for buildings at passive house level by 2015. One can be hopeful that the goal of nNEB will be implemented in 2020. Indeed, if the goals mentioned above are to be completed, drastic measures must be taken.

The decision making process leading to constructing plus houses relies on many factors. The most important factors found in this study are the cooperation process, BHAGs, budgetary restrictions, exceeding regulations, technology, willingness and ambition, BREEAM (and renovation). From these different factors, the most important factor is the cooperation process and more specifically, the early stages of the cooperation process. By including all the relevant actors at the early stages, the decision to construct a plus house will be more informed and the chosen solutions to realise the plus house will be holistic and interconnected. In addition, inclusion in the early stages provides an ownership to the entire project, which will add value to the processes following the planning process.

This study has provided recommendations for actors on both policy level and sector level (see Chapter 9). The concluding recommendations for policy makers are to tighten the energy demands. Higher requirements will lead to further development. For the construction sector, the concluding recommendations are to be more ambitious and to focus more on the early stages of a cooperation process. By following these recommendations, I believe more plus houses can be successfully completed.

To answer the initial question, "Are plus houses the future?": the answer based on my study is yes. Plus houses may not be the go-to alternative in the immediate future but the expansion of plus houses will come. As Figure 11 shows, there is an evolutionary change of buildings, and eventually the requirements in TEK10 will probably be plus house level. However, when this time comes, other concerns than energy will probably be of equal importance. Thus, the focus on other aspects of a building should start already now.

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INTERVIEWEES:

ARILD GUSTAVSEN. Centre Director of The Research Centre on Zero Emission Buildings. Interviewed on April 8th, 2016 in Trondheim

THOMAS HAUGEN. Managing engineer in Veidekke. Interviewed June 1st, 2016 over Skype.

ØYVIND MORK. Chairman of the Powerhouse board and Administrative Director in Asplan Viak. Interviewed on April 5th, 2016 in Trondheim.

APPENDIX A: DEFINITIONS OF A PLUS HOUSE/PLUS ENERGY BUILDING

Who	Definition	Translation	Important elements	Source
Build the Future	Plus Energy Buildings – PEBs – buildings which generate a surplus in the annual balance of final energy and primary energy.	--	Generate a surplus in energy	(Build the Future, 2014)
Energiråd Innlandet	Et plusshus er et hus som produserer mer energi enn det bruker. I tillegg til energireduserende tiltak av bygningskroppen og i brukssammenheng legges det vekt på produksjon av egen energi ved hjelp av solfangere, jordvarme eller andre relativt enkle løsninger.	A plus house is a house that produces more energy than it uses. In addition to energy reducing measures in the shell of the building and in relation to utilization, weight is put on production of own energy with solar collector, geothermal heat or other relatively simple solutions.	Energy production more energy consumption Energy reducing measures Solar collector Geothermal heat	(Energiråd Innlandet, 2014)
Enova	Et plusshus skaper mer energi gjennom sin levetid enn det som ble brukt til produksjon av byggevarer, oppføring, drift og rivning av bygget.	A plus house creates more energy throughout its lifetime than what is used for production of construction materials, construction, operation and demolition of the building.	Energy production Compensation Materials production Construction Operation Demolition	(Enova, 2016a)
Futurebuilt	Energibruk relatert til drift av bygningen skal over året minst kompenseres gjennom produksjon av fornybar energi. For å regnes som plusshus, må det produseres overskuddsenergi på 2 kWh/m^2 BRA pr år.	Energy use related to the operation of the building shall throughout the year at least be compensated by production of renewable energy. To be a plus house, there must be produced excessive energy of 2 kWh/m^2 BRA per year.	Energy use compensated by production of renewable energy Excessive energy	(Andresen et al., 2015)
Lavenergi-programmet	Et plusshus produserer mer energi enn som går med til å produsere materialer, bygge, drifte og rive huset.	A plus house produces more energy than what is required for producing materials, construction, operation and demolition of the building.	Energy production Compensation Materials production Construction Operation Demolition	(Lavenergiprogrammet, 2015b)
Paroc	The plus energy concept is based on buildings having an energy efficiency level of a passive building and additional integrated active energy supply systems that exploit solar or wind energy	--	Energy efficiency level as passive house Active energy supply systems Exploit solar and wind	(Paroc, 2016)
Powerhouse	Plusshus er et bygg som gjennom driftsfasen genererer mer energi enn det som ble brukt til produksjon av byggevarer, oppføring, drift	A plus house is a building that throughout the operating phase generates more energy than what was used for production of construction materials,	Energy production Compensation Materials production	(Powerhouse, 2016b)

	og avhending av bygget.	construction, operation and demolition of the building	Construction Operation Demolition	
Steinar Anda and Anne Sofie Bjelland	Dette kan være passivhus som i tillegg produserer all energi til romoppvarming og tappevann, samt elektrisk energi til lys, elektriske apparater etc. I tillegg produseres det et overskudd over året som leveres til nettet.	This can be passive houses that in addition produces all energy for space heating and tap water, and also electric energy for lighting, electrical appliances etc. In addition, there is a surplus produced throughout the year that is delivered to the grid.	Passive house Production of energy Energy surplus produced	(Anda and Bjelland, 2013)
ZERO	Bygninger som gjennom driftsfasen genererer mer energi enn det som ble brukt til produksjon av byggevarer, oppføring, drift og avhending av bygget	Buildings that throughout the operation phase generates more energy than what is used for production of construction materials, construction, operation and demolition of the building	Energy production Compensation Materials production Construction Operation Demolition	(Nordby, 2009)

APPENDIX B: INTERVIEW GUIDE ØYVIND MORK

1. Kan du fortelle litt om din rolle i både Powerhouse og Asplan Viak?
2. Så du var med på hele Powerhouse Kjørbo-prosessen?
3. Hva var de største utfordringene dere hadde med det prosjektet? (Hvis det var noen spesifikke)
4. Det var egentlig mitt neste spørsmål: at jeg har lagt merke til denne prosessen og da kan jeg egentlig spør om dere som i Asplan Viak har gjort dette før eller om det har vært helt annerledes? Du nevnte det så vidt.
5. Men det ble egentlig bestemt helt fra begynnelsen av - at det var sånn samarbeidet skulle være?
6. Så lurer jeg litt mer generelt om hva du tenker om at passivhus blir kravet i 2020?
7. Så lurer jeg litt på hva du syns om konseptet standardisering som et verktøy for bygg?
8. Så tenkte jeg litt på dette her fokuset på energi versus klimagassutslipp. Jeg vet jo med Kjørbo så har dere hatt fokus på begge deler, og det er jo i BREEAM, men sånn som i passivhusstandarden er det jo kun på energi. Så jeg lurer litt på hva du tenker om det fokuset?
9. Men du sa på det foredraget du hadde at 95% av materialene var enten gjenvunnet eller gjenvinnbare.
10. Det her nevnte du litt på foredraget, men jeg tenker på det med kostnader med å bygge plusshus - at folk tenker sikkert at det er mye dyrere, men som du sa at i lengden så, ja.
11. Da lurer jeg litt på veien videre, om dere har mange planer i Powerhouse-samarbeidet om flere plusshus utenom Brattøra?
12. Men på de byggene dere tenke på da, er det renovering eller er det nybygg?
13. Da nærmer jeg meg slutten, så jeg lurer på om du har noe du vil legge til som du føler du ikke har fått sagt?

APPENDIX C: THEMATIC ANALYSIS OF INTERVIEW WITH ØYVIND MORK

Powerhouse Kjørbo and plus houses	Passive house as demand from authorities	Standardization as a tool	Focus on energy versus GHG emissions	Other important aspects
The biggest challenge was probably to get all the actors to work as integrated as we did. That was in a way the key to the whole success (Q3) I don't think I've been a part of any project, construction project, where the collaboration has worked in the way that everyone comes to the table… throws in everything you've got of competence without it being a discussion of "it's your fault" or "you have got to get your act together" and that sort of stuff. Instead, it was more "how can we help each other to get this to work" and "if you need more from me, I'll be back in two days and have a solution". This attitude, instead of "it's not my job, it's your job"... I think if we hadn't got into that mode, we wouldn't have managed to pull it of (Q3) We haven't worked in that way before [like in Powerhouse], but I can say that we will assuredly work this way again. The philosophy is very close to how we want to work. That is, we want to work interdisciplinary. I always say that if we pour some architects, some planners, some economists and a few engineers into a casserole, stir it around, then you can get a very exciting dish out of it. And that's how we want to work (Q4) What I think has been the most fun about this [Powerhouse] is that it is possible to sit down and just set this hairy goal and then have focus on what we are going to be able to manage. That is one of the things that have been the biggest trigger for myself and for most of the other people in the project. It is amazing what you can do if you just really want to. And most of the time it works out well, also economically. If you just put some good will into it (Q13)	Passive house is too passive, to be a bit funny. It's obvious that you understand that there is more to a Powerhouse compared to a passive house. So the authorities should go considerably further when we reach 2020 (Q6) And not least - if they don't get the regulations to follow along - they should at least build their own buildings with a standard that is much further than passive house. You can just look at Regjeringskvartalet. If that's not an energy positive building, I think that would be a shame. And now I am speaking carefully (Q6)	Standardization is a very interesting topic, because if we go beyond just energy, there has been talk about standardization for 20-30 years. Consequently, one commercial building is not very different from the other… To find new solutions and draw up every detail every time instead of standardizing, I think this has been a weakness in the construction sector in a way. Because it has contributed to low industrialization... and that again has made the efficiency or the productivity of the construction sector to fall in the last ten years (Q7) And then you try to compensate and improve the efficiency with BREEAM, for example, and with more model planning and standardization. I think that the question has at least two answers: one being that there is nothing wrong with standardizing some things, as long as you standardize good elements... But if you want innovation, you can't base everything on standard solutions. So it has to be both of these (Q7)	The advantage of focusing on energy is that it is very easy to communicate; you can measure the energy use. So there is really no discussion around that. But it is clear that what means something to the climate in the world, it is the GHG emissions. So I actually think that one should consider both (Q8) Energy is a part of the GHG account; the energy can be produced in different ways, which gives different GHG emissions, right. Materials can be collected in different ways, a lot of different GHG impact. So I think both, but you can say that Powerhouse has primarily focused on the energy side. And that is to a large degree because to have something that is easy to communicate (Q8)	...probably it costs somewhere around 10-15% more than if you had built a standard building. But what is a standard building today? …What are we comparing against? A big share of this, what we have done now, we would probably have done even if we didn't call it a Powerhouse. But we have been willing to pay around 200NOK/m2 more to live in a Powerhouse. And most of that will be paid back by reduced energy bill (Q10) …in a long perspective this is pretty sure to be profitable. Also because it is planned in a life cycle perspective, so a lot of the materials that are used will hold for 60 years. Some things will have to be replaced, it is calculated that the solar panels will have to be changed once over 60 years, for example. And heat pumps and some fans must be changed and maintained, but a lot of it will hopefully remain through most of the building's lifetime (Q10)

APPENDIX D: INTERVIEW GUIDE ARILD GUSTAVSEN

1. Kan du fortelle litt om ZEB først?
2. Kan du fortelle litt om din rolle i ZEB?
3. Du nevnte det så vidt, men jeg lurer litt mer spesifikt på hvilken rolle dere har i prosjektene?
4. Så dere er egentlig med i hele prosessen?
5. Så lurer jeg litt mer spesifikt på, siden jeg har Powerhouse Kjørbo som hovedcase, hvilken rolle dere har hatt i den prosessen? Er det det samme du nettopp sa, eller…?
6. Så så jeg Campus Evenstad, at det er det prosjektet som tar sikte på det høyeste nivået. Hvilke suksessfaktorer eller tiltak er det som har gjort at det skal bli best?
7. Så syns jeg det noen plasser er litt vanskelig å se hva som er forskjellen på ett plusshus og et nullutslippshus, men jeg leste en artikkel fra Teknisk Ukeblad som du var med på hvor det sto at et plusshus kun kan nå et nivå av nullutslippshus. Kan du forklare litt rundt dette?
8. Når jeg har sett på plusshus-caser, så er det jo energi de fokuserer mest på , så jeg lurer litt på hvilke tanker du har på det fokuset versus klimagassutslipp?
9. Men det blir vel bare bedre og bedre med EPDer?
10. For det jeg også har tenkt mens jeg har sittet med oppgaven er det at er veldig stort fokus på energi, og det er jo viktig det, men akkurat i Norge så er det jo veldig ren energi, så fokuset burde kanskje heller vært mer på klimagassutslipp i forbindelse med produksjon av materialer og rivning og transport.
11. Hva tenker du om at passivhus blir krav fra myndighetene fra 2020?
12. Så lurer jeg bare på hva du tenker om konseptet standardisering som verktøy for bygg?
13. Men da vil dere delta i den prosessen med nesten nullenergi og nullenergi standard?
14. Har du noe du vil legge til som du føler du ikke har fått sagt?

APPENDIX E: THEMATIC ANALYSIS OF INTERVIEW WITH ARILD GUSTAVSEN

Powerhouse Kjørbo and plus houses	Passive house as demand from authorities	Standardization as a tool	Focus on energy versus GHG emissions	Other important aspects
We participated early there too, helped to set the ambition level. Powerhouses have their own definition and ZEB has its own definition, but it is possible to adapt and see how it adheres. ZEB reviewed the Powerhouse definition (Q5) When it comes to measures, we see that many of our demonstration buildings end up with using a lot of photovoltaic. And in addition, heat pump and very energy efficient constructions. Passive house levels are often the basis, and often more than that, more insulation, even more airtight. And when it comes to GHG emissions, the GHG emissions from materials are extremely important. The architects have also, Snøhetta for example, pointed to focus on choosing the right materials as one of the most important results (Q14)	They originally planned to have passive house requirements from 2015. The requirements that were introduced are almost at passive house level. In 2020 the aim is nearly zero energy buildings. That is the ambition. But it is yet to be defined and to see whether the authorities actually introduces this as a requirement (Q11) It is a bit early to say anything about this yet. EU is saying this: from 2020 the requirement shall be nearly zero energy for new buildings. But nearly - what is nearly? It is too vague if you ask me. It will be enough to just have a little bit - and what is a little bit? It is both vague and imprecise (Q11)	I think it is important. It is important to ensure that the different actors use the same methodology. And when you have calculated a building's energy demand, you can say: "I used that calculation method". So, yes, I think it is an important tool in the development of the future's buildings (Q12) ZEB is contributing in the development of a standard for calculating GHG emissions for buildings. Another standard is also needed, on definition of the different levels. What is a zero energy building, what is a nearly zero energy building, what is a zero emission building and with the different levels also. When a calculation standard is ready, then it is possible to calculate the level of the buildings (Q12)	I've been thinking a bit about that lately actually… When you say zero energy building, you don't say anything about how the energy is produced, whether it is coal power, hydropower or based on other sources. It is implicit here that you compensate with renewable energy. When you focus on emissions, you get a more integrated handling of the problem where you look at the quality of the energy you use and how the energy is converted (Q8)	Yes, there is no established standard on this, neither internationally nor in Norway. There is work going on towards a standard on calculating GHG emissions in buildings, so that has to be set before you move on (Q7) Since there is no established standard, a plus house can be a different concept to different people. Some might say that a building is a plus house of it produces renewable energy, without considering how this relates to the energy used by the building. We think that a building as a minimum should harvest renewable energy to compensate for energy that is used for operating the building. You can also look at the energy used during the life time of the building, for example including one or more of the following phases: energy needed for extraction and production of building materials and building services, construction, operation and demolition of the building (Q7) What is general is that there is no defined standard and the various actors operate with their own definition, but everyone will probably have a large share of renewable energy production on or close to the building to call it a plus house (Q7)

Appendix F: Interview guide Thomas Haugen

1. Kan du fortelle litt om din rolle i Veidekke?
2. Kan du fortelle litt kort om Veidekke?
3. Da lurer jeg på om du kan fortelle litt om hvordan prosessen i et byggeprosjekt foregår?
4. Jeg lurer på hvilke erfaringer du har med samarbeid mellom forskjellige aktører i en byggeprosess?
5. Så det er enda mye samarbeid selv om dere har begynt å bygge?
6. Hvordan tenker du at en samarbeidsprosess burde vært i en perfekt verden?
7. Så lurer jeg litt på denne Kunsthøyskolen. Det skal være passivhus. Skal det være noe BREEAM inni bildet?
8. Kunsthøyskolen er jo et statlig bygg. Syns du at passivhus er et høyt nok nivå for offentlige bygg i dag?
9. Så litt mer innpå plusshus. Er det mye snakk om plusshus i bransjen?
10. Nå er det jo slik at passivhus skulle bli krav i fjor, men så har de bare strammet TEK10 inn og ambisjonen er jo nesten nullenergi bygg innen 2020. Har du noen tanker om dette?
11. Hva tenker du om standardisering som et verktøy for bygg?
12. Det er jo generelt veldig stort fokus på energi. Hva tenker du om energi versus klimagassutslipp, hvis du ser de to opp mot hverandre?
13. Har du noe du vil legge til som du føler du ikke har fått sagt?

APPENDIX G: THEMATIC ANALYSIS OF INTERVIEW WITH THOMAS HAUGEN

Powerhouse Kjørbo and plus houses	**Passive house as demand from authorities**	**Standardization as a tool**	**Focus on energy versus GHG emissions**	**Other important aspects**
Internally at Veidekke there isn't much talk about plus houses actually. There has been more talk about BREEAM-certification (Q9) [The project leader from developer] came up on the roof of a building project and said: "Crap, we should have installed solar panels here"… It's positive that a developer would say that: it shows that they focus on it (Q9) From our point of view it revolves around what can sell. It's obvious that if you can sell in a plus house, without too much extra costs, then you'll have a sales argument as well (Q10) A plus house need some energy sources and for now that's solar panels or geo-wells. I think it's a question of cost (Q10)	It is positive that they are pushing for more environmentally friendly buildings. That's the way we should go. And for the contractors it's more: as long as we get paid to construct a plus house, we will construct a plus house (Q10) But [a governmental developer] should definitely go ahead and set an example on environmental issues, to push the development in the right direction because they are able to (Q8)	I think it is very positive to standardize it, to put a label on it. Then you are able to distinguish buildings from each other. If you can market it as a plus house, then that's positive. If you didn't have standardization, then you wouldn't have a scale, a name on it, and then you would have to maybe just provide e.g. the u-value of the energy use per m^2. And if you're not an engineer or in the construction industry, that wouldn't sell too well (Q11) And I think e.g. BREEAM is very positive and to construct a BREEAM Excellent is highly valued. Simultaneously it is cost benefit. What do they get back from constructing a BREEAM Excellent building? It will probably have some extra costs… So it is very interesting to see what they benefit from it. You will achieve lower operating costs, but in terms of marketing and that sort of thing (Q11)	I think you have to look at the totality of it. We as contractors often have strict demands in the construction process. On thing is when the building is done, how much energy it consumes and how environmentally friendly it is then, but it is a very large process to construct a building and this can generate large amounts of waste…. We are in the actual construction process where a lot can be done to minimize the carbon footprint of the building (Q12) …[a developer] is demanding EPD on paint. We go to the subcontractor and told them that they must deliver EPD. They have gone to the producer and said that they need and EPD. Then the producer says they don't have an EPD on the product. Then we have to go back to [the developer] and say we weren't able to provide and EPD… The way I interpret this is that [the developer] is pushing the industry to go ahead… and maybe the industry needs it too. You need someone who is a driving force, I think that's positive (Q13)	In a perfect world, we would have more time in advance… to involve our subcontractors. If they get involved it creates an ownership to the whole process… In a perfect world we would have better more time to involve the painter or other professions and they would be able to say: "I need two weeks, and this is how the work schedule should be set up". At the same time, when a subcontractor is deciding how much time they need, they may say more time than what is needed, and then it is our job to push this so [the project] is done within a reasonable time. But there is something in getting an ownership of the process and the planning, to actually be a part of it (Q6) …So on a daily basis I work "down" towards the subcontractors, "up" towards the developer and "up" towards the responsible designers (Q4) [When explaining developer setting unrealistic demands for subcontractors)…"you have to be done in one week, you don't get one day more". This does not create goodwill with the subcontractor. You get off to a bad start from the beginning (Q6)

Appendix H: Energy efficient buildings and the most important measures to achieve the given category

Project	Category	Measures				
Maison Air et Lumière (Velux, 2016b)	Plus energy house	Solar panels on the slanted roof	Concrete base insulation, wood-frame well insulated	Heat pump connected to solar panels	Natural light and intelligent ventilation	
Multikomfort Larvik (Multikomfort, 2016)	Plus house	Energy from sun	Energy from ground water	Full usage and recycling of waste water		
Powerhouse Brattørkaia (Powerhouse, 2016c)	Plus house	Energy efficient ventilation and lighting, utilization of daylight	Use sea water for heating and cooling	Demand control of lighting, heating and cooling	Materials with low embodied energy and energy efficient construction	Solar panels on the roof, roof is slanted and turned south for more sun
Powerhouse Kjørbo (Powerhouse, 2014)	Plus house	Heat insulation, low air leakage, utilization of daylight	Efficient shading device	Energy wells and heat pumps	Large solar cell installation	Materials with low embodied energy
Private house Larvik (Nilsen, 2015)	Plus house	Solar panels	Ventilation heat pump with hot water production and heating of the house	Recycling of heat in the shower water	Demand control of lighting, heating and cooling	
Settlement Freiburg (International Energy Agency, 2009, Anda and Bjelland, 2013)	Plus house	High level of insulation and ventilation heat recovery	Passive solar heat, slanted roofs to take full advantage, solar panels are also roofing	Energy is generated in a regenerative way	Mainly used wood from local forests	
The Home for Life Denmark (Velux, 2016a, Anda and Bjelland, 2013)	Plus house and carbon neutral	Solar panels on the slanted roof – heats 70% of tap water	Energy-optimized windows + much daylight	Slate covered walls + use of wood	Demand control system of ventilation and sun screening	Venetian blinds for shading device and extra insulation during winter
Wicona Test Center (Wicona, 2010)	Plus house and carbon neutral	Solar panels on the roof	Demand control of heating and lighting			

Project	Category	Measures				
Campus Evenstad (Statsbygg, 2015)	Zero emission building	Use of solid wood (massivtre)	Focus on material choice – reuse and recycling	Produce local, renewable energy		
Forsvarets logistikk-organisasjon (Byggeindustrien, 2015)	Zero energy building	Solar panels on roof	Usage of sea water (sea water heat pump)	Censor controlled ventilation	Shading device	
Skarpnes boligfelt (Skjævestad and Husbanken, 2014)	Zero energy and zero emission building	Solar panels on roof – covers ventilation, heat pump, lighting	Energy wells with heat pump	Efficient ventilation installation that combined with energy wells has a 90% recycling result	Demand control of technical installation and shading device	Materials with low emissions and local materials

Project	Category	Measures			
Haukåsen barnehage (NCC, 2016)	Passive house and BREEAM Very Good	Solar collector for heating water	Energy well	Heat pump	Shading device
Heimdal VGS (Kreative Trøndelag, 2015)	Passive house	Ventilation (specific fan power, recycling, efficiency)	High ambitions for daylight	Insulation (u-value and low air leakage)	Material choice according to environmental impact
Nesttunbrekka 99 (Byggeindustrien, 2013)	Passive house and BREEAM	Waterborne heating	Heat recycling with 85% efficiency	Shading device	Demand control of lighting and heating
Office and commodities Fantoft (Sweco, 2016)	Passive house and BREEAM-NOR Excellent	Uses today's best practice solutions for heating, cooling, ventilation and lighting		Excellent air resistance with infiltration number 0,4 and heat loss according to NS 3701	
Sandstuveien (Hårvik, 2016)	Passive house and BREEAM Excellent	Energy wells with heat pumps	Permanent shading device	Solar panels on the roof	Materials that reduce the need for cooling and heating
Veritas-senteret (VVSForum, 2015)	Passive house and BREEAM	Sustainable and innovative solutions that contribute to energy efficiency, flexibility and a good working environment			