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Abstract

The building sector accounts for nearly 40 % energy consumption and 36 % of greenhouse gas emission in Europe. In 2010, the European Union introduced Energy performance building directive (EPBD) recast with the target to reduce 90% of CO2 emission by 2050 with respect to 1990 level. To achieve this target Net-zero energy building became a significant part of energy efficiency strategies for the reduction of greenhouse gases emission. The EPBD recast requires all the newly built building to be nZEB from December 2020. This thesis investigates the extend of preparedness of Norwegian building sector for implementation of NZEB from 2021.

Based on the main and supportive research questions, methodical triangulation approach was followed. It includes qualitative analysis with the case study and document analysis and quantitative analysis by the online survey. In the case study, EPBD recast transposition in Norway was explored. Also, national building codes were examined for energy efficiency and renewable energy regulation in document analysis. Furthermore, the opinion of various professionals involved in the building sector was gathered through google forms in the online survey. The findings from the three methods were analysed and discussed to draw the conclusion.

The study found several factors affecting the readiness of the Norwegian building sector for implementation of NZEB. These are the ambiguity of the government for implementation, lack of legislation, technical issues, economic issues, the fragmented interest of professionals and lack of information.

The study concludes that NZEB is not a widespread concept in Norway, in the absence of proper legislation there is a limited competence in professionals. Hence, the Norwegian building sector is not yet prepared for NZEB from December 2020.

Preface

This Master thesis marks the completion of my master's degree in City and Regional Planning at the University of Stavanger. The thesis was carried out in the spring of 2020 at the Department of City and Regional Planning with the supervision from Harald Nils Røstvik.

I would like to sincerely thank my supervisor, Harald Nils Røstvik, for his valuable guidance, feedback, and interesting web meetings throughout the entire period of my thesis. Further, I would like to thank all the professors of my department for feedbacks on the presentations made for the thesis during the master tutoring classes.

Finally, I would like to thank my family for supporting my up and downs during the journey of master degree, especially to my seven-year-old son who had always adjusted to my routine and encouraged me even during the tough time of COVID 19.

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List of Abbreviations and Acronyms

ACH – Air change per hour

BREEAM - Building Research Establishment Assessment Method

CHP – Combined Heat and Power

DHW – Domestic Hot water

Dibk – National Building Authority

EU – European Union

EPBD – Energy Performance Building Directive

EEA – European Economic Area

EPC – Energy Performance Certificate

HVAC – Heating, ventilation, and air conditioning

Kommune – Municipality

NZEB – Net Zero Energy Building

nZEB – nearly Zero Energy Building

PH – Passive house

Solar PV – Solar Photovoltaic

TEK – Norwegian building code

kWh – Kilo Watt Hour

KfW - Kreditanstalt fuer Wiederaufbau

Chapter 1 Introduction

Globally buildings are responsible for more than 35% of final energy consumption and nearly 40% of CO2 emissions (Abergel, Dean, & Dulac, 2017). In Europe, the building sector contributes to 40% of final energy consumption and 36% CO2 emission (Energy, 2019). The building sector unprecedented and continued global growth rate in coming 40 years adds 230 billion square meters in new construction, " adding the equivalent of Paris to the planet every single week" (Abergel et al., 2017, p. 2) this raises concern on increase in energy use and related emission. To limit the energy consumption and CO2 emission, a framework with energy policies has been implemented in the European Union (EU) known as energy performance building directive which focuses on improving the energy performance of the building and moving the new construction towards Nearly Zero Energy Building (NZEB) from 2020. The improvement in the energy performance of the building and introduction of NZEB is an effective way of reducing emission and fighting against climate change. As EU is binding strict legislation on new construction in recent years this study aims to understand the incorporation of NZEB in Norway, as new buildings will have an important effect on future buildings-related energy use and emissions.

1.1 Background

Global energy consumption causing climate change associated with greenhouse gas emission has been concerning mankind since first published international report " Our Common Future" in 1987 placing climate change at the core of concern (Meadowcroft et al., 2019, p. 2). Later in 1992 drive for energy efficiency began at Rio Summit with the establishment of the United Nations Framework Convention on Climate Change for abating climate change. In 1997, the Kyoto protocol was adopted which came into force in February 2005 for reducing greenhouse gases emission by fixing limitation target to the base year. The EU has a target of 8% reduction by the end of 2012 compared to the base year 1990. For abiding this reduction target buildings sector plays a vital role in policies and actions. In response to compliance of the Kyoto protocol in 2003, EU directive 2002/91/EC called Energy Performance of Buildings Directive (EPBD) was established (Delbeke & Vis, 2015). Since then the EPBD has undergone many revisions, in 2010 the EPBD recast directive 2010/ 31/ EU was a major modification of energy usage in the building sector with fixed a target of 20 % reduction in energy consumption, 20% increase in renewables and 20% reduction in emission and need of nZEB for the new building from 2020 (EU, 2010).

In Norway, the annual energy demand in the building sector is nearly 40% of the total energy used, of which 22% is residential energy demand and 18% is non-residential demand (Sartori, Wachenfeldt, & Hestnes, 2009). An average Norwegian household consumes nearly 22000 kWh of energy yearly out of which 70 % is used for space heating and domestic hot water (Nord, Qvistgaard, & Cao, 2016). According to Enova (2016) report, the total energy consumption of the building is increasing and there is an increase in construction of the new building in residential as well as non-residential sector. Although 99% of energy demand is met by renewable hydropower, in some cases during summer generation is lower than demand, thus getting energy from the European electricity grid. The growing energy demand and uncertainty of dependence on one renewable source require a new energy-efficient solution for a new building like NZEB.

The buildings sector is considered a key sector for reaching the 2 degrees or below the goal of Paris Agreement along with pursing the United Nation Sustainable Development Goals such as climate change, infrastructure, and sustainable cities. Each nation as per Paris Agreement has to declared fixed reduction target in there nationally determined contributions. For abiding the Paris agreement in March 2015 Norway set a target of 40% reduction compared to 1990 level by 2030 in addition to being carbon neutral society by 2050 (KLD, 2015). In order to achieve its target climate goal, the Norwegian government declared the energy requirement of building to passive house level by 2015 and nearly zero-energy level by 2020 (Knudsen & Dalen, 2014). Recently, Norway has updated its reduction target by at least 50 per cent and towards 55 per cent compared to 1990 levels by 2030 (KLD, 2020). This is a highly ambitious goal, to achieve it we need to focus on constructing the new building as NZEB

1.2 Research Question

We are in 2020, as per EPBD recast directive all the newly constructed buildings should be NZEB from December 2020. The issue of this study is we are close to December and there is no information about NZEB after 2015 onwards from the Norwegian government and national authority. To gain a complete understanding on the relevance of NZEB in Norway, an in-depth study is required. Focusing on the current stand of the government, national building documents and competence of practitioner in the building companies can help to know the readiness for NZEB as well as a factor affecting it.

The purpose of this study is to understand the status of competences for Net Zero Energy Building in Norway, with special focus given on net-zero energy building concept and current legislation in Norway. The main research question for this study is:

> How far is the Norwegian Building sector equipped for implementation of the Energy Performance of Building Directive, 2010/31/EU for all new buildings after 2020 and its challenges in integration with renewable energy technology?

Moreover, the title "Status of NZEB in Norway" is an underlying question throughout this study. To be able to answer the research question following supportive questions need to be addressed:

1. How has the Norwegian government dealt with EPBD recast directive about NZEB so far and what is the current status?
2. Is the current Norwegian legislation facilitating NZEB?
3. To what extend are Norwegian companies and institutions ready to implement the NZEB directive for new buildings from 31st Dec 2020.

In this study the term 'Norwegian building sector' used in main research question comprises of Ministry of local government and regional development, Ministry of Petroleum and Energy, Dibk, all the Norwegian building companies and Enova SF.

To have a thorough understanding on the readiness of Norwegian companies and institution following topics are addressed through questionnaires about awareness of directive among professionals, the energy efficiency measures used, renewable technology and its barrier considered in Norway for the future project, government funding and involvement in NZEB.

1.3 Scope of thesis

This study focuses on EPBD recast directive 2010/31/EU about NZEB for the newly built building from 2021 in Norway and its adaptation by the Norwegian building sector. To know the status of NZEB in Norway the survey has been conducted from February 2020 to May 2020 among the building professional all over Norway. The various professionals involved are categorised in seven groups: architecture, energy advisor, construction company, housing cooperative, solar company, geothermal company, Kommune for gathering the data about their understanding and preparedness of EPBD recast and involvement in NZEB projects.

Also, to know the current legislation and Norwegian stand on EPBD recast directive EU direct, National Building Authority (Dibk), Ministry of Local Government and Modernisation and Ministry of petroleum and energy are approached.

1.4 Structure of thesis

This thesis is structured in six chapters followed by a conclusion. The first chapter introduces the background of research and identifies the research question. Chapter 2 deals with the research methodology used in the study. The triangulation of the case study, document analysis and the online survey are used to answer the main and additional research question. The next, Chapter 3 is about the theoretical framework needed to understand the concept or principle of NZEB, in this chapter a detailed overview of EPBD recast, concepts such as BREEM, plus energy houses, passive strategies, energy-efficient strategies, solar PV, solar PV/T, geothermal, a heat pump that is used in the latter part of the thesis and the survey are explained. Chapter 4 deals with qualitative analysis and findings for this study. The qualitative analysis involves case study analysis and document analysis for answering the question related to the government stand on EPBD recast and legislation about it. Chapter 5 include online survey analysis and findings. Data is collected through google online survey and analysed. In Chapter 6 there is a discussion on the findings from the three methods of analyse thus answering the research question on the readiness of the Norwegian Building sector in respect to EPBD recast for all new buildings after 2020 and its challenges in integration with renewable energy sources. Additionally, the evaluation of the study and its limitation also done in this chapter. Finally, Chapter 7 concludes the study and recommends future research.

Chapter 2 Research Method

This chapter describes the research design adopted for this thesis and explain the design method and data collection with the three data sources: online survey, case studies and document analysis. Since NZEB are not so widespread in Norway today, there are few works of literature on this subject. Thus, using the three different methods provide a broader way of collecting data and reaching a conclusion.

In this study I have described the Chapter 3 theoretical framework in very detail to build a better understanding of NZEB design concept and its integration with renewables-based on various scholarly works of literature and three books: Net Zero Energy Design: A guide for Commercial Architecture by Thomas Hootman, Net Zero Energy Building concept and framework by Attai Shady and Solution sets for Net Zero Energy Buildings: Feedback from 30 Net ZEBs worldwide by François Garde, Josef Ayoub, Daniel Aelenei, Laura Aelenei, and Alessandra Scognamiglio that focus mainly on design and operation of NZEBs.

The research design adopted to answer the research question is described in section 2.1.

2.1 Research Design

Durrheim (2004) defines research design as a strategic framework for planning the research, it is a bridge between the research question and implementation of research approaches. This section describes the mixed-method research design approach which is further detailed in the triangulation method to explain how it is applied to the research question.

2.1.1 Mixed method research design

Mixed method research design includes both qualitative and quantitative data collection and analysis parallelly (Kemper, Stringfield, & Teddlie, 2003). In this research quantitative method is with an online survey, while document analysis and case studies are qualitative methods. As Sale, Lohfeld, and Brazil (2002) has described :

> "A combination of both approaches provides a variety of perspectives from which a particular phenomenon can be studied, and they share a common commitment to

> understanding and improving the human condition, a common goal of disseminating knowledge for practical use. Both approaches provide for cross-validation or triangulation – combining two or more theories or sources of data to study the same phenomena to gain a more complete understanding of that phenomenon (interdependence of research methods) and they also provide for the achievement of complementary results by using the strengths of one method to enhance the other (independence of research methods)" (Sale et al. 2002, p 46).

This combined approach of case study, document analysis and online survey will cross-validate the finding of each method and thus, strengthen our result. The mixed-method design is further classified into four major types: Triangulation Design, the Embedded Design, the Explanatory Design, and the Exploratory Design (Creswell & Plano Clark, 2006). In this thesis, Triangulation design is used for answering the research question.

2.1.2 Triangulation Design

Triangulations help in studying the research question with a different perspective that complement and verify each other. According to Creswell and Plano Clark (2006) triangulation design is a well-known approach in mixing method where different but complementary data is collected on the same topic to get the best understanding of the research problem. The design overcomes the weakness of the quantitative methods such as large sample size, trends and generalization with detail in-depth study in qualitative method. This is done "...by combining multiple observers, theories, methods, and empirical materials, researchers can hope to overcome the weakness or intrinsic biases and the problems that come from single-method, single-observer, and single-theory studies. Often the purposes of triangulation in specific contexts are to obtain confirmation of findings through the convergence of different perspectives. The point at which the perspectives converge is seen to represent reality" (Bailey-Beckett & Turner, 2001, p. 2).

Triangulation validates the result of the study through two or more methods, thus confirming its reliability and validity. It is used for both qualitative and quantitative research studies. Triangulation method is of four types – Data triangulation, Investigator triangulation, Theoretical triangulation and Methodical triangulation (Denzin, 1970). In this study, I'm using methodical triangulation method which requires data through interviews, secondary documents, questionnaires and observation.

I have collected the data from the online google survey, document analysis of national document and case study of EPBD recast in Norway and finally compared and interpreted the conclusion.

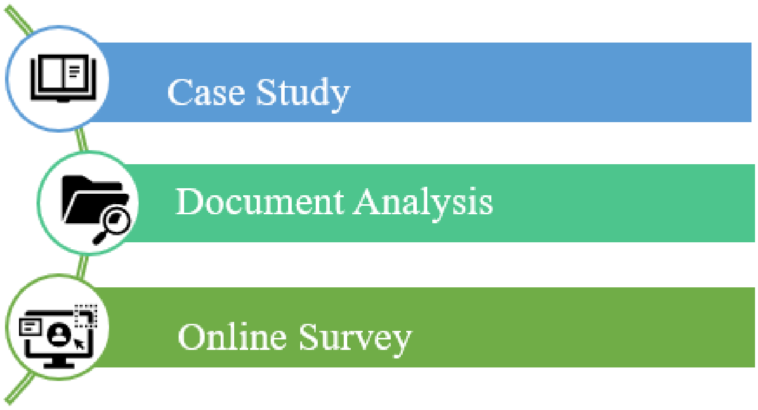


Fig. 2.1: Triangulation method: case study, online survey, and document analysis for the study.

2.2 Research data

This section describes the data source used to answer the research question. The research aims to explore preparedness for the implementation of EPBD in Norwegian Building sector from December 2020, since this is open and exploratory research question so different data source can be used. There is a need to study existing data such as documents, to understand the research within that field, solely relying on documents is insufficient and limit the study. Therefore, there is a need for quantitative data and qualitative data (document analysis and cases studies) to know the readiness of institutions and companies for the implementation of NZEB. The main data source for the study is google survey questionnaires providing quantitative data to analyse the status of NZEB in Norway.

The data source can be primary or secondary (Salkind, 2010). The primary source is original data collected by the researcher from the first-hand source using a method like a survey, interviews, field observation and experiments while the secondary source is government publications, websites, books, journal article, internal records (Salkind, 2010). This study uses both primary and secondary sources for data collection. The survey results are primary data while the documents and case studies are secondary data source. A brief description of Document analysis, Case studies and Online survey are presented below.

2.2.1 Documents analysis

Frey (2018) describes document analysis is a type of qualitative research which involves a systematic procedure for analysing and evaluating the document while addressing the specific research question. This can be used solely or in the mixed-method study where it is used to triangulate findings gathered from another data source such as survey (Frey, 2018). In this thesis document analysis is used with other analysis methods of the triangulation, thus reducing bias. The document analysis investigates the additional research question 'Is the current Norwegian legislation facilitating NZEB?' hence complementing the main research question on how far the Norwegian building sector is prepared for the implementation of directive from 2021.

The information is gathered from documents TEK 07, TEK 10, TEK17, NS 3700 and NS 3701 for this study. As Bryman (2012) has described documents from national authorities are the reliable source for statistical information and textual material. In addition to the document mentioned above, laws, regulations, directives, and other governmental website has been used for this study.

TEK 07,10,17 known as Byggteknisk Forskrift are Building Acts and regulation in Norway which describe the requirement about dimension, energy use and energy source and renewables for the buildings. NS 3700: 2013 Criteria for the passive house and low energy building: residential building and NS 3701: 2012 Criteria for the passive house and low energy building: Non-residential buildings.

For this research four completed pilot projects, Powerhouse Brattørkaia Visund Haakonsvern, Bergen Heimdal VGS Multikomfort Larvik depending on the availability of data have been described.

2.2.2 Case Studies

Rowley (2002) refers to the work of Yin Robert (1994) and describes "Case studies are one approach that supports deeper and more detailed investigation of the type that is normally necessary to answer how and why questions" (p.17). Since our research question is about how far the Norwegian Building sector prepared for EPBD implementation, a case study will enable to analyse within the specific context of net-zero energy buildings and Norway. Case study answers the second additional research question thus explaining the ambiguity of government in the transposition of EBPD recast in Norway for NZEB from 2021 and the Norwegian government current stand about it.

The case study - EPBD recast transposition in Norway is based on government document and the email correspondence with Brussels – EU direct, Inger Grethe England - Senior Advisor of National building Authority (Dibk), Sindre Samsing - Fagdirektør of Ministry of Local Government and Modernisation and Tom Andreas Mathiasson - Adviser of Ministry of Petroleum and Energy. The collection of information for the case study with the ministries was a long procedure and involves lots of reminder with email correspondence.

2.2.3 Online Survey

Online survey consists of the largest portion of this study in terms of collection of data for research as well as for analysing the research question. Bryman (2016, p. 229) has described an online survey "have increasingly become the preferred choice largely because of the growing availability of software platforms for the design of questionnaires" (p.229). The main strength of the online survey is easy global reach, flexibility, speed, technological innovation, convenience, ease of data entry and analysis, question diversity (multiple choice), low administration cost, easy follow up (Evans & Mathur, 2005). However, there are several weaknesses of the online survey such as perception as junk mail, low response rate, respondent lack of online experiences, privacy issue and technological variation (Evans & Mathur, 2005).

The online survey answers the third additional research question 'To what extend are Norwegian companies and institutions ready to implement the NZEB directive for new buildings from 31st Dec 2020' thus letting us know about the Status of NZEB in Norway.

I have chosen an online survey as it enables me to reach different professional within the building sector all over Norway which would have been impossible within this time frame. For the online survey, I have selected Google forms to collect data because Google Form offer free services with an easy to create unlimited questions (multiple-choice, small answers) and can easily send by email with a link to the unlimited number of responded. Moreover, Google Form is integrated with Google spreadsheet that provides clarity of collected data.

There are no strict rules for the survey questionnaires but to make efficient survey design relevancy and accuracy are two important consideration for the main outcome of the reliable survey (SurveyMonkey, 2009). The three main factors for effective relevancy of survey search are: be familiar with the question, know the objective and know the kind of information needed. Accuracy in questionnaires is important to collect suitable data in a reliable manner (SurveyMonkey, 2009). Both these considerations have been included while making a survey question for this study.

The questionnaires are mixed of open and closed questions set very clearly, so the respondent can understand and answer. Each question and the answer alternative have been explained in a way to understand the research needs of the study. To make it simple answer alternative have limited one choice option. It was challenging to limit the question to only nine questions but was done to increase the likelihood of a respondent to answer the whole survey.

Krosnick (1999) acknowledged that " the survey research community solely believes that representative sampling is essential to permit generalization from a sample to a population" (p. 539). A representative sampling includes a relevant category of people that reflect the character of the population. Initially, there were nine categories considered while making the google survey but latter the two categories Dibk and Statsbygg were excluded in survey analysis. Dibk is only involved in the preparation of building codes and not in building project so was excluded from the survey. It was contacted for legislation only through email correspondence. There was no reply from Statsbygg so is excluded from the analysis. Finally, for this study, seven categories are considered for drawing inference and applying it across the entire building industry. We used the stratified sampling method for selecting the architects, energy advisor, solar companies, geothermal companies, housing cooperative, construction industry and Kommune.

The list from Norske arkitekters landsforbund was the main source, it includes 3780 architects in the private and public sector (NAL, 2020) but only the leader in the architect firms were contacted so the sample size considered for the architect in the survey was nearly 170. The list of 41 registered members team (medlemslag) in housing cooperative from Norske Boligbyggelags Landsforbund (NBBL, 2020) was taken in which 20 were considered for the survey. Furthermore, the list of 220 registered construction company from Norsk eiendom (NorskEiendom, 2020) was taken in which nearly 50 practitioners were considered in the survey. The rest 60 professionals considered were from Kommune, solar energy companies, energy consultant, geothermal companies based on the availability of email address. The final data sample considered for the study due to time constrain is 300, out of which 99 responded. The survey was sent in all the major city of Norway and it received responses from 24 cities. The detail is given in section 5.1

One of the biggest challenges was acquiring the email address of the appropriate individual in the companies. This was a time a consuming process. Each company website was thoroughly studied as well as the contact employee page was explored in detail to pick the email address of the concerned person. Even sometimes email was sent to the company general email address to know whom to contact. The survey was distributed by email with a link. It included a cover letter describing the purpose of the survey as well as assuring respondents' anonymity and using the responses for academic purpose. The email was sent individually to each professional instead of sending all at once through a long list of the email address to increase the chance of response.

Due to COVID 19, pandemic and lockdown in March – April the online survey response was severely affected as people after many reminder were not willing to respond due to different working situations after the lockdown is lifted in May I got 99 responses.

2.3 Reliability and Validity

Reliability and validity are the two most important concept in research methodology to evaluate the quality of research. Reliability is defined as “the degree to which a measure of the concept is stable”(Bryman, 2012, p. 715). It is the consistency of a measure, the extent to which result can be replicated.

Validity is “the issue of whether an indicator (or set of indicators) that is devised to gauge a concept measures that concept” (Bryman, 2012, p. 171). It is about the accuracy of measure.

Reliability and validity were kept in mind while making questionnaires for an online survey. Each question was designed to a great clarity to make sure each respondent understands the questions, in the same way, to ensure reliability and answer choices were made clear to ensure validity.

Chapter 3 Theoretical framework

In this chapter, the theoretical framework is discussed. The chapter starts with a description of the Evolution of NZEB concept. Further, NZEB definition is defined followed by the last section which includes details on the NZEB design principle as well as a brief description of Integrated progress delivery for NZEB.

3.1 Evolution of NZEB Concept

This section about the evolution of NZEB concept describes how energy-efficient building was evolving due to the global oil crisis of 1970 towards the sustainable and energy-neutral building of today.

Passive House Concept

The energy crisis of 1970 enforced energy conservation features in housing. In 1976, Wayne Schick and University of Illinois design team developed 'Lo-Cal' house with low energy requirement for heating. This concept brought a revolution for super-insulated homes in the 1980s. There are many significant buildings built during this period like Saskatchewan Conservation House (1976) in Canada, Leger House (1977) in the USA, Naturhuset (1976) in Sweden. The first zero energy house is Esbensen and Korsgaard built-in 1975 at Technical University of Denmark ' DTH zero energy house' (Butters & Leland, 2012; Ionescu, Baracu, Vlad, Necula, & Badea, 2015).

By the mid-1980s Sweden and Denmark made low energy building legal requirements for new buildings at the same time there were development for thermal insulations, prevention of thermal bridging and passive solar energy (Butters and Leland, 2012). During this period Norway was slowly moving towards energy-efficient houses as compared to neighbouring countries Sweden and Denmark. The 'House Chanelle' built-in 1988 designed by Harald Røstvik in Norway is an excellent example of integration with solar (Butters & Leland, 2012; Scognamiglio & Røstvik, 2012; Shady, 2018). Inspired by the energy-efficient house of 1970 Wolfgang Feist together with Bo Adamson developed the Passive house concept (Ionescu et al. ,2015). The first Passive House built was Kranichstein in Darmstadt Germany in 1994. "Passive House (PH) is a building standard that is truly energy-efficient, comfortable and affordable at the same time" (Passipedia, 2020). There are five basic principles for the construction of PH which includes thermal insulation, insulated windows, ventilation heat recovery, airtightness of a building, absence of a thermal bridge. The PH limits peak load of 15kWh/m2 per annum for annual heating and cooling demand each, an envelope airtightness of 0.6 volume ACH at 50 Pa and compliance with the requirement of the renewable primary energy demand of < 60 kWh/m2 per annum (Passipedia, 2020).

Although PH concept was developed in Germany it is voluntarily adopted in many European countries. Some heating-dominated countries like Belgium, Denmark and Sweden have made it mandatory standard in their countries. (Shady, 2018, p. 34). In Norway, the first passive house project was a single-family house built in 2005 at Tromsøya designed by Steinsvik Architects (Andresen, Dokka, Klinski, & Hahn, 2007, p. 148).

The NZEB design principles mentioned in Section 3. 3.1 emphases on the Passive architecture as a fundamental prerequisite to achieving net-zero energy buildings. Passive design strategies use architecture and the climate to channelize available natural resources to ensure thermal comfort, ventilation, and lightning.

Green Certification

There are several green certification programs and rating systems supporting high-performance buildings target. Some of the globally accepted certification programmes are Green building tool (GB Tool) developed in Canada, Leadership in Energy and Environment Design (LEED) of the USA, Comprehensive Assessment System for Building Environment Assessment Method (CASBEE) of Japan, Building Research Establishment Assessment Method (BREEAM) in the UK, High environmental quality (HQE) in France and VERDE developed in Spain (Sinou & Kyvelou, 2006).

BREEAM in Europe and LEED in the USA are the two most famous energy rating systems which are associated with NZEB design (Shady, 2018). This thesis will describe BREEAM certification in brief since it is used in online survey questionnaires. BREEAM is a sustainability assessment method developed by Building Research Establishment Limited in 1990 in the UK. It set standards for the environmental performance of building through design, specification, construction, and operation phases for both new as well as refurbishment projects (McPartland, 2016). It focuses on ten categories for sustainability such as energy, waste, land use and ecology, water, health and wellbeing, pollution, transport, materials, management, and innovation. Each category consists of issues having goals and criteria. Each issue has defined the performance target and assessment criteria. Credits are awarded when criteria specific performance target is achieved (NGBC, 2012).

BREEAM certification is based on a credit list. Credits awarded in each criterion are added together for the total score. Depending on the total score building is rated and certified on a scale of Pass (≥30%), Good (≥45%), Very Good (≥55%), Excellent (≥70%) and Outstanding (≥85%), where the percentage is out of 100% (NGBC, 2012). BREEAM excellent and outstanding is two categories used in google survey for collecting data to analyse the status of NZEB in Norway. BREEAM adapted to the local Norwegian condition is called BREEAM NOR, it relates to relevant standards and rules in environmental and energy areas (NGBC, 2012). BREEAM NOR contributes to a greener and sustainable building industry.

Energy Performance Certificate

Energy Performance Certificate (EPC) was introduced by EPBD directive 2002 / 91/ EC as a requirement for EU members from 2006, with the final deadline for implementing mandatory energy labelling scheme by 2009. It is considered a powerful market-driven tool for regulating the energy efficiency of buildings. The EPC ranges from A to G, where A is very efficient, and G is very inefficient. This certificate provides energy performance rating and recommendation for the cost-effective improvement of building to consumers and plays an important role in the decision to buy or rent that property (Olaussen, Oust, & Solstad, 2017).

The rate of implementation of EPC is however slow and varies from country to country. In Norway, the energy labelling system for houses and dwelling was fully implemented by July 2010. The energy performance certificate also known as energy label is a legal document in Norway since 2010 and must be shown to buyers. It consists of data identifying the building, agent issuing certificate, energy characteristics on a scale of A to G and inclusion of renewable energy sources in heating system (Olauseen et al., 2017).

Energy Performance of Building Directive

The first version of Energy Performance of Building Directive (EPBD) 2002/91/EC came into force in 2003 and was to be implemented by 2006. EPBD determines the framework for European countries to develop regulations for energy-efficient building. It requires member states to implement Article 7 (Energy Performance Certificates), Article 8 (Inspection of boilers), and Article 9 (Inspection of air conditioning systems) by early 2009. However, EPBD 2002 did not state the methodology to the member states (Shady, 2018).

In 2010 EPBD recast 2010/ 31/EC came into force promoting energy performance of buildings in member states through cost-effective measures. The focus was on a 20% reduction of greenhouses gases and energy consumption and a 20% increase in renewables. The EPBD recast made nZEB obligatory to member states. It does not give a definition of NZEB but set a general framework and asked member states to develop their national definition and their national approach. The generic framework provided by EPBD for development of definition states:

> "nearly zero-energy building means a building that has a very high energy performance (…) The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced onsite or nearby"(EU, 2010).

The EPBD recast requires all the new buildings from Dec 2020 to be nearly zero-energy buildings. Fig 3.1 illustrates the progression of EPBD recast 2010 in member states describing the time frame and deadlines for achieving the nZEB goal.

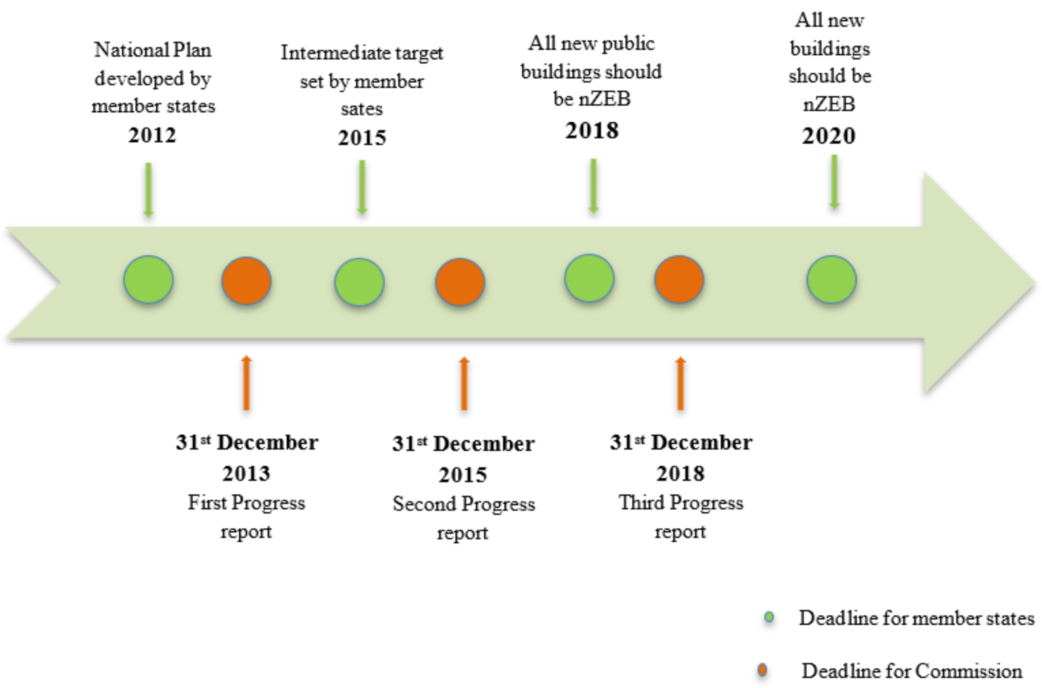


Fig. 3.1: Overview of the process towards nearly zero energy building in Europe (Killingland et al., 2013, p. 8)

However, we are in 2020. There are many EU members without a national definition of NZEB and Norway is one of them. Although Norway is not the EU member but being in EEA, Norway follows some parts of EPBD regulations. In order to comply with regulations, the Norwegian government has developed standards for necessary minimum requirements for buildings. The most prominent national standard for the calculation of energy performance of the building is NS 3031 which complies to evaluate energy performance as per Norwegian building regulation (TEK). The other national standard is Passive house requirement NS 3700 for residential buildings and NS 3701 for commercial buildings, it is Norwegian adaptation of passive house definitions because of local climate, different construction solutions and building traditions (Lindberg, 2016). The study describes EPBD recast relevance for Norway in detail in section 4. 1 of the case study analysis.

Plus, Energy houses:

The term Plus Energy Building was coined by Rolf Disch in 1994 (Shady, 2018). Though, there is no standard definition of plus energy houses. It refers to a "building with an energy performance that is so good, that the energy generated by the building is higher than the energy used by the building. This energy balance is mostly done on an annual basis" (Kapsalaki, 2016). Germany is a pioneer for plus energy building 'Heliotrope' and has lots of programs promoting this concept. The plus energy buildings are wide-spreading in Europe. Now, there are significant examples of plus energy houses in Norway such as Powerhouse Kjørbo and Powerhouse Brattøraia, Innovation park Stavanger. Nowadays plus energy house is being observed in the Norwegian building industry that why it is used in online survey questionnaires to know the skill of professionals.

Thus, it is important to know the definition of plus energy houses. In absence of a standard definition, there are various Norwegian definitions of plus energy houses given by Enova, Futurebuilt, Lavenergiprogrammet, Powerhouse, ZERO and lots of literature on plusshus (plus energy house). I'm mentioning the definition given by Powerhouse "Plus-energy implies that the building during its lifetime shall produce and export energy that compensates for energy use for other life cycle stages. This must be compensated with self-produced and exported energy based on renewable energy (solar, wind and heating and cooling from the sea, air or the ground via heat pump "(Powerhouse, 2016).

The illustration in Fig 3.2 by Voss (2012) describes the balance concept for grid-connected building and the relationship between nearly zero energy building, net-zero energy building and plus energy building. The nearly Net ZEB has a larger energy demand than the production can cover, Net ZEB is a balance between demand and production whereas the Net plus energy building produces more than the demand.

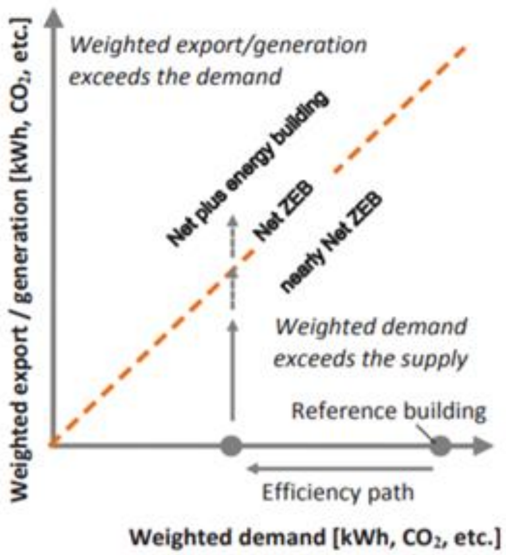


Fig. 3.2: Graph representing the path towards a Net Zero Energy Building (Net ZEB), with the nearly and plus variants (Voss, 2012, p 23).

3.2 NZEB Definition

NZEB is a high energy performance building which generates energy from the renewable energy source to meet its requirement annually. According to Sartori, Napolitano, and Voss (2012) in general, the NZEB is connected to energy infrastructure through two-way energy grid exchanging the energy during the year. The term NZEB is a balance concept between building and grid. The difference between supplied energy to grid and the building energy demand throughout the year is balanced after applying the appropriate weighting factors for energy carrier.

“Net ZEB balance: |weighted supply| - |weighted demand| = 0” (Sartori et al., 2012, p. 222).

This approach increases the renewable energy share within the grid infrastructure as well as reduce associated carbon emission. There are several definitions of NZEB, depending on priorities and perspective of a diverse set of parties involved. It also varies based on balance metrics for measuring performance threshold and different boundaries system. The thesis will discuss four definitions based on boundary system and balance metric defined by Torcellini et al. , (2006) in “ Zero Energy Building: A Critical Look at the Definition” and explained by Hootman (2012) in his book Net Zero Energy Design: A guide for Commercial Architecture.

Net Zero Site Energy Building

A net site zero energy building produces at least as much energy as it uses annually when accounted for at the site. The measurement time range is annual (Hootman, 2012).

Net Zero Source Energy Building

A net-zero energy source energy building produces or purchases at least as much renewable energy as it uses annually when accounted for at the energy source. Source energy is primary energy which includes generation and transmission losses for producing electricity. It is measured by multiplying the appropriate factor related to providing energy at the site (Hootman, 2012).

Net Zero Energy Emissions Building

A net-zero energy emissions building produces or purchases at least as many emissions-free renewable energies to counterbalance the emission producing energy sources it uses annually. The energy use of the building is measured in the mass of carbon equivalent greenhouse gas emission. These buildings are carbon neutral for building energy operation (Hootman, 2012).

Net Zero Energy Cost Building

A net-zero energy cost building receives enough financial credits for the energy the building export to the grid as it is charged for energy services and energy used on the utility bills annually (Hootman,2012).

3. 3 NZEB Design Principle

All the four definitions of NZEB mentioned in the last section focus on energy balance and energy neutrality of the building. The sum of the amount of energy consumption and energy generated by the building is zero. The energy-neutrality is the core concept for NZEB (Shady, 2018). There is exist little documentation on the principle of NZEB, it is designed based on the guiding principles of the Trias Energetica approach that includes both passive and active strategies.

Trias Energetica is the oldest design approach developed in the Netherlands in 1979 by Kees Duijvestein to design energy-efficient sustainable buildings. This design method includes three-step: (1) Limiting the energy demand, (2) Using sustainable energy sources such as solar energy, wind or geothermal instead of finite fossil fuels, (3) in case of insufficient sustainable source use fossil fuel as efficiently as possible (Shady. 2018). Fig 3.3 illustrates Trias Energetica approach, it focuses first on the energy savings of the building, then focuses on renewable energy solutions and cleanest fuel for reducing environmental impact.

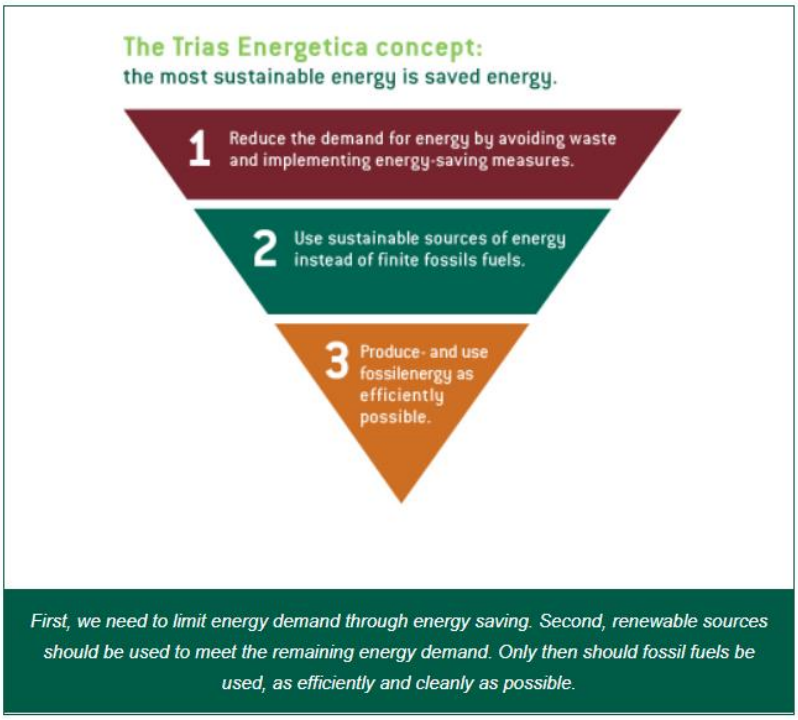


Fig. 3.3: The Trias Energetica approach ("Eurima ", n.d.)

In addition to Trias Energetica generic approach for designing the energy-efficient building, Shady (2018) identified the four principles addressing energy efficiency, indoor environmental quality, renewable energy, and carbon emission related to the energy consumption of building for designing NZEB. The four-design principles are:

1) "Reduce the energy demand for all newly constructed buildings. The energy demand value is for the sum of the demands of buildings, space heating, space cooling, DHW, auxiliary energy, ventilation, lighting, and appliances.
2) Improve IEQ, allowing for maximum thermal comfort and avoidance of overheating. This includes air quality control through mechanical ventilation.
3) Fix a percentage of renewable energy demand to be covered by renewable energy annual balance.
4) Reduce the overarching value for primary energy consumption and carbon emissions per year. It is also important to amend additional measures to address mobility and materials' embodied energy issues" (Shady, 2018, p.31).

The design varies depending on the building topology and climate type. As a designer, we can use these four principles together with Trias Energetica design approach to achieve NZEB. Based on these design principles Garde, Ayoub, Aelenei, Aelenei, and Scognamiglio (2017) in his book "Solution Sets for Net Zero Energy Buildings: Feedback from 30 Net ZEBs Worldwide" has categories the implementation of NZEB design in three categories - Passive, Energy Efficiency and Renewable Energy System. Fig 3.4 shows first, energy is reduced by passive strategies followed by the energy-efficient design of the building which further reduces the energy consumption. Although passive strategies together with the energy efficiency alone cannot reduce total energy consumption it is substituted by energy generation through the renewable energy system.

Fig. 3.4: Net ZEB design: Out progression and measure examples (Grade et al.,2017 p.17)

3.3.1 Passive Strategies

Passive Strategies reduce the energy demand of building (such as heating, cooling, ventilation, and lighting) by using architectural design in the early design stage. In Passive design, the building geographical factor (site location) and meteorological factors (such as climate, temperature, humidity, sunshine, and wind speed) are considered for design. Based on climate and site location the building's geometry (building mass, shape, slope), natural lighting and natural ventilation are provided to reduce the energy demand of building (Hootman, 2012; Oh et al. , 2017).

Climate is an important variable in the design of NZEB because it influences the external thermal load of the building. The most common climate classification is the Koppen climate classification system which divides the global climate in five classes from A to E which is further subdivided into types and subtypes. Climate responsive NZEB design passively mitigate the thermal load and use the free energy of climate and site (Hootman, 2012). The passive strategies and renewable energy rely on access and control of climate (sun, wind) thus, proper building orientation becomes primarily most important for NZEB, although it’s very challenging as orientation is influenced by urban design, architectural context and existing building. Higher exterior wall to floor area ratio optimized the passive strategies such as daylight and natural ventilation. Building depth and letter form buildings (such as L, H or E) are other important consideration for NZEB (Hootman, 2012).

There are many passive strategies available around the world concerning four-building services heating, cooling, ventilation, and lightning. The passive strategies will vary depending on site and climate. The study mentions some of the passive strategy described by Hootman (2012) for buildings. The passive strategy used for both heating and cooling need of building is thermal mass, thermal zoning supper insulation, airtightness, advance building envelope, optimized building form while night purge, natural ventilation, evaporative cooling, site vegetation and solar shading are used for cooling needs alone. For lighting, the passive strategy such as daylighting and solar tubes are used. And for ventilation natural ventilation, night purge, fan ventilation and passive dehumidification are used in buildings.

3.3.2 Energy efficiency strategies

Passive strategies alone are not enough to meet all the interior requirement of light, comfort, air quality and hot water of the building. Some kind of additional equipment like HVAC system is needed to ensure indoor environmental quality. The heating, cooling, lighting, domestic hot water (DHW) and plug load of the building can be addressed by the energy-efficient design such as radiant heating, mechanical air heat recovery, air-source heat pump, radiant cooling, ceiling fan, evaporative cooling, energy-efficient lighting, LED, advance light control, heat recovery, efficient household and office appliances (Grade et al, 2107; Hootman,2012).

Hootman (2012) has rightly stated: “Reduce, Reuse, Renewable” (p.236) as a hierarchically important process in achieving net-zero energy balance of the building. First, the reduction of load followed by efficiency measures, next reusing the waste energy in the system back into beneficial use and finally these low energy solutions are offset by onsite renewable energy generation in NZEB.

3. 3. 3 Renewable energy system strategies

Net-zero energy building is a combination of passive strategies, energy-efficient system and renewable energy. As mentioned by Grade et al. (2017) the renewable energy system can be within the building footprint, on-site or offsite. The renewable energy system strategies are used to address the electricity, heating, cooling and DHW demand in net-zero energy building. Electricity is provided by Solar PV and wind turbine; heating, cooling and DHW are provided by solar thermal, biomass-fired boilers, geothermal and biomass powered combined heat and power (CHP). The following paragraph will describe in detail about the solar, geothermal and heat pump renewable energy system as these are used in online survey questionnaire for the data collection on the integration of renewables with building to analyse the status of NZEB in Norway.

Solar PV

Solar Photovoltaics or Solar PV is the most preferred renewable energy source for net-zero energy building because of its adaptability, cost-effectiveness and integration at a different scale (Hootman, 2012). Solar PV work on the principle of the photovoltaic effect that is converting light directly into electricity. Solar PV cells are made from layers of semiconductors such as silicon. Two types of semiconductors combine to form solar cells: the p-type, 'p' for positive, which carry the 'holes' or positive charges, and the n-type, 'n' for negative, carry electrons or negative charges. These are created by doping the semiconductor with other elements or compounds. Layering these materials together enhanced the ability to conduct electricity. Many solar PV cells are combined to create a solar PV module or panel, these are in turn put together to create larger solar PV arrays.

Solar PV generally operates at a capacity factor of around 20%, whilst the efficiency of commercially available cells currently ranges from about 8% to about 20%. There are several types of solar PV panels. The most common is crystalline silicon, which is of two types: monocrystalline and polycrystalline. It is mature technology occupying 80% of the market and is used on rooftops and utility-scale application. Its efficiency is between 15% to 20% and modules generate typically about 150-250 watts of power (Coley, 2008). The next most common is the Thin Film PV modules, their efficiencies are lower ranging between 8% to 12% and module generates less power around 150 watts. Thin-film PV is flexible and comes many sizes which make a thin film good application for building-integrated PV (BIPV) (Coley, 2008).

Concerning NZEB, the production capacity of solar modules depends on how PV modules are placed, their orientation and tilt angle onto building site as well as the aesthetical requirement of building to provide opaque or transparent PV modules, governs the efficiency of the module (Grade et al, 2017).

While the electricity is produced by the solar PV arrays installed onto the building it requires several electrical components to make use of produced electricity, this complete system is called the Solar PV system. The PV system is composed of PV modules arranged in an array and the balance of the system. The balance of system composed of mounting and racking, wiring and conduit, a PV disconnect for the array, and an inverter to convert the electricity to AC connected to building electrical panel board make the system fully functional. PV system on the building can be grid-connected or off-grid. In the grid-connected building there is net metering which performs the importing and exporting electricity, making net-zero energy buildings feasible whereas, in off-grid building, the storage battery is provided to meet the energy demand of building during all seasons and night (Hootman,2012). Fig 3.5 explains how solar PV work in residential buildings:1) solar panel converts sunlight into DC, 2) Inverter convert DC into AC, 3) Surplus energy produced is sent to the grid during overproduction period and credited, 4) Credit applied and the meter runs backwards giving the user retail rates for surplus electricity in case of no electricity generation during winter or night grid provides the electricity.

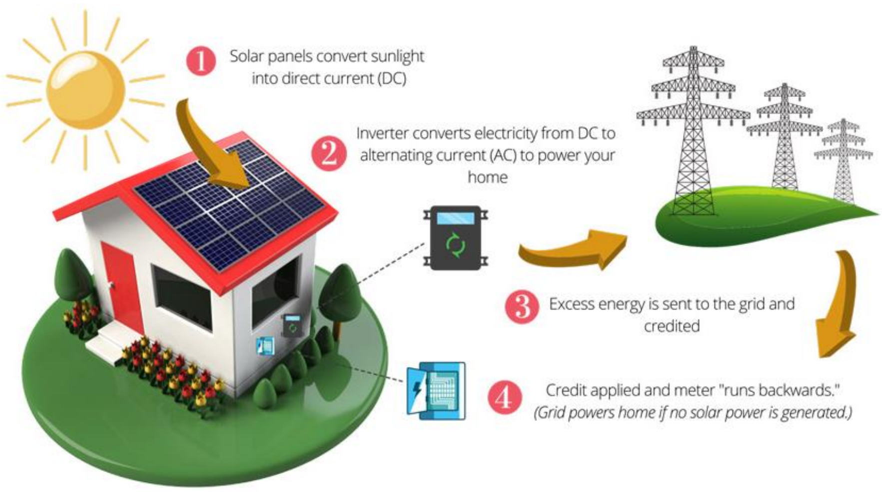


Fig. 3.5 : On site residential solar PV ("Solardirect ", n.d.)

Solar thermal

The solar thermal collector absorbs the incoming solar radiation, convert it into thermal energy which in turn heats the working fluid (water or air). The heat generated is used in heating the building, generate electricity, solar cooling, or hot water. Fig 3.6 illustrates the working of the solar thermal collector system. It consists of collector that collects the solar heat, a pump to circulate the working fluid or heat, storage tank for storage of hot water and back up the heating system to deliver the desired heating demand at all time. Solar thermal can be classified depending on temperature as a high-temperature system for generating electricity (point collector) whereas low-temperature system for swimming pools, DHW, building heating (Hootman, 2012; Coley, 2008).

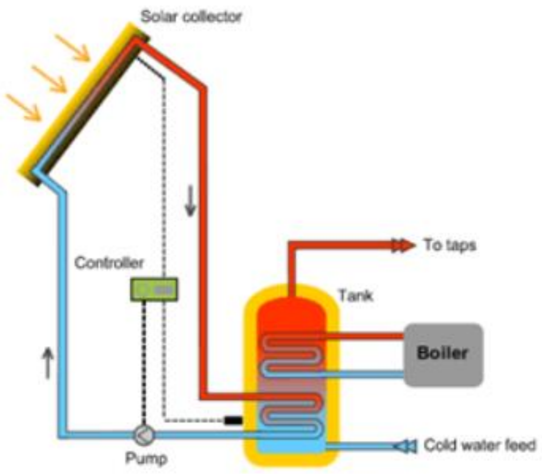


Fig. 3.6: Solar thermal collector system ("Solar energy system ", n.d.)

There are many types of the collector which generated different temperatures, in buildings mainly flat plate collector and evacuated tubes collector are used. Flat plate collector is used for water heating and district heating. It operates at moderate temperature and is cost-effective. Whilst evacuated tube produce higher water temperature so is used for solar water heating and space heating (Grade et al, 2017).

Solar air heating is also solar thermal technology which collects solar energy to heat air. The hot air can be used for heating building and DHW.

Solar PV/T

Solar PVT is a combination of photovoltaic (PV) and solar thermal system which produces both electricity and heat simultaneously from one integrated system. This is also known as a hybrid solar system. Fig 3.7 shows the flate PV module The PV/T utilities more solar radiation by removing the heat generated by PV modules, thus cooling the modules and increasing their efficiency as well as using waste heat via heat transfer medium (water, air or nanofluid) through the heat exchanger for space heating, cooling or DHW. There are different type of PV/T depending upon the medium for transfer of heat such as water-based PV/T, air-based PV/T, nanofluid PV/T, phase change PV/T and PV/T with heat pipes (Das, Kalita, & Roy, 2018), as well as it varies based on the configuration of the glazing and PV technology used (Good, Andresen, & Hestnes, 2015).

It can be integrated onto the buildings as building Integrated photovoltaic thermal (BIPVT). This technology is increasing in connection to low or zero energy buildings as it requires less space (Good et al, 2015).

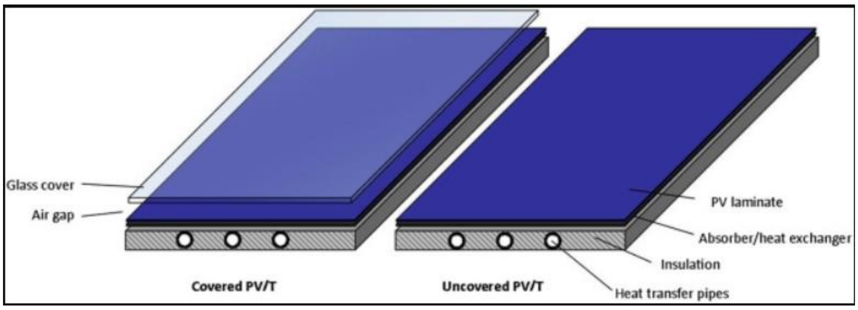


Fig. 3.7: Flate PV/T module (Good et al, 2015,p.988)

Geothermal

The Geothermal heat pump or ground source heat pump (GSHP) are used in commercial as well as residential buildings for providing heating, cooling and DHW. Geothermal heat pump exchanges the heat from the ground. In winter geothermal heat pump transfers the heat stored in ground into building and in summer extracts the heat out of building to earth. The ground act as the source in winter and sink in summer. At the depth of 4- 6 meters below earth surface temperature is constant, heat can be pumped in summer to the ground (nzeb, 2020). The heat can be extracted from the ground through closed or open-loop systems. GSHP has three major components: 1) Earth connection between GSHP and soil through tubes (horizontal, vertical or submerged), 2) Heat pumps to transfer the heat from the fluid in earth connection to the distribution system and 3) Heating / Cooling distribution system from heat pump to ambient space (nzeb,2020).

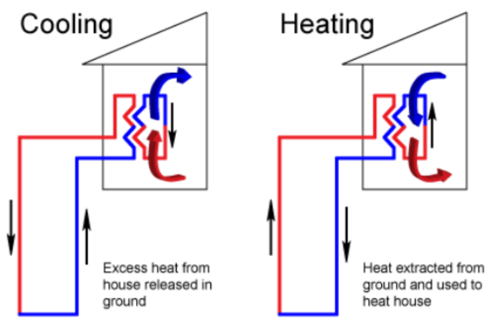


Fig. 3.8: Simplified diagram of a Geothermal heat pump ("viridiant total solutions ", n.d.)

Fig 3.8: illustrates the working of a Geothermal heat pump in summer for cooling and winter for heating. There is an increase of 28% in geothermal energy use in Norway since 2015 leading to 3.0 TWh per year of use in 2018 (Kvalsvik, Midttømme, & Ramstad, 2019).

Heat Pump

There is lots of discussion on heat pump some consider it as hybrid application, renewable technology or low carbon technology (Kemna & van Elburg, 2002).In this report, I'm considering it as renewable energy technology. "Heat pumps are considered a renewable energy technology because they produce more energy than they consume, the more energy they produce relative to what they consume the more renewable energy they provide"(Glenergy, 2020).

The heat pump is an electrical device which operates on the principle of vapour compression refrigeration cycle extracting heat from a cool source and transferring it to a warmer temperature. The compressor pumps the refrigerant between two heat exchanger coils, refrigerant evaporates at low pressure and extract heat from the surrounding, then refrigerant is compressed and condenses at high pressure releasing the heat. Heat pumps are very flexible device as they draw heat from the various source such as outside air, air from indoor space that needs cooling, from a water tank or outside the body of water (Hootman, 2012). Moreover, Hootman (2012) has mentioned heat pumps as an important technology in a switch from onsite combustion of fossil fuel like natural gas to electricity. It has high efficiency greater than 100% and requires a small amount of electricity to converts low-quality heat into high quality. In NZEB where electricity is generated by on-site renewables, heat pump plays an important role in space heating and domestic hot water.

Air to the air heat pump is a well-established technology in Norwegian residential buildings. Norwegian Heat Pump Association (NOVAP) annual heat pump sales rate has raised to 73 000 heat pumps in 2016 providing 700GWh renewable energy and contributing to 63% of energy-saving (Stene, Alonso, Rønneseth, & Georges, 2018).

Integrated Process Delivery

This section briefly describes the need for an integrated approach as NZEB requires complex design, construction, and operation.

NZEB involves integrated process delivery instead of the conventional design process of buildings. In conventional design first, the architect design building form, façade, articulation, aesthetic features, then energy engineers design the HVAC after that builder will execute the construction based on drawings, blueprint, or model. There are less interaction and communication between different professionals in this process. Whereas integrated process delivery is a comprehensive approach to building system and equipment it requires synergies among the system, high building performance, human comfort, and environmental benefit (Shady, 2018). NZEB requires a collaborative multidisciplinary team of architect, energy consultant, renewable energy solution provider, housing cooperative, the construction company working together for energy-neutral buildings. The survey questionnaire has included different professional in the building sector as NZEB needs multiple teams professional in the integrated delivery process.

Chapter 4 Qualitative data analysis

This chapter comprises of case study analysis and document analysis. In case study analysis section 4.1 the research will describe the issues with the implementation of EPBD recast in Norway and will address the first additional research question about Norwegian government dealing of EPBD recast directive on NZEB so far and its current status.

In section 3.1 of the theoretical framework, the EPBD recast directive about NZEB from December 2020 for the new building has been discussed, now in the case study analysis, the study will describe its implications in Norway.

4. 1 Case Study transposition of EPBD recast in Norway

In May 2010, the EU adopted Energy performance of building directive recast 2010/ 31/ EU, making it essential that all new buildings should be nearly zero energy building from 31 December 2020 however, all the new building occupied and owned by public authorities should meet the requirement by 2018 (EU, 2010). The directive includes 31 articles with different suggestions concerning various aspect of building energy use. The member states shall implement a methodology for calculation of energy performance, establish minimum energy requirement, issue energy certificate for building, regular inspection of heating and air conditioning system and increase the number of NZEB. Since the directive has no concrete values in its definition about nZEB, EU member states can define nearly zero energy building based on their situation and climate.

Norway is a part of the European Economic Area (EEA), so implementation procedure is different from EU countries. The EEA joint committee, that consists of diplomats from EU and EEA countries through a screening process determines the legal acts for EEA countries. Although the deadlines for transposition for both EU and EEA nation are usually same, the EEA joint commit in case of delay can set a new deadline that must be transposed into Norwegian Law (Haldorsen, 2016). The implementation of EPBD directive 2002/91/EC is one example which was delayed several times and after a lot of challenges was finally transposed in Norwegian law by 2010. Although the EPBD recast 2010/31/EU is built on the already implemented directive 2002/91/EC with more innovations included such as the concept of nZEB, it not formally included in the EEA agreement. Thus, Norway is not obliged for the implementation of EPBD recast (Toleikyte et al., 2016). The Norwegian white paper on climate (Miljødepartementet, 2012) and buildings (Kommunal- og regiondepartementet,2012) focuses on phasing out of fossil-based energy provision and reducing energy consumption in buildings, established that from 2015 all-new building requires to meet passive house standard and by 2020 all-new building should meet NZEB standards (Knudsen & Dalen, 2014).

After evaluating the EPBD recast directive in 2015, the Norwegian authorities found that its connection to the internal market is not clear and has limited impact on the functioning of the internal market. Hence at EEA committee meeting, Ministry of Petroleum and Energy decided that EPBD recast directive should be incorporated into EEA agreement with necessary adaptation and process of incorporating will be quick (OED, 2015). Although it was told to be a quick process, the concept of NZEB in the Norwegian context is still not fully defined (Tor Brekke, Olav Karstad Isachsen, & Strand, 2018).

Even though Norway has not yet implemented EPBD recast the content and ambition of the directive are practised in strategies and planning of future building regulations. Norway does not follow the formal procedure required in directive but has stringent building standard and regulation from 2017 that includes a higher share of renewable energy (Toleikyte et al., 2016).

Norway has interpreted some of the directive articles and included it in building standards and measures. The articles adopted in Norwegian building standards which are relevant for this thesis are discussed below:

> *Article 2: "nearly zero-energy building means a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby" (EU, 2010)*

This article suggests the member states develop their national definition based on their national and regional context. Around 15 countries such as Austria, France, Denmark, UK and Netherlands have a national definition for nZEB in place (BPIE, 2015). Although Norway has no national definition yet, the effort has been done by authorities for the development of a national definition of NZEB.

In 2013, the national office of building technology and administration (Dibk) assigned Rambøll and Link to develop a proposal for a national definition of nZEB that resulted in a 73-page report called " Nesten nullenergibygg forslag til nasjonal definisjon" (Killingland et al., 2013).

The report in agreement with the directive suggested that "Nearly zero-energy buildings in Norwegian conditions should have 70 % lower energy demand than TEK10 (current regulation level). Energy use is calculated as net delivered energy to the building. Energy deliverables are weighted by their impact on climate or ratio of renewables" (Killingland et al., 2013, p. 3). Furthermore, in March 2017, the Norwegian building authority delivered its first suggestion for NZEB requirement and the road map towards NZEB definition to Ministry of Local government and Modernisation and Ministry of Petroleum and Energy, yet Norway has not formalised its national definition of NZEB, its underdevelopment (Tor Brekke et al., 2018).

> *Article 3: "Member States shall apply a methodology for calculating the energy performance of buildings in accordance with the common general framework set in Annex I. This methodology shall be adopted at national or regional level" (EU, 2010).*

Based on article 3, in 2010 the Norsk standard, a Norwegian organisation which works in coordination with European standardization organisation published the methodology called Norwegian national standard for the calculation of energy performance of buildings – NS 3031. It is used to calculate energy performance, average energy consumption of different types of building and provides standard values for air flows, thermal losses, ventilation or setpoint temperatures in compliance with Norwegian building regulations (TEK).

> *Article 9: "The national plans shall include (...) intermediate targets for improving the energy performance of new buildings, by 2015(...) Member States shall ensure that: (a) by 31 December 2020, all new buildings are nearly zero energy building(...)Member States shall draw up national plans for increasing the number of nearly zero-energy buildings"(EU, 2010).*

In 2012, Norwegian government (Kommunal- og regiondepartementet,2012) announced that all new building should conform passive house standard by 2015 and nearly zero-energy level by 2020 (Knudsen & Dalen, 2014; Toleikyte et al., 2016). With this announcement, Norway implemented article 9 partially. The Norwegian passive house standard focuses on environment-friendly low energy building. It is developed in the adaption of the German passive house definition given by the Passivhus Institut to suit the local climate. There are two passive house standard NS 3700 for residential and NS 3701 for non-residential building (Knudsen & Dalen, 2014). Although Norway has partially implemented article 9 due to absence of a precise definition of nearly zero energy building, the nZEB are constructed on Passive house level in relation to final energy with a higher share of renewable energy (Toleikyte et al., 2016). Moreover, Norway has made a huge investment in the research centre for Zero Emission building and zero-emission neighbourhood showing its willingness for achieving the target.

> *Article 11: "Member States shall lay down the necessary measures to establish a system of certification of the energy performance of buildings. The energy performance certificate shall include the energy performance of a building and reference values" (EU, 2010).*

The Energy performance certificate is mandatory in Norway from July 2010 in all transactions (buy or renting) related to buildings. The Ministry of Petroleum and Energy together with the Ministry of local government and regional development is responsible for the implementation of the energy performance certificate. It labels the building on the scale of A to G.

These above-mentioned articles from the directive have been adopted in the Norwegian building industry. Although Norway has not yet implemented EPBD recast fully. The Norwegian government is funding a lot of research programmes Zero Emission Building research centre, FEM ZEN (2017-2024) and Future built (2010-2020). FEM ZEN is an eight-year programme in collaboration with 10 public enterprises such as DiBK, NVE, Statsbygg and 29 private company working for developing knowledge, solution, and products for the zero-emission neighbourhood. Moreover, Future built is a ten-year program in the municipalities Oslo, Bærum, Asker and Drammen developing 50 pilot projects. Around ten of the completed projects are nZEB and plus energy buildings (Stene et al., 2018).

4.1.1 Analysis of the current situation

Subsequent exploration of the available documents, literature, and material on the website of government and European Union to understand the current stand of Norwegian government on implementation of EPBD recast, did not have any information after 2018. This question leads me to contacted European Union -EU direct, Inger Grethe England -Senior Advisor of National Building Authority (Dibk), Sindre Samsing - fagdirektør of Ministry of Local Government and Modernisation (Kommunal- og moderniseringsdepartementet bolig- og bygningsavdelingen) and Tom Andreas Mathiasson - Adviser of Ministry of Petroleum and Energy to know Norway's stance on EPBD recast. Though I contacted European union direct, they suggested contacting the relevant national authority in Norway for its stance on the directive. The study briefly describes and evaluates the email correspondence with several Norwegian government authority.

4.1.2 Correspondence with National Building Authority

To know about the implementation of NZEB in Norway from 2021, I contacted the national building Authority (Dibk), a government firm responsible for approving laws and rules related to building and construction. This study is thankful to Inger Grethe England, Senior Advisor, Dibk for her support to answer the queries and providing the right contact information in the Ministry of Local Government and Modernisation.

Inger Grethe England (Personal communication, April 29, 2020) tells that the requirement of EPBD recast directive 2010/ 31/ EU are not enforced in Norwegian regulation since it is not yet implemented in EEA treaty. Hence, the building sector has no obligation to EPBD recast.


IE

Inger Grethe England <ige@dibk.no>
Wed 29/04/2020 15:33
To: Reeta Kiran
Cc: Jana Bedau <jab@dibk.no>; Christine M. Karlsen <cmk@dibk.no>

Dear Reeta Kiran

Thank you for your inquiry concerning implementing the Energy Performance of Building Directive, 2010 / 31 / EU of Nearly zero energy buildings (NZEB) in Norway.
Your e-mail have been forwarded to me from Jana Bedau.

The Energy Performance of Building Directive, 2010 / 31 / EU is not yet implemented in the EEA treaty. The requirements in the directive are not entered into force in Norwegian regulation. Until the directive is implemented in the EEA treaty the Norwegian building sector has obligations concerning the Norwegian regulations on technical requirements for construction works (the Building Codes) and not the Energy Performance of Building Directive, 2010 / 31 / EU, www.dibk.no and https://dibk.no/globalassets/byggeregler/regulation-on-technical-requirements-for-construction-works--technical-regulations.pdf .

Fig. 4.1: Screenshot of communication with Inger Grethe England about the status of EPBD recast in Norway.

On future query with her about when the EPBD recast 2010/ 31/ EU will be implemented in the EEA treaty and who are involved in it from Norway. The study found that EPBD recast is the responsibility of the Ministry of Petroleum and Energy and date of implementation is not yet finalized (Inger Grethe England, Personal communication, April 30, 2020). While going through the information provided by her, I found that there has been no updated on EPBD recast by the government since 2015. She also gave the contact of Sindre Samsing, Fagdirektør, in the Ministry of Local Government and Modernization for further clarification.

Inger Grethe England <ige@dibk.no>
Thu 30/04/2020 14:08
To: Reeta Kiran

Dear Reeta Kiran,

The Ministry of Petroleum and Energy is responsible for the EPBD recast 2010/ 31/ EU
and the negotiations concerning the implementation of Norwegian adaptation in the EEA agreement. The date of implementation is not established yet.

You can find more updated information about EPBD recast 2010/ 31/ EU on the Goverments web site
https://www.regjeringen.no/no/sok/id86008/?term=bygningsenergidirektivet

Best regards

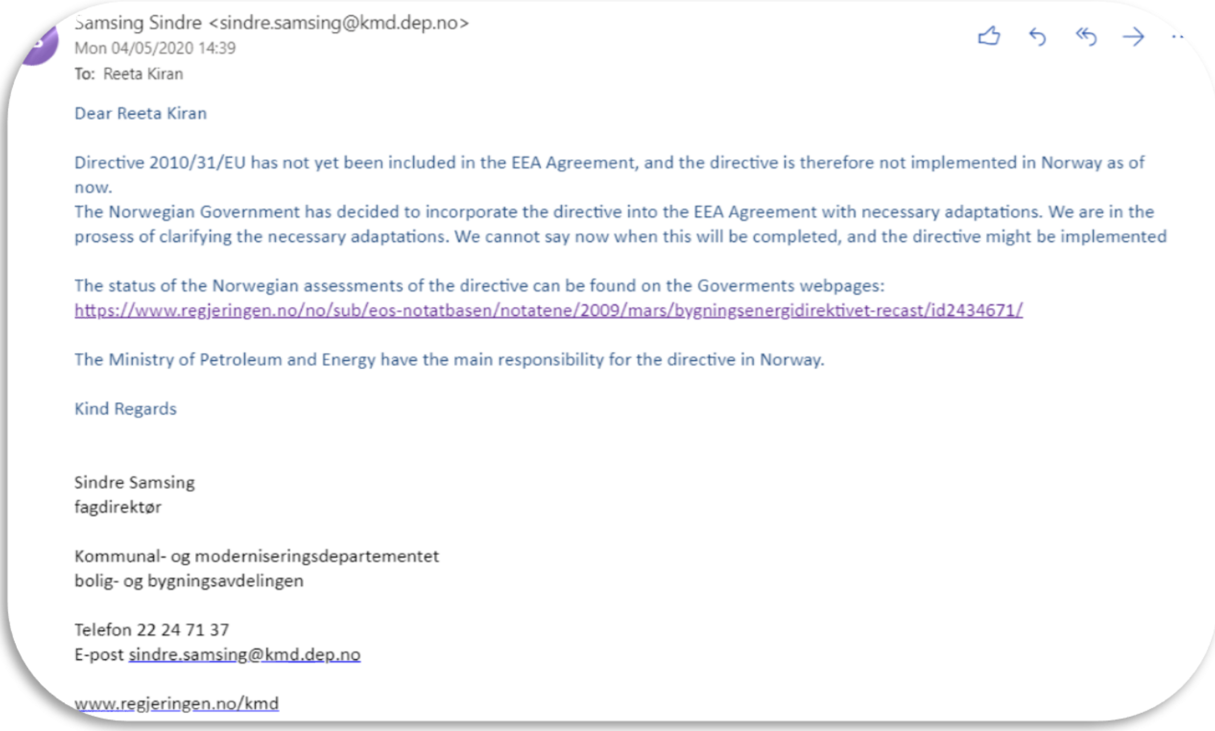
Inger Grethe England
Senior Adviser

Mobile: 91 52 57 65

Fig. 4.2: Screenshot of correspondence email with Inger Grethe England.

4.1.3 Correspondence with Ministry of Local Government and Modernisation:

The Ministry of Local Government and Modernisation was addressed to know when is EPBD recast is going to be implemented in EEA agreement and why it is taking so long? Sindre Samsing (Personal communication, May 05, 2020) mentioned that EPBD recast is not part of EEA agreement still. He emphasis on Norwegian government decision for incorporating the directive in EEA treaty with necessary adaption but is uncertain about the timeline.



Samsing Sindre <sindre.samsing@kmd.dep.no>
Mon 04/05/2020 14:39
To: Reeta Kiran

Dear Reeta Kiran

Directive 2010/31/EU has not yet been included in the EEA Agreement, and the directive is therefore not implemented in Norway as of now.
The Norwegian Government has decided to incorporate the directive into the EEA Agreement with necessary adaptations. We are in the prosess of clarifying the necessary adaptations. We cannot say now when this will be completed, and the directive might be implemented

The status of the Norwegian assessments of the directive can be found on the Goverments webpages:
https://www.regjeringen.no/no/sub/eos-notatbasen/notatene/2009/mars/bygningsenergidirektivet-recast/id2434671/

The Ministry of Petroleum and Energy have the main responsibility for the directive in Norway.

Kind Regards

Sindre Samsing
fagdirektør

Kommunal- og moderniseringsdepartementet
bolig- og bygningsavdelingen

Telefon 22 24 71 37
E-post sindre.samsing@kmd.dep.no

www.regjeringen.no/kmd

Fig. 4.3: Screenshot of correspondence with Sindre Samsing.

After quite a few emails with him, he provided the contact of Tom Andreas Mathiasson, who is an advisor in Energy and Water Resource Department, in Ministry of Petroleum and Energy responsible for EPBD recast directive in EEA treaty. He also told, Ministry of Local Government and Modernisation work with the Ministry of Petroleum and Energy for the part of the directive concerning nearly zero energy requirement of the building.
Since the directive is approaching the deadline to know the possible reason for the delay in the transposition of EPBD recast is important. When asked about the delay Sindre Samsing (Personal correspondence, May 07, 2020) told he cannot comment on government internal decision and evaluation.

Samsing Sindre <sindre.samsing@kmd.dep.no>
Fri 08/05/2020 09:19
To: Reeta Kiran

...

Fra: Reeta Kiran <r.kiran@stud.uis.no>
Sendt: 7. mai 2020 10:23
Til: Samsing Sindre <Sindre.Samsing@kmd.dep.no>
Emne: Re: Query related to Status of Nearly Zero Energy Buildings (NZEB) in Norway

Dear Sindre Samsing,

Thank you very much for all your support. As mentioned in your mail the directive is not applicable to Norway till now. I m eager to know the possible reason for the delay of integrating EPBD recast in EEA agreement. Since the directive, EPBD recast came in 2010, nearly 10 years have passed in spite of willingness of government for incorporation with required adaption it didn't happen.

I can't comment on the Governments internal discussions and evaluations of the directive.

It will be a good insight for me to understand the reasons for the delay, in spite of willingness shown in TEK 10 (very strict energy requirement regulation for a small dwelling) they were rather loosed up in TEK 17 regulation.

There was no changes in energy requirements from TEK10 to TEK17, and there has never been an loosening of the energy efficiency requirements introduced in TEK10.

Fig. 4.4: Screenshot of email correspondence with Sindre Samsing.

4 .1.4 Correspondence with Ministry of Petroleum and Energy

Tom Andreas Mathiasson (Personal communication, May 12, 2020) clarifies that the Norwegian position has been to implement the directive with necessary adaptation but did not say anything about when.

Mathiasson Tom Andreas <Tom-Andreas.Mathiasson@oed.dep.no>
Tue 12/05/2020 10:43
To: Reeta Kiran

Dear Reeta Kiran,

The Ministry of Petroleum and Energy has deemed the Energy Performance in Buildings Directive to be on the limit of what can be viewed as EEA relevant. The Norwegian position has been to implement the directive with necessary adaptations.

Please look here for further information:
https://www.regjeringen.no/no/aktuelt/norsk-standpunkt-til-bygningsenergidirektiv-ii/id2407959/

https://www.regjeringen.no/no/sub/eos-notatbasen/notatene/2009/mars/bygningsenergidirektivet-recast/id2434671/

Best regards,

Tom A. Mathiasson
Rådgiver | Adviser
Olje- og energidepartementet
Norwegian Ministry of Petroleum and Energy

tma@oed.dep.no
Telefon: +47 222 46 287 Mobil: +47 922 43 201
regjeringen.no/oed – Facebook - Twitter

Fig. 4.5: Screenshot of correspondence with Tom Andreas Mathiasson.

4.1.5 Finding

After, several email correspondences with the people involved with EPBD directive 2010/31/EU in Norwegian authority, the study found there are two ministries involved for implementation of this directive. Besides, both the ministries have an unclear answer which shows the willingness of the Norwegian government for implementation but no worries about the deadline. Moreover, no one clarifies the reason for the delay in implementing EPBD recast in the EEA treaty though there are few months left in the implementation of the directive for nearly zero energy building from 31st December 2020. Since 2015 not much has happened on the directive for nearly zero energy building by 2020, authorities are still working on adaptions to make it EEA relevance. The finding of the case study is discussed in detail in section 6. 1 of the discussion chapter.

4.2 Document Analysis

Document analysis will look at the national building codes keeping in mind the second research question on the current Norwegian legislation facilitating NZEB. The five sets of documents – TEK series: TEK 07, TEK 10, TEK 17 and NS 3700 and NS 3701 are keys to analyse. These documents show the extent of compliance by Norwegian authority towards EPBD recast and its influence on the technical requirement of buildings. As mentioned in section 3.3 of the theoretical framework the design principle of NZEB is based on low energy requirements of the building. Thus, this study will focus on the energy efficiency requirement part of the TEK series.

NS3700 and NS 3701 are used in the online survey to know the energy-efficient strategies used in the Norwegian building sector by various professionals.

4.2.1 TEK series

The Norwegian Building Code (Byggforskerien) TEK is an important national document which describes the progression of building construction towards EPBD regulations. TEK is a series of the document existing in Norwegian building design and practises for 60 years. According to Gullbrekken and Time (2019) " Byggforskserien (..) show and document the development of regulations and technical solutions and are a unique source for studying (the technical) development of Norwegian housing models" (p. 38). Document analysis of the building codes is done to understand the Status of NZEB in Norway since the TEK series presents the willingness of government and forces the construction industry to enforce the regulations for design and construction of the building. The Norwegian building regulation started in early 1949 focusing on satisfactory indoor climate by setting a minimum requirement for insulation, in 1965 the requirement was barely updated to meet the already practised U value in construction moreover in 1985 the thermal regulation was tightened (Christian Mjønes et al., 2012; Gullbrekken & Time, 2019). The later series in 1987, TEK 97, TEK 07, TEK 10, TEK 17 focuses on setting stricter demand on minimum U value and energy efficiency.

4.2.2 TEK 07

The EPBD directive 2002/ 91/ EC affected the technical regulation TEK07 published in 2007 making low energy housing a standard. TEK 97 was revised several times till 2010 with a major update in the energy section in 2007. TEK07 regulations are based on much of the same framework of TEK 97 updated and given name TEK 07(Christian Mjønes et al., 2012). TEK 07 was enforced from September 2009. This was the first building code in Norway with energy performance approach, setting the maximum net energy demand per year for buildings (Stene et al., 2018). The energy demand of the building was reduced with an average of 25 %. The insulation requirement for wall, floor, ceiling, and glazing increased besides stricter limit for air leakage was made. Minimum 40% of the net heating needs must be covered by energy supply source other than electricity and/or fossil fuels. Other energy sources can be solar panels, local and district heating, heat pump, pellet stove, wood stove, bio boiler or biogas and this energy supply must be used throughout the building lifetime (TEK, 2007).

4.2.3 TEK 10

TEK07 was updated to TEK 10 implementing EU directive regarding the energy performance of building EPBD 2002/ 91/ EC. TEK 10 came into operation from 1st July 2010. This was a more detailed and elaborate report on the regulations and requirements expected from the construction sector. It was optional to follow TEK 07 or TEK 10 building regulations during 1st July 2010 to 1st July 2011. The net energy requirement for building in TEK 10 is different from in TEK07. TEK 10 along with energy requirement focuses on indoor climate requirements too. It has defined maximum airspeed, the maximum operating temperature during summer and winter, maximum CO_2 level and minimum daylight requirement. In addition to increased heat exchanger efficiency requirement from 70% to 80% and prohibiting fuel oil boilers for space and water heating. However, 40% of the net heating need for building below 500 m^2 of heated floor space (BRA) should be covered by renewable energy sources remained the same as TEK 07. The U values requirement changed for door and windows (TEK ,2010).

Due to EBPD recast in 2010, the Norwegian government announced government policy to promote that all new building will have passive house level from 2015 and nearly zero energy building by 2020 (Knudsen & Dalen, 2014). According to EU regulation, TEK version must be updated every fifth year, regardless of announcement for TEK15, it was delayed from 2015 to 2017 and was enforced as TEK17 in the year 2017.

4.2.4 TEK 17

TEK 17 came into force from 1st July 2017 yet the developer can choose TEK 10 or TEK 17 during the transitional period from July 2017 to 31 December 2018. TEK17 focus on the simpler and clearer regulatory framework that contributes to reduced construction costs and construction time. It gives increased flexibility for choosing solutions as per market demand and profound emphasis on documentation to prevent errors (TEK ,2017). TEK17 is adapted to Norwegian passive house standard NS 3700 (residential buildings) and NS 3701 (non - residential building). The U values and minimum energy efficiency requirement for the different elements of the building were further stringent. Buildings with > 1000m2 heat gross internal area (BRA) requires 60% of the total heating need to be covered by multiple source heating systems and low-temperature heating system whereas smaller building was exempted (TEK17). However, in TEK 10 the requirement for energy supply solution for the small dwelling was more rigid. The removal of the requirement of energy supply solution for building with less than 1000m2 BRA in TEK 17 promotes cheaper housing promise of government. By removing energy flexibility, the possibility of water-based heating and connection to district heating is reduced. This weakened the implementation of renewables source in the future building (Nord, Skrautvol, Eliassen, & Tereshchenko, 2018).

4.2.5 NS 3700

NS 3700 is Norwegian Standard for a passive house. It was first published in 2010 and later updated in 2013. It includes three categories of building – passive housing and two classes of low energy building (StandardNorge, 2013). It was not mandatory till 2015 however to get approval as a passive house it must be followed. Passive house level was declared obligatory criteria from 2016. During this period according to Nykamp (2017) “ Buildings have become part of the energy policy, and consequently, debates focus more on if and how energy produced in buildings can be delivered to the net. The building code, in effect from January 2016 requires all buildings to conform to a “passive house level” ” (p. 90). This was incorporated in TEK 17 regulation. TEK 17 regulation together with NS 3700 made passive house level obligatory for all new buildings.

While doing the document analysis I summarized the changes in the upper limit of energy-saving measures of building elements and net energy demand for different building categories in TEK07, TEK 10, NS 3700 and TEK 17 regulation in table 4.1 and 4.2. This shows in Norway the net energy requirement has been constantly made stricter through the evolution of building codes to enable NZEB. The total energy demand of building category mentioned in table 4.2 is used in section 4.2.7 of the pilot project to understand the completed NZEB project in Norway.

Table 4-1: Overview of changes in energy-saving measures for dwelling in different technical regulation based on the specification in TEK 07, TEK 10, NS 3700 and TEK 17 (self-made)

Energy Saving measure	**TEK 07**	**TEK 10**	**NS 3700**	**TEK 17**
U-value outer walls [W/ (m2 K)]	≤ 0.18	≤ 0.18	≤ 0.15	≤ 0.18
U-value roof [W/ (m2 K)]	≤ 0.13	≤ 0.13	≤ 0.12	≤ 0.13
U-value floors [W/ (m2 K)]	≤ 0.15	≤ 0.15	≤ 0.12	≤ 0.10
U-value windows and doors [W/ (m2 K)]	≤ 1.2	≤ 1.2	≤ 0.80	≤ 0.80
Proportion of window and door areas of heated gross internal area	≤ 20%	≤ 20%		≤ 25%
Annual mean temperature efficiency ratio for heat recovery systems in ventilation systems (%)	≥70%	≥ 70%	≥ 80%	≥ 80%
Specific fan power (SFP) in ventilation systems [kW/(m3/s)]	≤ 2.5	≤ 2.5	≤ 1.5	≤ 1.5
Air leakage rate per hour at 50 Pa pressure difference	≤ 3.0	≤ 2.5	≤ 0.6	≤ 0.6
Normalised thermal bridge value, where m2 is stated as heated gross internal area [W/ (m2 K)]	≤ 0.03	≤ 0.03	≤ 0.03	≤ 0.05

Table 4-2: Total net energy demand limit based on TEK 07, TEK 10, TEK 17 for the relevant building category used in the Pilot project section of the study (self-made).

Building Category	**Total Net Energy Demand (kWh/m2 heated gross internal area per year)**		
	TEK 07	TEK 10	TEK 17
Small house	125	120	100
Apartment buildings	120	115	95
Kindergarten	150	140	135
Office Building	165	150	115
School Building	135	120	110

4.2.6 Enova Subsidies:

Enova SF is a public enterprise established in 2002. It was owned by Ministry of Petroleum and Energy till May 2018 after that it was hand over to the Ministry of Climate and Environment (Enova, 2018). Enova is responsible for facilitating financial support for new energy-efficient building construction as well as for renovating old ones. There are several funding programmes by Enova supporting evaluation, design and construction of low energy and passive house as well as heating and cooling based on renewable energy sources, including heat pumps (Stene et al., 2018). Enova programme “Innovative technologies for the next generation of advance building” (Stene et al., 2018, p. 8) promotes the market introduction of nZEB. In this programme, Enova provides subsidies for full-scale NZEB demonstration projects. All the pilot NZEB project has been supported by Enova.

4.2.7 Pilot Project

There is 9 completed Zero Emission Building pilot project in Norway. All these buildings are designed on the principle of NZEB, reducing energy demand by passive and energy efficiency measure while providing the required energy by on-site renewables. These are different types of buildings two of them are educational institute - Heimdal VGS in Trondheim and Campus Evenstad in Hedemark, four are residential building - Mulitcomfort in Larvik, Skarpnes in Arendal, Zero Village Bergen and living laboratory in Trondheim, two are newly constructed office building - Powerhouse Brattorkaia, Visun Haakonsvern and one is renovated office building -Powerhouse Kjørbo. In most of the pilot project building passive measure like advance building envelope, advance glazing, thermal mass, sun shading, solar tubes and low carbon concrete is used, further energy efficiency measures like advanced lighting control, heat pumps, displacement ventilation, heat recovery are provided. Moreover, the renewable energy measure such as solar PV and combined heat and power is the preferred solution for electricity production and heat pumps for heating demands (Stene et al., 2018). The study describes four of the pilot projects which are NZEB and plus energy building in residential, school and office building category in detail.

1.Powerhouse Brattørkaia:

Powerhouse Brattørkaia is the world's Northernmost energy positive building located in Trondheim. It is an office building of 18000m² and holds 500 workplaces. Many leading players of Norwegian construction industry and ZEB's partner came together to build the first plus energy house in Norway, which throughout its lifetime produces more energy than involved in construction, operation, and demolition (Powerhouse, 2020). The powerhouse Brattørkaia is built on passive house standard NS3701, the building envelope has low U-valve, low thermal bridge value, low air leakage. The structural system of the building consists of thermal mass (low emission concrete) which absorbs and retains the heat and cold thus regulating the temperature without using electricity, solar shading system and utilization of daylight reducing artificial light. The rest of the energy demand is reduced by energy-efficient measures such demand control lightning system (LED technology), decentralised air handling units, demand control VAV system, high-efficiency heat recovery, displacement ventilation for excellent indoor climate and minimum energy use. In addition to it, the renewable energy source is used to generate energy such as seawater heat pump system for space heating and DHW and solar PV of 3000 m² at roof angle of 26 degrees generating nearly 5000,000kWh/a (Stene et al., 2018). The larger building footprint allows it to store surplus energy in summer and use it in winter when daylight is minimum. Powerhouse Brattørkaia is BREEAM NOR outstanding certified building.

Fig. 4.6: Powerhouse Brattørkaia ("POWERHOUSE ", n.d. (a))

2. Visund Haakonsvern, Bergen

Visund is an office building located at Haakonsvern near Bergen and is by owned by Norwegian Defence Agency (Forsvarsbygg). It has around 100 workplaces spread over three floors with floor heated area of 2031m². The building form is simple and compact to minimize heat losses, leakages, and cost. The hollow core concrete slabs and steel columns form the structural unit of the building, thick insulation of 200 mm on exterior wall and100 mm on interior sides reduces the heat losses (Sørensen, Mysen, Andresen, Hårklau, & Lunde, 2017). Optimum use of daylight, LED and the digital addressable lighting interface is used to reduce electricity lightning. The flexibility and controllability of the ventilation system are supplied by active air supply diffuser present in the building. These are highly efficient air handling units with demand control VAV system, enabling the night-time cross ventilation thus reducing cooling loads. High-efficiency heat recovery of 85%, is used. Thermal energy for space heating and DHW is given by a seawater heat pump system. The electricity is generated by solar PV of 310m² on rooftops. The building is operation since 2016, the energy generated by PV was 27.5 kWh/m2 whereas energy delivered to the building was 45.1 kWh/m2, although ZEB goal was not achieved during the first year of operation, it likely the building will achieve its ZEB goal in the future year of operation (Sørensen et al., 2017).

Fig. 4.7 : Visund, Haakonsvern , Bergen(Sørensen et al., 2017, p. 6)

3. Heimdal VGS

Heimdal VGS is an upper secondary school located in Trondheim, Norway. The building consists of a new high school and separate sports hall with a heated floor area of about 24 600m². It is zero-emission building, design with passive house standard 3701 for minimum energy requirement. The building has good daylight access, low heat loss, good thermal comfort and electrochromic coating windows changing colours as per demand. The ventilation system in school provides minimum energy consumption for fans keeping excellent indoor climate. The combined heat and power (CHP) with biogas fuel are used for domestic hot water and heating the swimming pool. The greywater heat pumps are also used for preheating DHW. In

Heimdal VGS 85% of the electricity is generated by combined heat and power plant with biogas and rest 15% electricity generated is by solar PV on rooftops and facades (Stene et al., 2018).

Fig. 4.8 : Heimdel VGS ("Byggeindustrien," n.d. (b))

4.Multikomfort Larvik

Multikomfort house is a two-storey single-family residential building with swimming pool. It is a plus energy demonstration house with heated floor area 200m². Passive house standard concept is used for building design (insulated, airtight, solar shade, windows) reducing the need for heating and cooling. Demand control lightning system, compact ventilation, and heating device (CVHD) and plate heat exchanger are used to increase the energy efficiency of the building. The renewable energy sources geothermal heat pumps, solar thermal panels are used to provide thermal energy while 150m² Solar PV on the rooftop at an angle of 17 degrees provide 19000 kWh/a of electricity and Battery pack provides 600Ah (Stene et al., 2018).

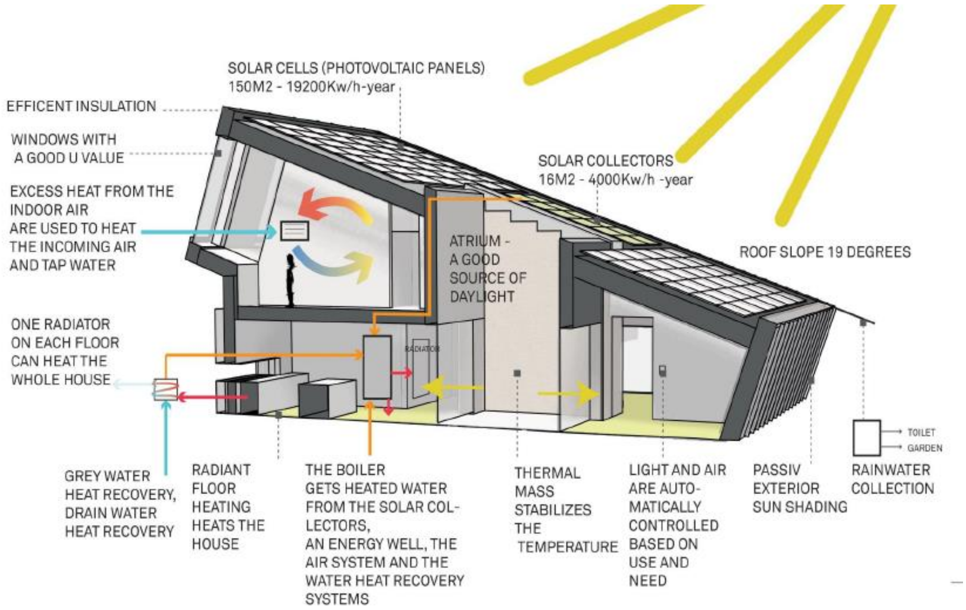


Fig. 4.9 : Multikomfort hus, Larvik ("ZEB ", n.d.)

Chapter 5 Survey Analysis and Finding

This section explains the analysis of the online survey. The level of competency of professional for NZEB is evaluated considering the third additional research question on extend of Norwegian companies and institutions ready for NZEB from 2021 and about the status of competency for NZEB in Norway. The online survey analysis will play a major part in the discussion section and conclusion.

5.1 Participation in online survey

The online survey received 99 responses in total. The survey was open from 17th February 2020 to 21st May 2020, initially, there was a regular flow of responses which decreased drastically during the COVID 19 lockdown period of more than forty-five days but after the ease in lockdown, there was a gradual increase in response. The approach was to send a reminder to respondent three times during three consecutive weeks via email to fill out the survey. According to my student email account that is used to conduct the study, approximately 300 professionals were individually mailed for the survey. In addition to 300 individuals that were surveyed many additional websites contact form especially for solar companies, Kommune, architecture and construction companies were filled out in an attempt to reach potential survey respondent. The detail about the survey method is discussed in section 2.2.3.

There is 33 % participation by the respondent and 67 % chose not to answer the survey. Although 33 % participation seems small, it is the opinion of the project leader and technical chief of the various companies all over Norway that make this survey worthy of knowing the status of NZEB in Norway. Fig. 5.1 illustrates the overall percentage of participation of professional in an online survey. To know the preparedness for implementation of NZEB survey was sent to all the major cities of Norway. There were responses from 24 cities with maximum participation of 21 professional from the Oslo followed by Bergen with 10 participants, Drammen with 9 participants, 6 participants each from Trondheim and Lillehammer, 5 participants each from Porsgunn and Sandnes, 4 participants each from Elverum and Kristiansand, 3 participants each from Bodø, Stavanger, Larvik and Notodden, 2 participants each from Fredrikstad, Hamar, Tromsø, Tonsberg, Konsberg and Strod and 1 participant each from Egersund, Gjøvik, Haugesund, Sola, and Arendal.

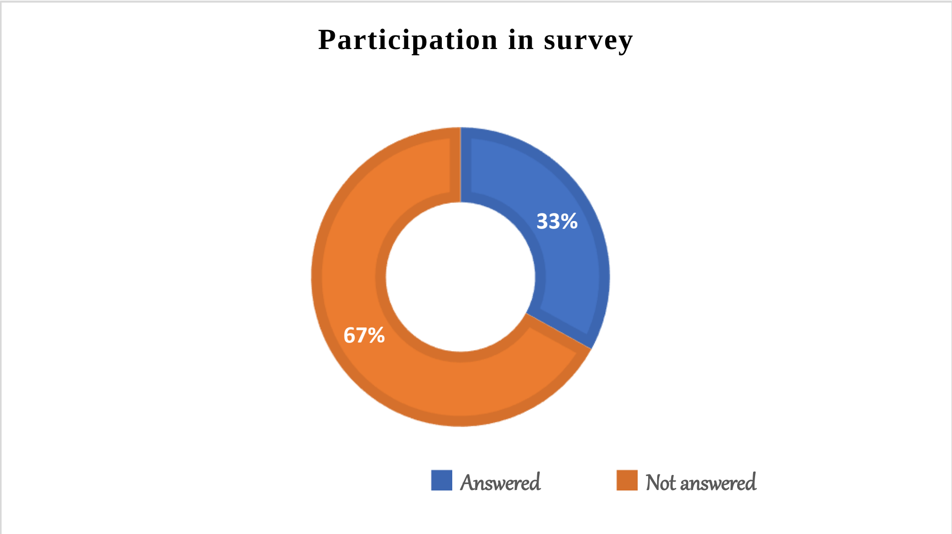


Fig. 5.1: Percentage of participation in Survey

Before analysing the survey result, I would shortly describe the reasons provided by the email correspondent who did not answer. The survey was sent as a reminder to individuals or the company general email address, the most general explanation in case of an individual for not responding was the unavailability of time to answer the survey, some thought their company is not suitable for this survey, some described COVID 19 crisis for having difficult working situation due closer of offices and some forwarded it to the other individual who never answered.

5.2 Analysis of Survey

The analysis of the survey follows the order of questionnaires from question 1 to 9. The findings are illustrated in 16 figures comprising of pie charts and bar charts that have been discussed in detail throughout survey analysis. The questionnaire is attached in Appendix 1

The survey questions were made at the beginning of the study in the early weeks of February during that period I was unaware that EU Directive 31/2010 is not yet implemented in Norway. There is no update since 2015 about the stand of Norwegian government for nearly zero energy building from 2020, this created the dilemma leading to question number 1 about awareness of the directive implementation for NZEB in Norway from 2021.

I was doing the case study analysis parallelly with the online survey. In the later part of April while trying to find the current status of the directive in Case study analysis, through email correspondence with government authorities I came to know the EPBD recast is not yet implemented in Norway.

Since I started my survey from 2nd week of February the responses of question number 1 from the different professional show the same understanding about the directive as me at the beginning of the study.

5.2.1 Question 1- Awareness of Directive

Through survey question 1 the professionals in the building sector were asked about their awareness on the implementation of EU Directive 31/2010 from December 2020 for Nearly Zero Energy Buildings in Norway. The EPBD directive for NZEB implementation is discussed in detail in section 3.1 of the theoretical framework and section 4.1 of the case study.

The survey result illustrated in Fig 5.2 shows 45% of the professional know that the directive should be implemented from December 2020 whereas 55 % answered they do not know about the directive implementation in Norway.

Additionally, illustration in fig 5.3 provides a detail about each category awareness on NZEB nearly 21 of the architect, 6 of energy advisor, 5 of the construction company, 6 of Kommune, 3 of housing cooperative, 1 of geothermal company, 1 of solar company professional told they are aware of the directive on NZEB implementation from 2021 in Norway.

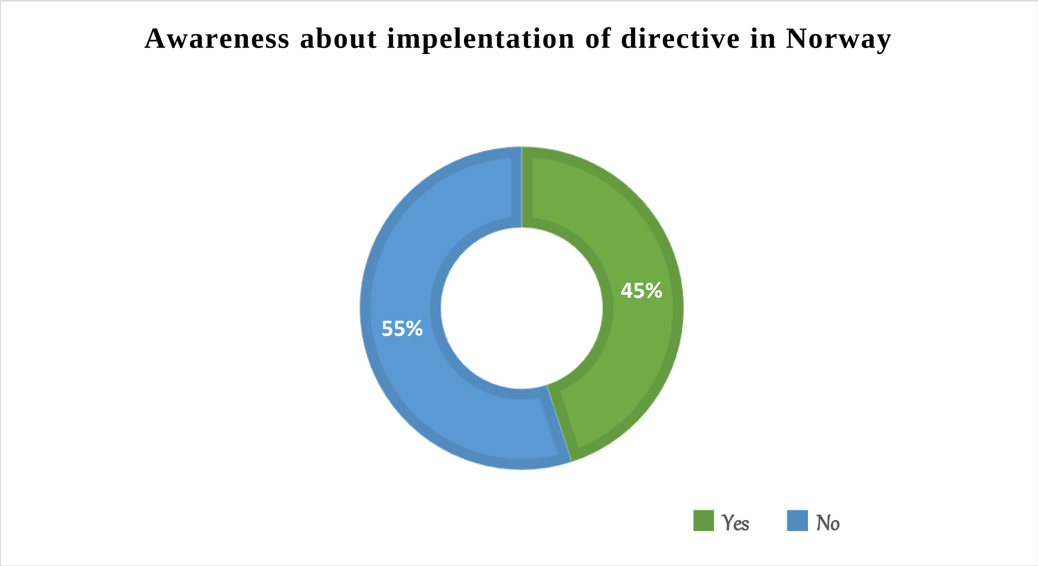


Fig. 5.2 : Percentage of awareness among professional about NZEB implementation of 31/ 2010/ EU (EPBD recast) in Norway from December 2020.

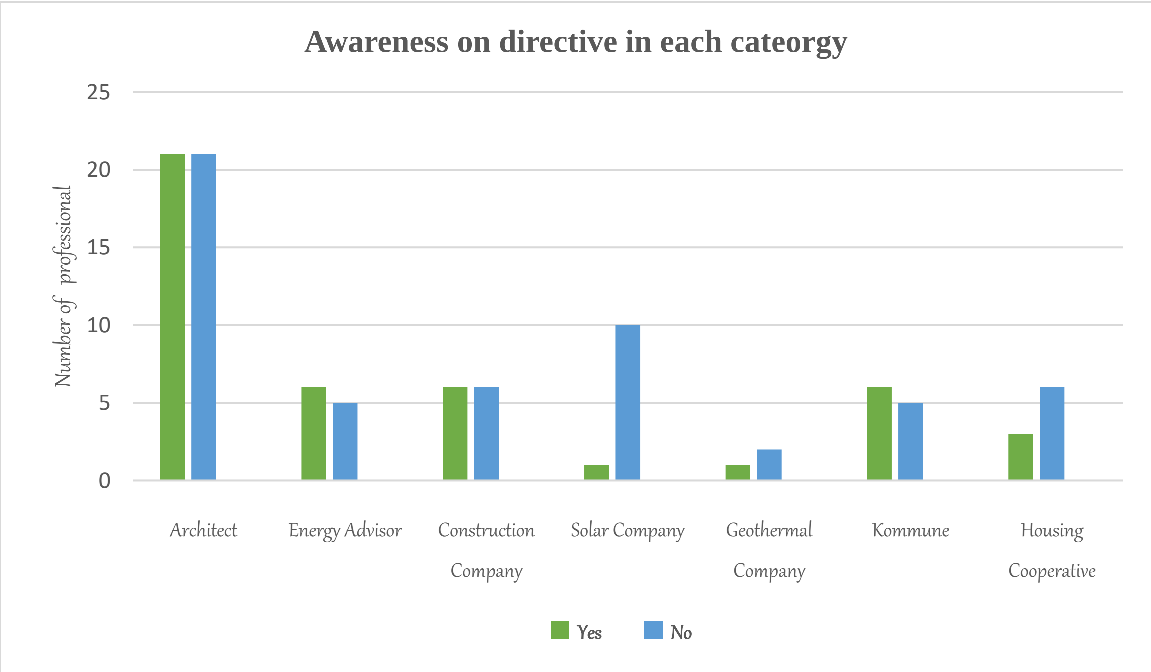


Fig. 5.3: Number of professional aware by each category on implementation of NZEB EPBD recast directive in Norway from 2021

5.2.2 Question 2 - Energy efficiency strategies

As discussed in section 3. 3 of the theoretical frameworks, the NZEB design principle is based on minimising the use of energy and meeting the rest of the demand with renewables. This question is about energy-efficient strategies used in Norway for achieving energy efficiency in the building which is the main concept of NZEB.

When asked about which strategy is mainly followed in Norway to realise energy efficiency of building 76% answered combined active and passive strategies (solar PV, solar thermal system, geothermal system) whereas 24% answered passive strategies alone (NS 3700: 2013 for residential buildings or NS 3701: 2012 for non-residential building) are used.

Fig 5.4 illustrates the percentage of professional using either of the strategies to achieve energy efficiency of building in Norway. In addition, Fig 5.5 shows the number of professional in each category using either of the strategies. Combined passive and active strategies are used by 34 architects, 10 energy advisor, 7 construction company, 8 housing cooperative, 6 Kommune, 6 solar company, 1 geothermal company and rest of the others professional in each category are still using only passive strategy.

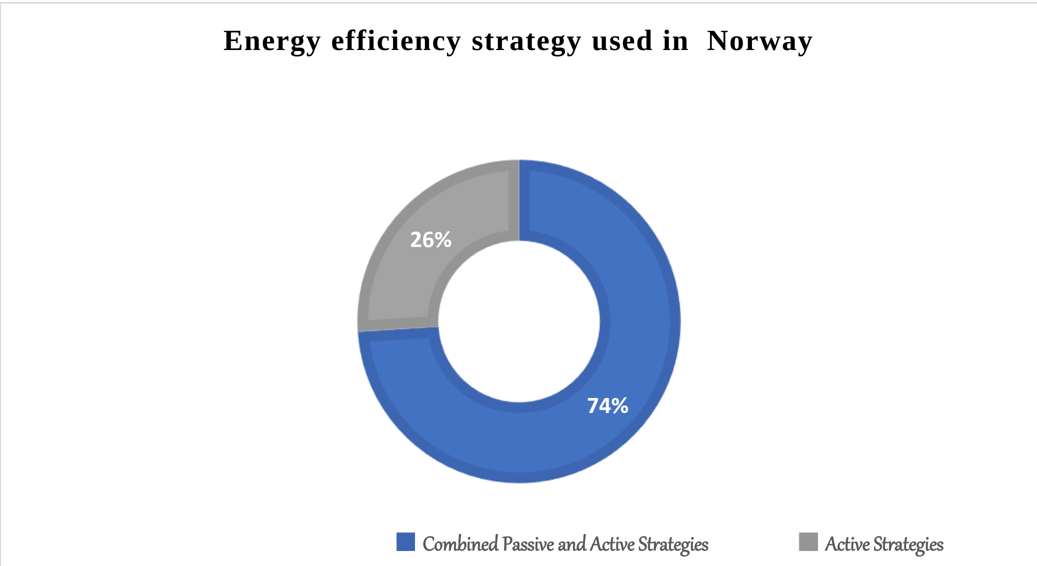


Fig. 5.4: Percentage of professional using active strategies alone and Combined passive and Active strategies in Norway to realise energy efficiency in buildings.

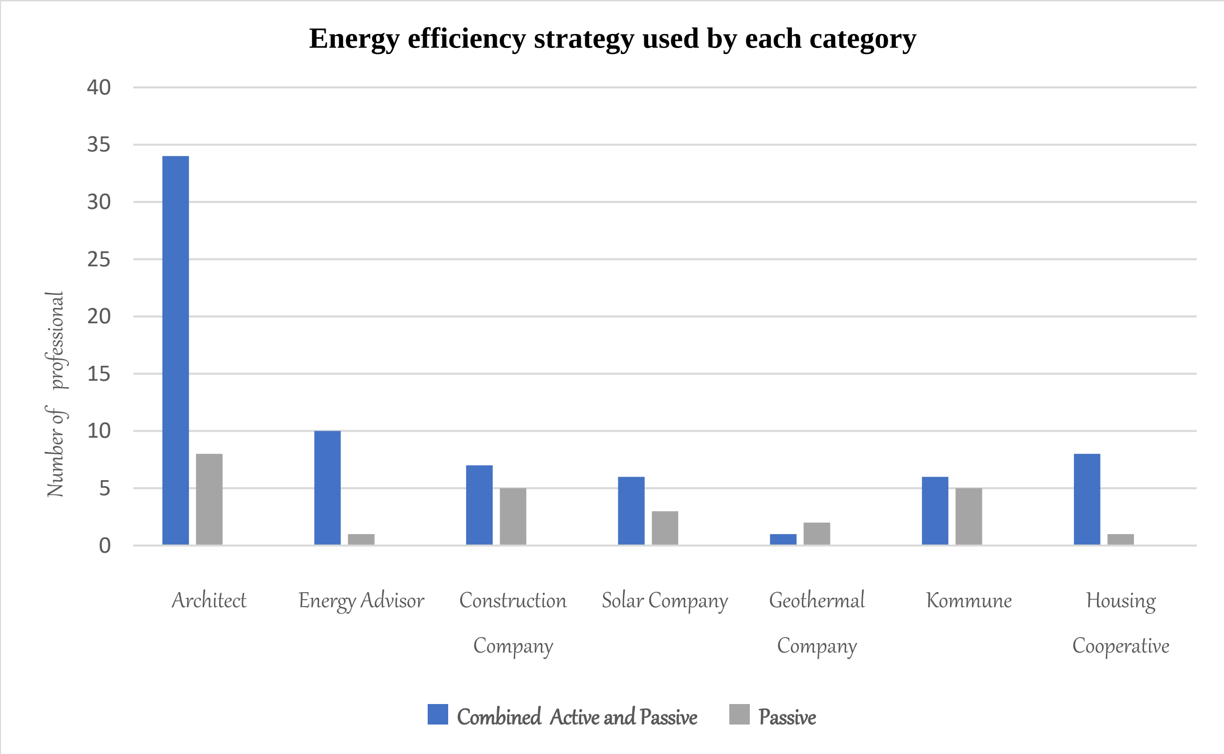


Fig. 5.5: Number of professional in each category using either Combine Active and Passive strategy or passive strategy alone for energy efficiency of building in Norway

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5.2.3 Question 3 - Electricity generation renewable technology

This question was asked to professional to know the increase of renewable energy technology for electricity generation such as solar PV, Solar PV/T in the projects. To achieve NZEB renewable energy is the third criteria after efficiency measures. Solar PV, Solar PV/T have been discussed in section 3.3.3 of renewable energy system strategies. Since in this question we are concerned about electricity generation in all types of building only solar option were mentioned in the multiple-choice answer, none was also one option as some project do not use renewables.

Fig 5.6 shows the percentage of preferred renewable energy technology used in the generation of electricity in buildings. Around 46 % of professional are using solar PV in their project, 9 % of them uses solar PV/T and 45% do not use renewable energy technology in their projects.

In addition, Fig 5.7 shows the number of professional in each category using different solar technology for the generation of electricity in buildings. Nearly 20 architects, 9 energy advisor, 7 construction company, 11 solar company, 3 Kommune, 2 housing cooperative and 2 geothermal company professionals are using either solar PV or solar PV/T in their projects. Still, there is a huge number of professional in each category not using any renewable technology in the project.

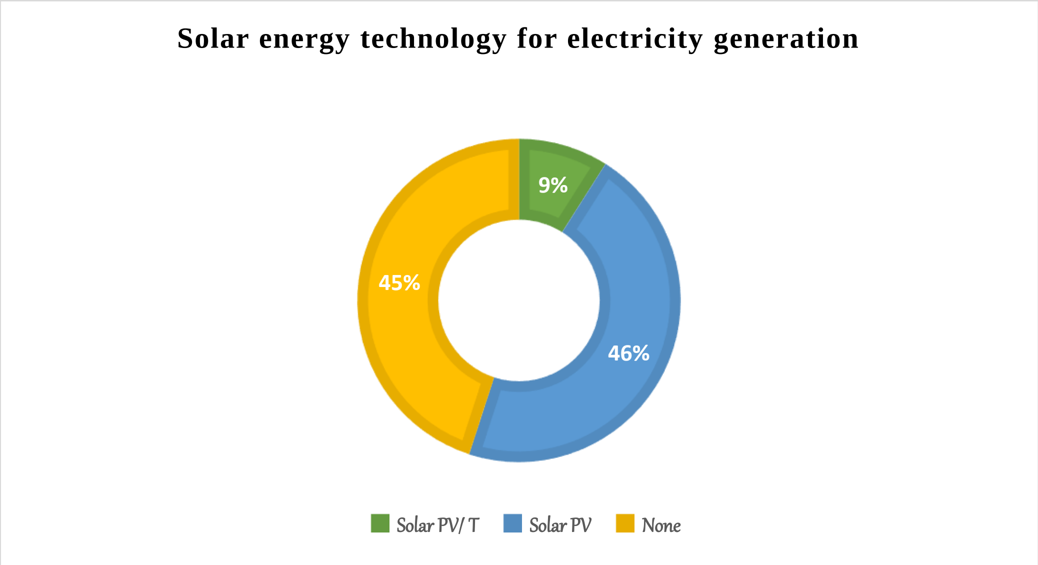

Fig. 5.6: Different Solar technologies used for generation of electricity in the project.

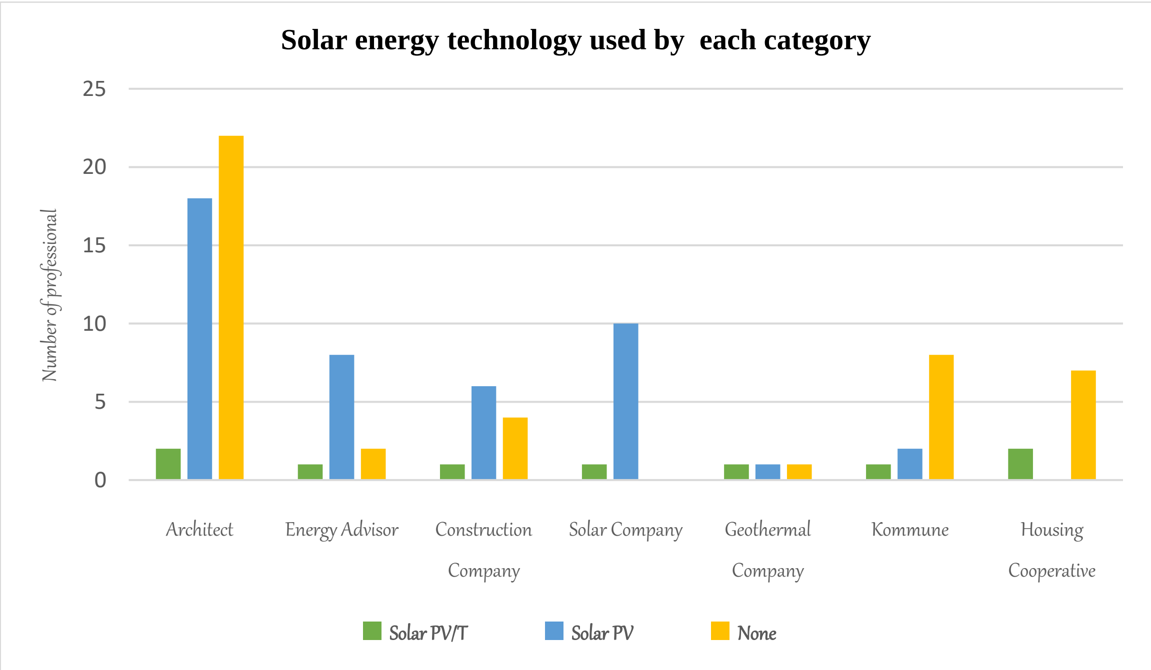

Fig. 5.7 Number of professional in each category using solar PV, Solar PV/T, or none of the technology in the projects

5.2.4 Question 4 – Thermal generation renewable technology

Question number 4 deals with renewable energy technology for generation of thermal heat such as geothermal, solar thermal and heat pump. These technologies have been described in brief in section 3.3.3 of the theoretical framework as an important technology for space heating and domestic hot water of buildings for achieving NZEB. After going through a lot of literature it was found that geothermal, solar thermal and heat pump are three heat generation technologies been significantly used in Norway for the onsite generation of thermal energy hence these technologies are mentioned in survey question (Kvalsvik et al., 2019; Stene et al., 2018).

The survey result shows 38 % of professional described an increase in uses of the heat pump in the project, 29 % of them stated an increase in geothermal in the project while only 7% told about the increase in solar thermal in the project. Still, there is around 26 % of professional stating no increase of renewable in the project. Fig 5.8 illustrates the percentage of professional using different renewable energy technology for heat generation of building.

Also, Fig 5.9 illustrates the details about each category using different renewable heat generation technology. Number of Architect using a heat pump, geothermal and solar thermal respectively is 13, 14 and 2. About 3 of the energy advisors uses geothermal and 6 are using the heat pump in their projects. In construction company 4 uses geothermal and 7 uses the heat pump, in Kommune 4 of professionals are using the heat pump, 1 geothermal and 1 solar thermal and in housing cooperative 1 is using the heat pump, 7 geothermal and 1 solar thermal in the projects. Moreover, in solar company 2 uses solar thermal technology and in geothermal company 2 are using geothermal for heat generation. Still, there are lots of professional not using any renewable technology in projects that are shown through the bar chart in Fig 5.9

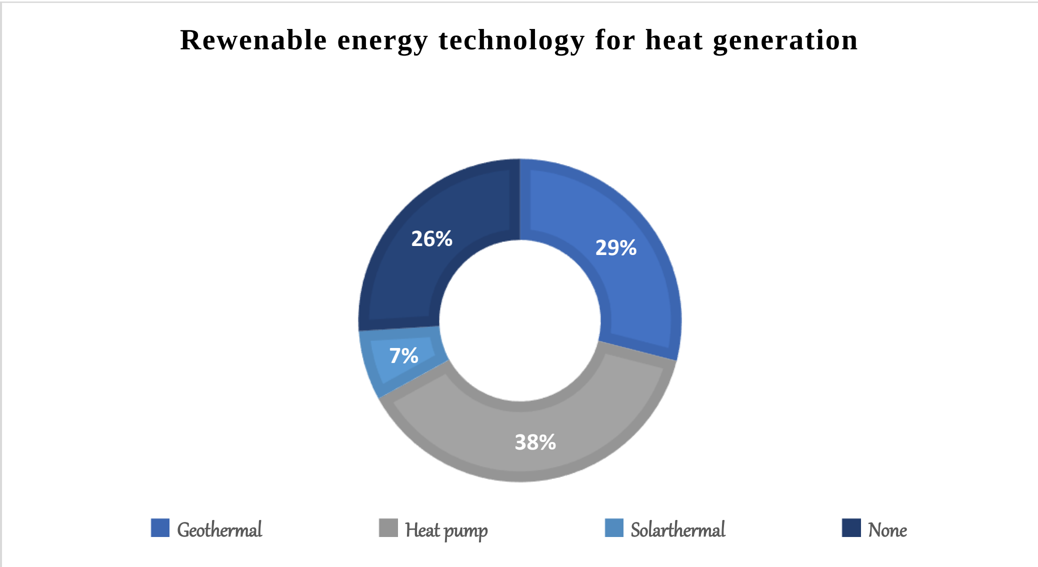

Fig. 5.8: Percentage of professional using different renewable energy technology for heat generation in building projects

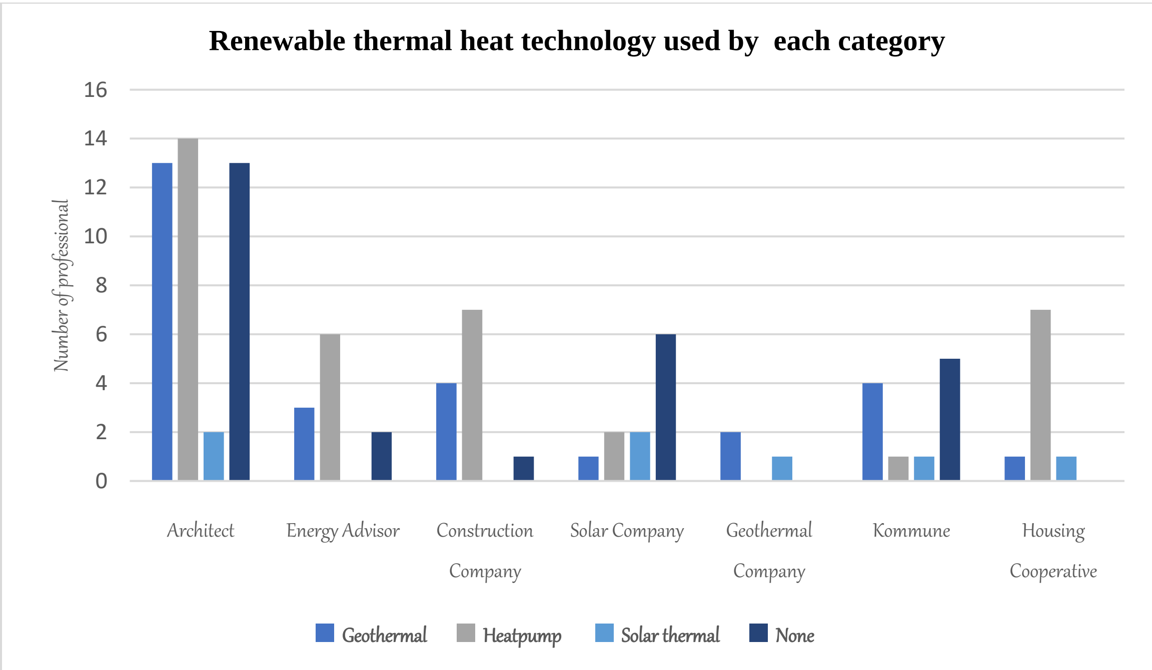

Fig. 5.9: Number of professional in each category using geothermal, solar thermal, heat pump or none of the renewable technology in the projects.

5.2.5 Question 5 – Competence for integrating renewable technology in future

Question 5 is about the preparedness of the professional or companies with the necessary competence for integrating renewable energy technology such as solar or geothermal technology in their future projects. The integration of renewable with the building is a necessary competence for achieving NZEB. This question clarifies about planning for adopting the integration of renewables with the building by professional.

The survey results illustrated in Fig 5.10 show 35% of professional is prepared for Solar technology, 32% are prepared for geothermal technology and 33% stated that they are not prepared for integrating renewable in future projects.

In addition, Fig 5.11 show category wise competence for integrating solar and geothermal technology. Around 16 architects, 11 solar company, 4 energy advisor professionals are prepared for solar technology. While 12 architect, 5 construction company, 4 housing cooperative, 3 Kommune and 2 geothermal company are prepared for integration with geothermal technology. However, there is a big number of professional in each category stating they are not prepared for the integration of renewable with the building.

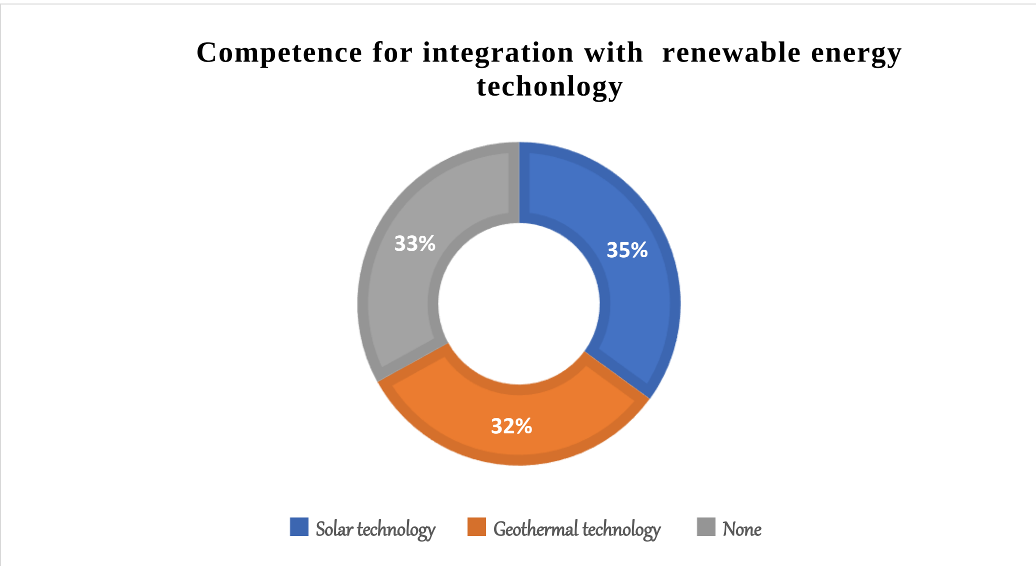

Fig. 5.10: Number of professional in each category using geothermal, solar thermal, heat pump or none of the renewable technology in the projects.

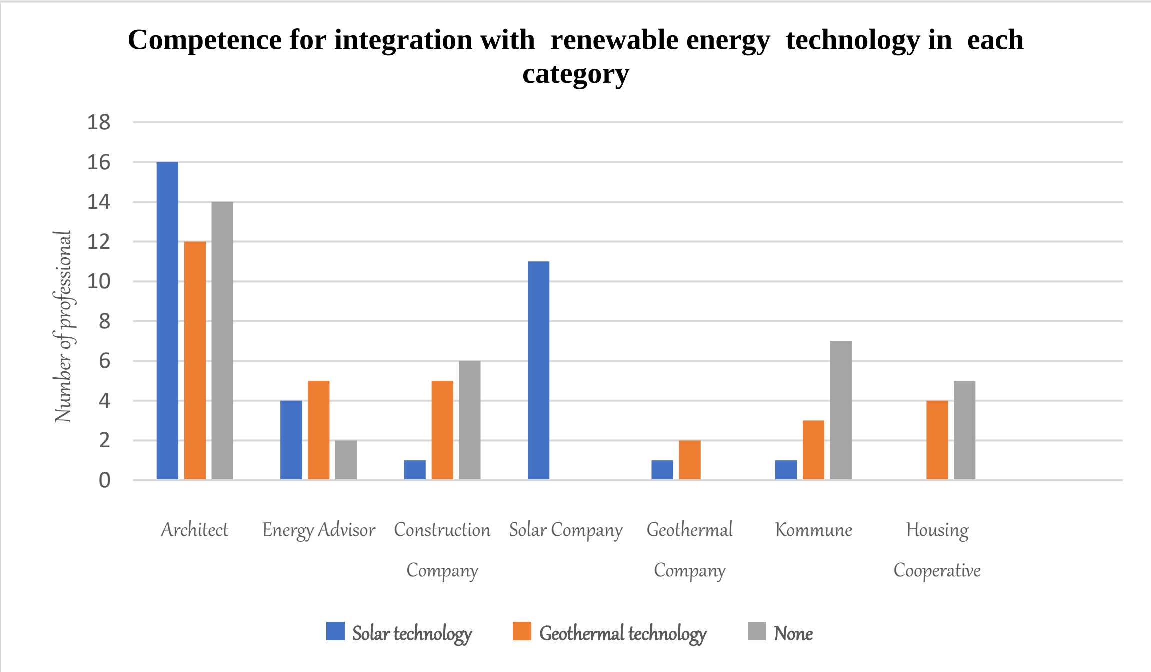

Fig. 5.11: Competence in integrating solar energy technology, geothermal energy technology and none of the renewable technology in the projects by professional in each category.

5.2.6 Question 6 – Criteria for selection of renewable technology

Question 6 is asked to know the three most used criteria in the selection of building integrated renewable energy technology in Norway. The five criteria: investment cost, maintenance cost, operational cost, availability in the market and financial incentives play a crucial role in selecting renewable technology thus decides the future of NZEB. This question was asked to know the major criteria among Norwegian professional for choosing the building integration with renewables.

The survey result illustrated in Fig 5.12 shows 92% of professional describes investment cost as main criteria followed by 61% financial incentives as second criteria and 41 % maintenance cost as third criteria. There is 28% of professional stating operational problems and 29% percentage of them states availability in the market also a criterion in selection.

More detail building integrated renewable technology selection criteria by each category of professional is shown in Fig 5.13. The bar graph demonstrates investment cost as the most important criteria by professionals in all category, financial incentives are the second important criteria for architect, energy advisor, construction company, solar company, and housing cooperative. Moreover, maintenance cost is the third important criteria among architect, Kommune and construction company.

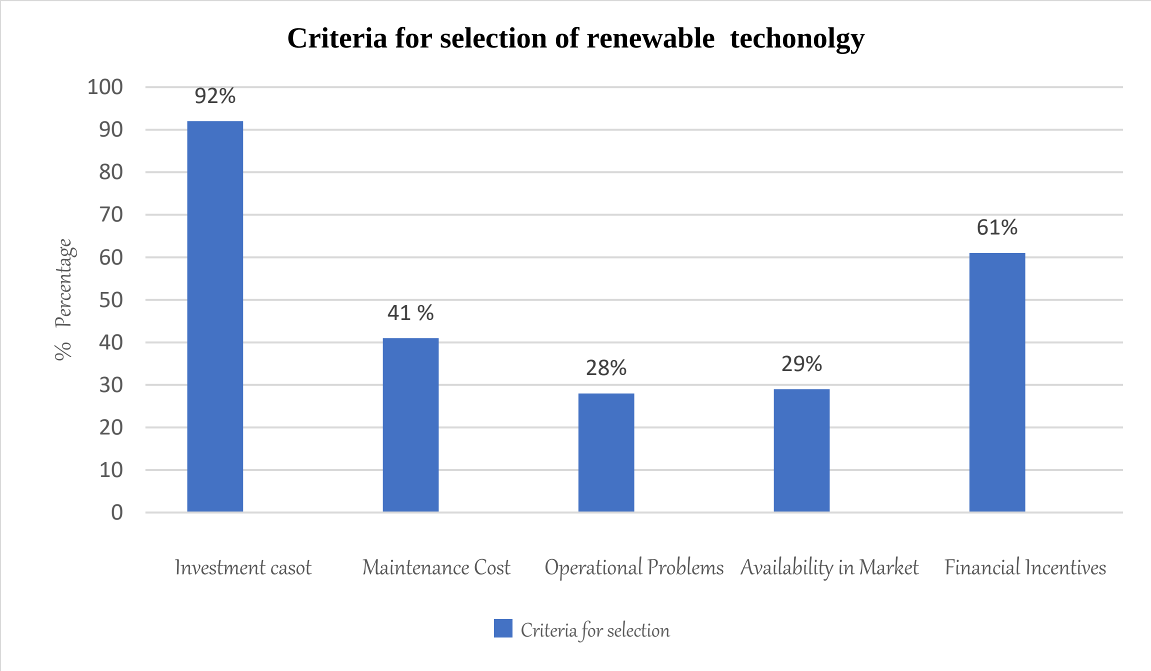

Fig. 5.12: Criteria among professional for selection of building integrated renewable energy technology in Norway.

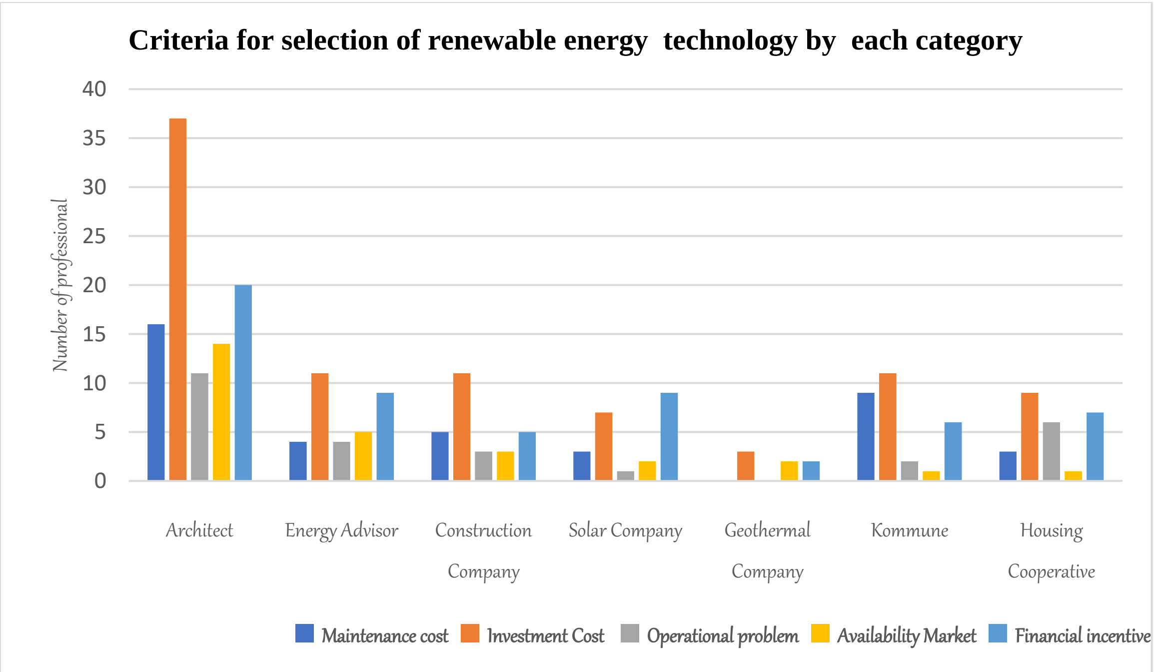

Fig. 5.13: Criteria for selection of building integrated renewable technology by each category based on maintenance cost, investment cost, operational cost, availability in the market and financial incentives.

5.2.7 Question 7 – Involvement in BREEAM, plus energy house and NZEB

This question is asked to know the present involvement of the professional in BREEAM Excellent or Outstanding, plus energy or NZEB types of buildings. As we are approaching December 2020 previous involvement of professional in these types of building will provide experience with NZEB technology.

The section 3.1 on the evolution of NZEB in theoretical framework chapter briefly describes Breeam outstanding and plus energy house. These two types of building are progression towards NZEB. Thus, is important to know how many professionals have been involved in these types of building too.

The survey result shown in Fig 5.14 demonstrates in the category of greater than five projects 6 professionals have been involved in Breeam outstanding whereas only 3 professionals were involved in Plus energy house and 2 professionals involved NZEB. In the category of fewer than 5 projects around 41 professionals were involved in Breeam, 23 professionals are involved in each plus energy house and NZEB. Furthermore, around 73 professional states, they have not been involved in any NZEB or plus energy house.

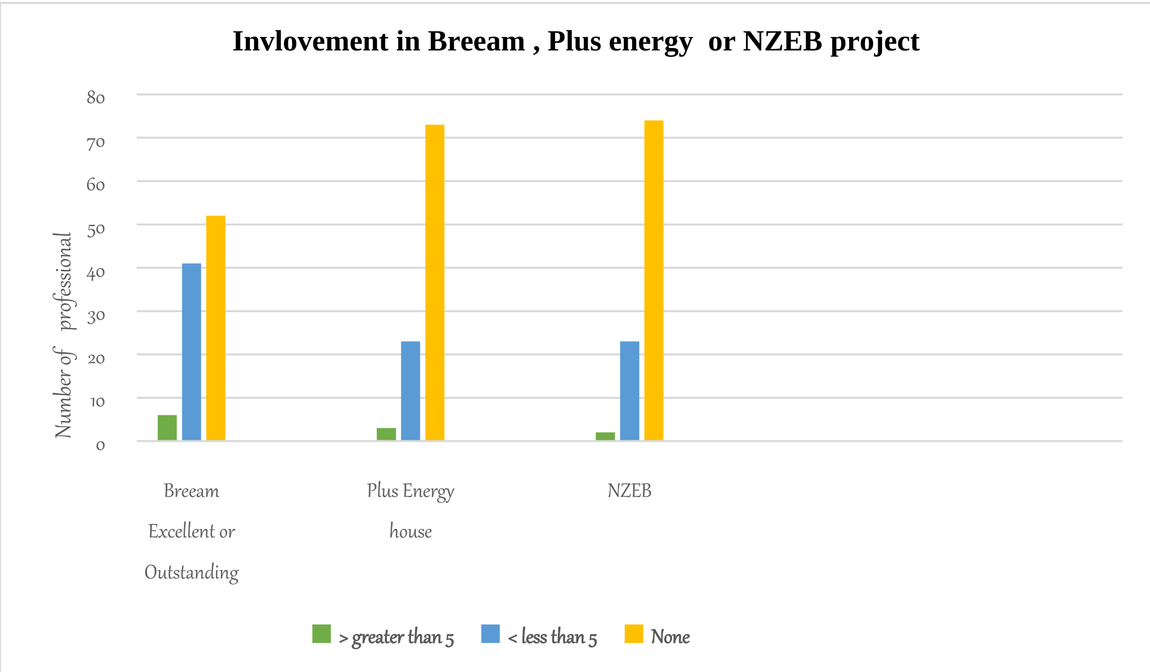

Fig. 5.14: Number of Professional involved in Breeam excellent or outstanding, plus energy house and NZEB.

5.2.8 Question 8 – Enova funding for NZEB

Question 8 is about the opinion of the professional about Enova Funding programme promoting NZEB.

NZEB is costly so it needs government support to increase its market uptake. The Norwegian government support energy-efficient houses and NZEB through Enova funding program (Enova SF). It is explained briefly in section 4.2.6 of Document Analysis.

The survey result in Fig 5.15 illustrates 52% of professional describes no financial support for NZEB whereas 48% of them feels Enova funding schemes supports NZEB.

Moreover, Fig 5.16 describes the opinion about Enova financial support by each category. About 22 Architect, 6 Energy advisor and 7 Kommune professionals feel the Enova funding programmes promote NZEB whereas as 8 construction company, 7 housing cooperative and 6 solar company professionals says there is no financial support from Enova.

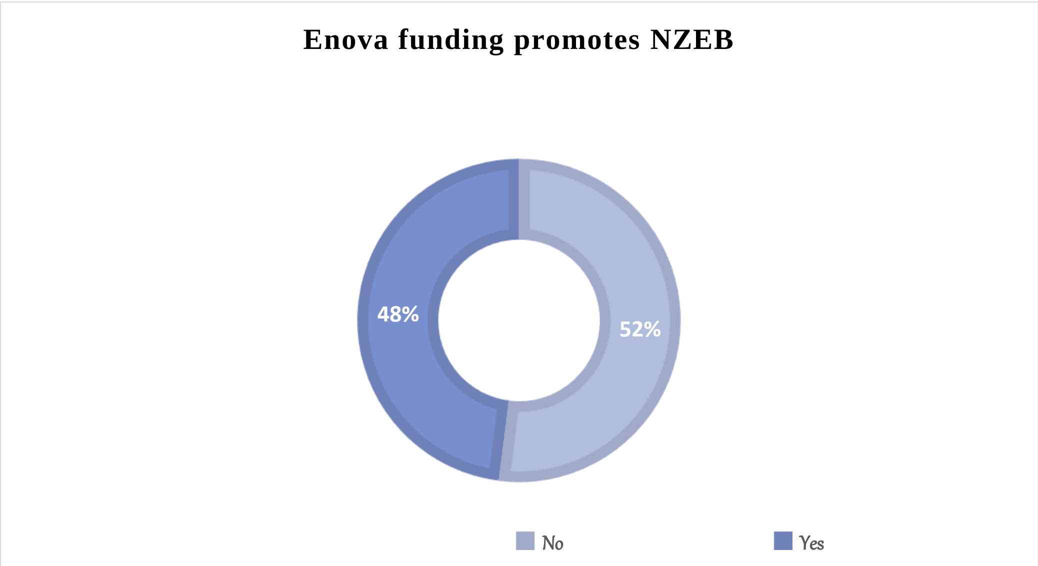

Fig. 5.15: Opinion of professional about support from Enova funding for NZEB.

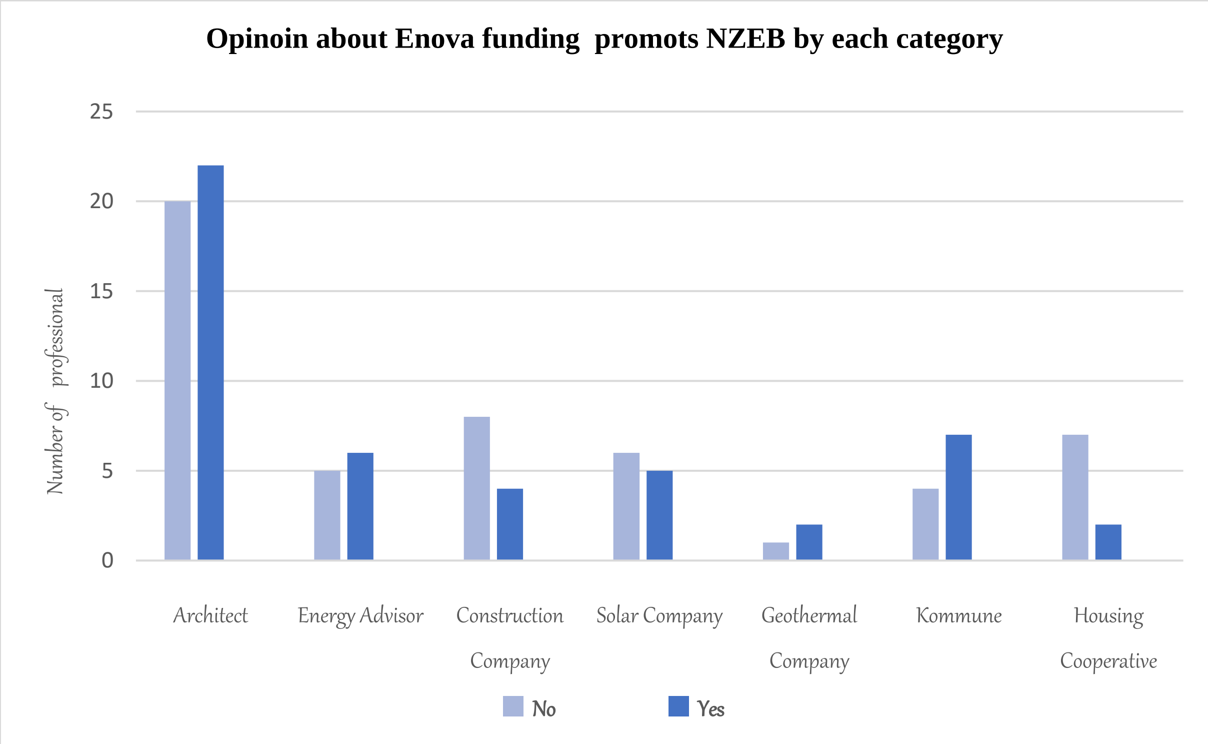

Fig. 5.16: Opinion on support by Enova funding for NZEB from each category

5.2.9 Question 9- Category of Professional

Question 9 is the last question of the survey; it is asked to know the respondent category. To know the preparedness of building sector towards NZEB from December 2020 it is important to know the readiness by each category as each category contributes differently in different phases of building construction. It is also helpful in knowing the interest of each category towards NZEB. The professionals are categorised in seven categories architect, energy advisor, construction company, solar company, geothermal company, housing cooperative and Kommune as described in section 2.2.3 of research method.

Although, the survey was sent to 300 professionals only 99 of them responded. The survey results shown in Fig 5.17 illustrates the percentage of respondents by each category. The overall survey 43% architect,11% energy advisor,12 % construction company,9 % housing cooperative, 11% Kommune, 11% solar company and 3% geothermal company professionals responded.

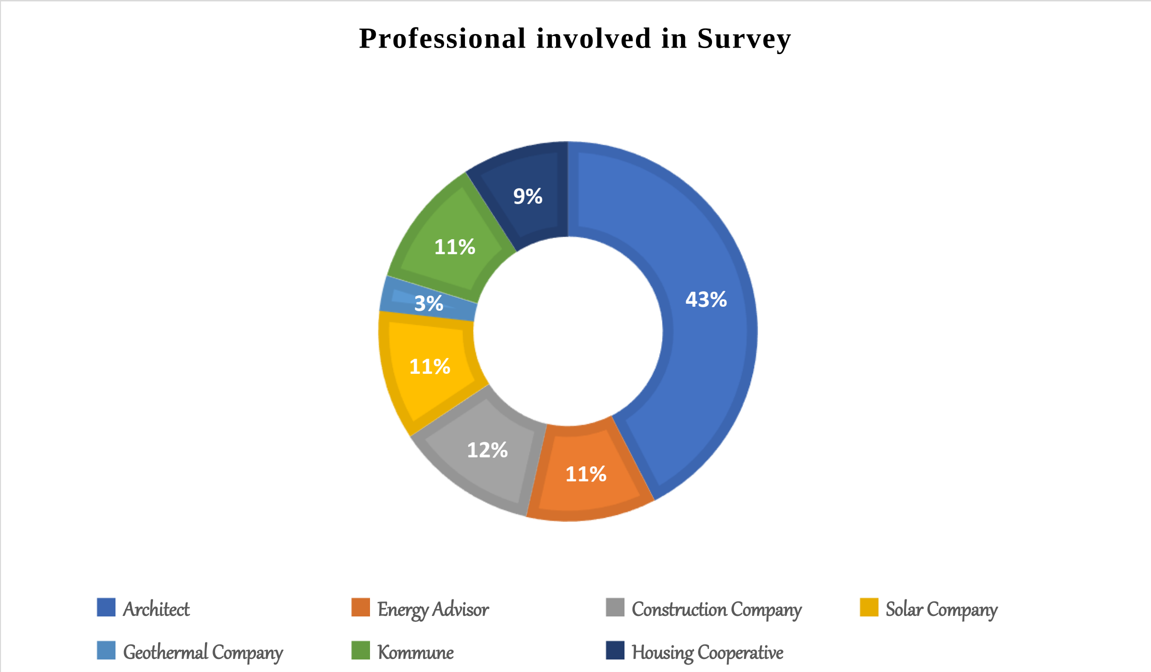

Fig. 5.17: Percentage of professional involved in the survey from each category.

5.3 Findings

The result of the online survey demonstrates important findings on the technical know-how and economical concerns of professionals in Norwegian companies and institutions towards NZEB. The finding is summarised based on the category of each professional to have a better understanding of the status of NZEB by profession.

Response from Architects:

42 architects participated in survey contributing to the highest participation of 43 % in the survey. 50% of them were aware of the implementation of NZEB from December 2020, 80% of them used combined active and passive strategies in their project for energy efficiency, 42% of the architect has used solar PV for electricity generation. This reveals solar PV is widely used by the architect. Although for the generation of thermal energy 30 to 31% of architect used geothermal and heat pump, only 4% of them used solar thermal. This signifies for space heating and domestic hot water heat pump is the preferred solution by the architect.

Nearly 38% have necessary competence for integrating with solar technology (solar PV) and 29% have competence for geothermal technology in a future project. The investment cost is one of the major criteria in opting renewable technology followed by financial incentives and availability in the market. 52% of the architect agreed that Enova funding schemes promote NZEB. About 57% of the architects have worked on Breeam excellent or outstanding project, however, only 19 % of architects have worked on the NZEB project.

The study shows Breeam certification is better known among architect than NZEB and they are better equipped for solar technology in future.

Response from Energy Advisor:

11 energy advisors participated in survey contributing to 11% of the survey. Around 55% of them were aware of the EPBD directive for the implementation of NZEB from 2021. 90% of them used combined strategy in their project, 81% of the energy advisor used renewable technology in the generation of electricity and thermal generation .72% of them used solar PV for the generation of electricity. 81% of them have competence in integrating with renewables technology however survey found energy advisor is more competent with geothermal technology. While selecting renewable technology investment cost, financial incentives and availability in the market were the main issues. Nearly 72% of them have worked with Breeam outstanding and only 45% of them have worked with NZEB. 55% of them agreed that Enova funding support NZEB.

The response of the energy advisor shows they are better prepared for the integration of renewable technology and NZEB.

Response from Construction Company:

12 professionals from construction company participated in the survey adding 12 % to the overall survey. Nearly 50 % of them knows about Nearly zero energy building implementation from December 2020, 58% of them used combined active and passive strategies in projects, 58 % of them have used solar PV for the generation of electricity while 58% of them used heat pumps for the generation of thermal energy. Moreover, 42% of them have the necessary competence to integrate with geothermal technology in the future project though maintenance cost and financial incentives are the major concerns. Only 33% of construction company

professional has worked with Breeam outstanding and 8% of them have done NZEB. 33% of professional stated Enova is supporting NZEB.

The finding shows more than half of professional in construction company are unaware of energy efficiency strategies and not prepared for integration with renewable technology thus seems unprepared for NZEB.

Response from Housing Cooperative:

9 professionals from housing cooperative participated in survey contributing 9 % to survey. 33% of them know about EU directive 31/2010 implementation from December 2020 in Norway. 88% used a combined strategy for energy efficiency in the project, 22% used solar PV/T for electricity generation and 77% used heat pump for thermal energy generation. For a future project, nearly 44% are prepared and have competence for geothermal technology integration. The main concern in selecting renewable options is investment cost, operational problem, and financial incentives. 22% of professionals agreed that Enova supports NZEB. In the housing cooperative, only 11% of professionals have worked on Breeam and none has worked with NZEB.

The housing cooperative has not worked with the NZEB project, this shows the unawareness of the professional towards NZEB.

Response from Kommune:

There were 11 professionals from Kommune in survey adding 11% to survey. Nearly 55% of them knows about the implementation of NZEB from December 2020, 54% used combined strategies for energy efficiency of buildings, 18% have used solar PV for electricity generation in their projects and 36% used geothermal for the generation of thermal energy, In Kommune nearly 63% told that they don’t have necessary competence for integrating with renewables whereas 27% have competence for geothermal technology. While selecting renewable technology investment cost, financial incentives and maintenance cost are the main criteria for professional. 64% of them agreed that Enova supports NZEB.

The survey shows that only 18% of them have worked with Breeam outstanding and no one has experience with NZEB project.

Response from Solar Companies

11 professionals from solar companies participated in the survey contributing 11% of the survey. Only 9% of the professional knows about the implementation of the EU directive on NZEB. 50% have used combine strategies for energy efficiency of buildings, for the generation of electricity 91% used solar PV and 9% have used solar PV/T in their project. about 50% of them have not used renewable technology for the generation of thermal energy in their project. Being a solar company, they have necessary competence for solar technology in future projects although financial incentives, investment cost and maintenance are major obstruction. 45% told Enova funding support NZEB.

Although the majority of professional in solar companies are unaware of NZEB implementation directive from 2021 nearly 45 % of them have worked with NZEB projects. This shows they know the NZEB concept but are unaware of regulations.

Response from geothermal companies

There were 3 respondents from geothermal company comprising 3% of the survey. 33% of them know about the implementation of NZEB from December 2020. 33 % used a combined strategy for energy efficiency. 67 % have used geothermal for the generation of thermal energy in past and are prepared for a future project but are worried over investment cost, financial incentives, and availability in the market. 67% agreed about Enova supporting NZEB. The survey revealed that geothermal companies are also equipped with solar thermal technology.

The results show 66% of professional in geothermal companies have worked on NZEB projects

Summary of the responses is presented in Table 5.1 showing the percentage of technical competency and selection criteria for NZEB by each category based on the online survey results. The table highlights the % of professional who affirmed to the directive for the implementation of NZEB in Norway, % of them using combined active and passive technology, % of them using solar PV, solar PV/T, solar thermal, geothermal, heat pump, % of them having competence in future for geothermal or solar technology, % of professionals having different criteria for selection of renewables, % of them involved in BREEAM outstanding, plus energy house and NZEB as well as % of professional affirming ENOVA support.

Table 5-1: Summary of the technical competency possessed by professionals for NZEB and the selection criteria for renewable technology in percentage by each category based on their participation in the survey as well as their involvement in BREEAM, plus energy, NZEB.

	Architect	Energy Advisor	Construction Company	Housing Cooperative	Kommune	Solar Companies	Geothermal companies
Participation in Survey	43%	11%	12%	9%	11%	11%	3%
Affirmative with Directive	50%	55%	50%	33%	55%	9%	33%
Combined Passive and Active Strategies	81%	91%	58%	88%	54%	54%	33%
Solar PV	43%	73%	58%	0%	18%	91%	33%
Solar PV/T	5%	9%	8%	22%	9%	9%	33%
Heat Pump	33%	55%	58%	78%	9%	18%	0 %
Geothermal	31%	27%	33%	11%	36%	9%	66%
Solar Thermal	4%	0%	0%	11%	9%	18%	33%
Future Competence for Solar	38%	36%	8%	0%	9%	100%	33%
Future Competence for geothermal	29%	46%	41%	44%	27%	0%	67%
Criteria for renewable Investment cost	88%	100%	92%	100%	100%	92%	64%
Criteria for renewable Financial incentives	48%	21%	12%	17%	14%	21%	5%
Criteria for renewable maintenance cost	38%	10%	12%	7%	21%	7%	0%
BREEAM outstanding	57%	72%	33%	11%	18%	45%	100%
Plus, energy house	26%	36%	33%	0%	9%	36%	66%
NZEB	19%	45%	0%	0%	0%	46%	66%
Affirmative Enova Support	52%	54%	33%	2%	63%	45%	66%

Different professionals are equipped differently about NZEB, but the common finding is they are not prepared for 2021. Among architect solar PV are preferred whereas all other professionals have competence for geothermal and heat pumps. Breeam outstanding appears to more established than other energy-efficient building types. The energy advisor, solar companies and geothermal companies have been more involved in NZEB projects while housing cooperative, construction company and Kommune are unaware of this technology. The investment cost is a major consideration for renewable technology thus needing financial incentives for NZEB. Housing cooperative and construction company seems worried about Enova funding schemes for NZEB.

Chapter 6 Discussion

This chapter is divided into three sections. The first section discusses the finding of the three methods used in the study to know about the readiness of the Norwegian building sector for NZEB from 2021 and challenges in integration with renewables. In this section findings from the case study, document analysis and the online survey are grouped in five categories for better understanding of legislative, technical, financial, professional, and informative roles in NZEB in Norway. The second section concisely answers the research question since the underlying facts have already been answered in the previous section 6.1 in detail. The third section is the evaluation of the study and its limitation.

6.1 Discussion on the findings

This section has a holistic approach to all the research questions and this study. The main discussion that has emerged based on the finding from chapter 4 and chapter 5 about Norwegian struggle in implementation of NZEB from December 2020 is divided into 5 categories. These categories are derived as the convergence for answering the three research questions about government status of implementation, facilitation by legislation and competence of Norwegian professional for NZEB. These five categories are Legislation, Technology, Economic Cost, Diverse interest of professional and Lack of information. Herein, all these categories are discussed in detail.

6.1.1 Legislation

The EPBD recast is not yet implemented in Norway. However, the case study analysis in section 4.1 found that many of the articles have been adapted in Norwegian building codes and national standards with modification in relation to final energy (Toleikyte et al., 2016). The adaption of these articles shows the willingness of government for implementing EPBD recast and the same was confirmed by Sindre Samsing and Tom Andreas Mathiasson in the email correspondence. In 2017, Dibk submitted its first report on a road map towards NZEB and its suggestion for a national definition of NZEB to the ministries yet nothing has happened (Tor Brekke et al., 2018).In the absence of NZEB definition in legislation, the future of NZEB from 2021 seems ambiguous. As described in the theoretical framework section 3.1 about the need for a national definition of NZEB for abiding the EPBD recast directive, Norway needs a national definition of NZEB and proper legislation to build NZEB from 2021.

In Norway, the Ministry of Local Government and Modernisation together with the Ministry of Petroleum and Energy is responsible for EPBD recast directive. Additionally, it was clarified by Sindre Samsing in the email correspondence emphasising that main responsibility for implementation of directive lies with Ministry of Petroleum and Energy,

The document analysis about the TEK series progression found national building codes are updated to be technically aligned with the requirement of EPBD recast. Every amendment of TEK 07, TEK 10, TEK 17 has placed stringent energy efficiency requirement for the new building which is the main prerequisite for NZEB. This shows that the Ministry of Local Government and Modernisation has implemented those articles that directly concern the building through modification in TEK.

Though the Ministry of Local Government and Modernisation is focused on the energy efficiency of the building and has gradually modified the building codes to TEK 17 making passive standard mandatory for new buildings. Nearly ten years have passed since EPBD recast directive came despite the commitment by government in 2012 and 2015 (Miljødepartementet, 2012; OED, 2015; REGIONALDEPARTEMENT, 2012) for NZEB from 2020 nothing has happened about implementation it is a puzzling paradox. This was not clarified by ministries as Sindre Samsing stated “ I can't comment on the Governments internal discussions and evaluations of the directive” (personal correspondence, May 07, 2020) and Tom Andreas Mathiasson emphasis on the certainty of implementation of the directive with adaptation but did not specify when.

The Ministry of Petroleum and Energy traditionally focus on the cost-effectiveness of the policy in energy filed (Haldorsen, 2016). The implementation of NZEB will be costly. Since both theses ministry involved have fragmented focus towards directive thus delaying the implementation (Haldorsen, 2016).

It not only implementation of EPBD recast in EEA treaty that Norway needs, As suggested by Shady (2018) national authorities need national strategies to create an infrastructure for NZEB implementation to overcome the NZEB market uptake barrier, Norway needs strong institutional infrastructure for NZEB in future.

6.1.2 Technology

Norway has been working with the EU for technological development of NZEB. The Norwegian technical institute NTNU, SINTEF Building Infrastructure, ZEB research centre, ZEN research centre and Future built have been constantly working for innovative NZEB solutions (Stene et al., 2018). The pilot projects described in document analysis indicates Norway technical feasibility of NZEB for different building types. Additionally, the finding of the online survey on involvement in Breeam outstanding, plus energy house and NZEB projects demonstrate that the technological solution to construct NZEB exist in Norway. Although the professionals are more proficient with Breeam Outstanding as compared to plus energy house and NZEB. The survey result shows that only one-fourth of the professionals were involved in NZEB.

In the theoretical framework section, I have described the three prerequisites for NZEB design are passive strategies, energy efficiency strategies and renewable energy strategies. Survey result found that nearly 75% of the professional are using both passive strategies and energy efficiency strategies in their projects thus fulfilling the two requirements of NZEB design. These two strategies are also well defined in TEK 17 and NS 3700 and NS 3701. However, the third requirement for NZEB renewable energy strategy is not very clarified in building codes, there is no special requirement for smaller building less than 1000m². According to TEK 17 when renewable electricity is produced on the property (more than 20 kWh/m2 per year) specific energy limit can exceed by 10kWh / m2 per year. In contrary to Germany where there is a requirement of specific percentage share of renewable energy depending on the type of renewable source such as solar energy by 15%, geothermal and environmental energy (heat pumps) by 50% (Schimschar, Blok, Boermans, & Hermelink, 2011). Since there is no specification about renewables in Norwegian building codes the competence and preparedness among the professional for the renewables is still limited.

It is not only the building code, another important factor influencing renewable energy integration with the building is hydropower. The main source for the generation of electricity in Norway is hydropower nearly 92.3% of household electricity need is derived from it, and the rest small percentage by thermal power and wind power (Statistics Norway ,2020). According to Hagos, Gebremedhin, and Zethraeus (2014) "the electricity and heat sectors in Norway are 'monopolized' by hydroelectricity" (p. 41). Since it produces cheap electricity and is considered clean energy it has a strong influence on shaping Norwegian buildings (Sartori et al., 2009).

The impact of the indistinct building code for renewables and cheap electricity available was felt in the survey results showing nearly 50% of the professionals not using renewable energy technology for electricity generation in the projects and 25% of professional are not using renewables in thermal generation.

Presently few professional are integrating renewables with building, among those few professional solar PV seems to be recognized technology for electricity generation by architect, energy advisor, construction company and solar company and for thermal generation heat pump and geothermal technology are preferred choice among the professionals.

There is a need for clear dedication to increasing the share of onsite renewable energy technology in the building sector to construct NZEB and should be translated to building codes as a legal requirement in Norway.

6.1. 3 Economic cost

NZEB involves construction cost of building as well as renewable energy system cost. These two costs are interconnected, a more energy-efficient building will require smaller renewable energy system thus lowering the cost for renewable investment. Even with the reduction in the cost of renewables, there is a significant investment required for the purchase of a renewable energy system for NZEB. which needs a financial tool for procurement and grid parity to promote NZEB (Hootman, 2012).

The survey showed nearly all the professionals are concerned with investment cost for integrating renewables with the building. Lack of financial incentives and maintenance cost for renewable technology was also considered a barrier to the growth of building-integrated renewables.

To overcome cost issue, Enova provides financial support to individual and company with the ambitious innovative technical solution better than standard building code in the construction of the new building as well as for renovation. The survey revealed that nearly 52% of the professional thinks that Enova does not provide enough support for the growth of NZEB and renewables. The percentage was even more nearly 70% in a housing cooperative and construction company that affirmed the lack of incentives.

The study found that Enova innovation programme promotes NZEB only for demonstration projects. This is contrary to Germany KfW Renewable energy programme (Yildiz, 2014). There is a need for financial incentives to orient the building industry toward NZEB, despite supporting onsite renewable recently Enova has reduced the financial support of Solar PV from 10.000 kroner to 5.000 kroner as well as the subsidy rate for own electricity generation from 10.000 to 7.500 kroner from June 2020 (Enova, 2020). Enova's reduction in support schemes for renewable might be in response to the lower market price of solar PV but lowering the energy tariffs for PV generation is unappealing to become energy-producing building. Thus, hindering the growth of NZEB.

6 .1.4 Diverse interest of professional

Design, construction, and operation of NZEB require the integrated focus of multidisciplinary team involved as described in theoretical framework section 3.3.3. NZEB requires one team approach "if the builder is focused the cost, time, and quality triangle the architect might be focused on the architectural quality and innovation of design" thus encountering challenges (Shady, 2018, p. 96). An integrated process delivery will make NZEB possible.

But there exist fragmented interest of among professional involved as mentioned by Lindkvist, Karlsson, Sørnes, and Wyckmans (2014) " nZEB is characterized by a complex supply chain with various players and competing interests influenced by legislation" (p. 202). The finding from the survey result reveals the same.

The survey result finds the diverse interest of professional involved that affect the status of NZEB. The energy advisor, solar company and the geothermal company see NZEB as a way of increasing their market potential and providing the new innovative and competitive solution. Whereas housing cooperative and construction company who are directly involved in constructing the new building are happy following the minimum building standard. These two sectors mainly focus on the cost part of the building construction and are not concerned in involvement with renewables energy technologies. The fragmented interested of stakeholders in the building sector was highlighted by Lindkvist et al. (2014) "in Norway there is a mix of low and high energy ambitions which is a barrier for nZEB as "contractors are very likely to pick the low hanging fruit. The problem is the projects won't be ambitious enough or ambitious as is needed" (p. 202). The survey found the fragment interest of various stakeholder policymakers, architect, energy consultant, energy companies, housing cooperatives, construction company and Kommune involved, instead of a holistic approach needed for energy-neutral building.

Architects have a bigger responsibility as compared to other professionals. They are responsible for designing buildings and shaping our cities. NZEB is a new direction in architecture too, the architect needs to rethink the way the building is designed and the way PV is integrated into buildings (Scognamiglio & Røstvik, 2012). The survey found the architects are equipped with traditional passive strategies and energy efficiency measures. But only 66% of the architects are familiar with building-integrated renewable technology.

6. 1. 5 Lack of Information

There is no updated by the government after 2015 about NZEB as described in case study analysis. The survey result of 45% professional having the understanding that NZEB is implemented in Norway from December 2020 illustrated the absence of information about the current stand of NZEB by government. We are approaching December 2020 in few months yet there is no information on NZEB.

Technology for NZEB exist in Norway but the technical knowledge is not disseminated among all the categories involved in the building sector. The survey result showed the housing cooperative, construction company and Kommune lack knowledge and competence for NZEB.

There is a need for information distribution either by seminars, vocational education, or professional training to all professional for building NZEB in future. By empowering the multi-disciplinary professional we can enable the transition to NZEB in future.

6.2 Answering research questions

This section presents the concise answers to the research question based on the detailed discussion in section 6.1.

Q1 How has the Norwegian government dealt with EPBD recast directive about NZEB so far and what is the current status?

To answer this question, we did the in-depth study in Chapter 4 about the EPBD recast directive, all the government white papers related to NZEB, national documents as well as email correspondence with the ministries involved for implementation of the directive in Norway. This is also discussed in detail section 6.1.1 on legislation. The study found some interesting facts about the willingness of the government for the implementation of NZEB in Norway without bothering for the deadline. So far, the Norwegian government has done some modification in building standard as per the directive and huge investment in research centres for NZEB pilot projects. But that is not enough to align with the implementation of NZEB form December 2020. All the email correspondence shows the absence of effort in the last 10 years for implementing the EBPD recast directive in EEA agreement. We are in 2020, yet the government has no clarification about NZEB implementation, authorities are still working on adaptions to make it EEA relevance. This is the paradoxical stand of the government for NZEB.

The current status is the EBPD recast is not yet implemented in Norway, so NZEB will not be enforced from December 2020.

Q 2 Is the current Norwegian legislation facilitating NZEB?

For answering this question, Norwegian building documents have been analysed in detail in Document analysis section 4.2 and discussed in legislation and technical section 6.1.1 and 6.1.2.

The study found that there is a series of modification in building codes after the EPBD recast directive was launched. In recent years from 2010 to 2017 building codes have been revised several times until TEK 17. There is a special focus on the energy efficiency of building in each revision. The energy-efficiency regulation for building in TEK 17 are very stringent, in addition to obligatory passive house standard of NS 3700 (residential) and NS 3701 (non-residential). Thus, complying with the most of energy efficiency requirement of EBPD recast directive which is the main prerequisite for NZEB design. However, TEK 17 is indistinct about renewable energy technology for smaller dwelling less than 1000m².

The requirement directly related to the building has been modified by Dibk but code is not specific about renewable technology. Thus, we can conclude the building codes partially facilitated NZEB.

Q 3 To what extend are Norwegian companies and institutions ready to implement the NZEB directive for new buildings from 31st Dec 2020.

To answer this question, the online survey was done as described in the Chapter 5 survey analysis. The readiness and issues of professional in various companies are discussed in detail from section 6.1.2 to 6.1.5 on technology, economic cost, the diverse interest of professionals and lack of information for implementation NZEB from 31st December 2020.

Although currently, the legislation for NZEB is not in place. The study found that there exists technology for NZEB in Norway but is not disseminated among all the professionals. Nearly one-fourth of the professional has been involved in NZEB in the past. Majority of them involved in NZEB were energy advisors, solar companies, geothermal companies and architects, while construction companies, housing cooperative and Kommune seem ignorant.

The survey revealed the technological and economical barriers in the integration of renewables with the building. The diverse interest of professionals and lack of information is also a hurdle in achieving NZEB as discussed in detail in the discussion section 6.1.4 and 6.1.5.

Thus, we can conclude that only a few professionals who have been involved in NZEB in past seems to be prepared and rest of the majority in the building industry needs strong legislation, technology, financial support and information for NZEB implementation in the future. With the majority of professional having limited competence, companies and institutions are not ready for NZEB yet.

By answering the three additional research question, the study found the answer to our main research question. As described in section 1.2 the ‘Norwegian building sector’ considered for this study comprises of ministries, national authorities, Dibk, professionals in various companies and Enova SF.

How far is the Norwegian Building sector equipped for implementation of the Energy Performance of Building Directive, 2010/31/EU for all new buildings after 2020 and its challenges in integration with renewable energy technology?

Government’s ambiguity, the national authority partial facilitation of legislation and limited competence among professional for NZEB describes the plight of the Norwegian building sector. Though there exists technology for NZEB design due to lack of legislation, it is not enforced on all the professionals in the building sector. Economic cost also plays a major role in the decision for NZEB in the project. The legislative, technical, economical concerns for integrating with renewable technology together with the diverse interest of professionals and lack of information from the government are hindering the growth of NZEB in Norway. In the absence of proper legislation for the implementation of NZEB in Norway. The future of NZEB is blurred.

The study concludes that the Norwegian building sector is not prepared for implementation form 2021 it requires more time.

6.3 Evaluation of study

The study has produced interesting findings of Status of NZEB in Norway. The case study on EBPD recast transposition in Norway, document analysis and online survey have helped to understand the NZEB in the Norwegian context. The concept of NZEB is not widespread in Norway.

The empirical work for the study was the email correspondence with national authorities and the online survey with the senior professional in the different category of the building sector. Analysis of the finding was done through a framework based on the results from the case study, document analysis and the questionnaire in the online survey. The key findings have been categorised in discussion section 6.1 for better clarity and understanding of Norwegian building industry struggle for implementation of NZEB from December 2020. The concise answer to the research questions in section 6.2 is done to send a clear response to the study.

The methodical triangulation approach for the study has helped in exploring the main research question with three different methodological approach – case study, document analysis and online survey thereby converging and complementing the result. Thus, increasing the validity of the conclusion. The case study and document analysis give an understanding of the present legislation for NZEB and the ambiguity of the government for the implementation of NZEB form 2021. The online survey revealed a lack of competence of the professional for the implementation of NZEB.

The research, however, has some limitation. Due to COVID 19, pandemic there was not many survey responses as required for better insight about the challenges of the professional in implementing NZEB from 2021. The communication with government authorities was a very time-consuming process due to time constraint of the study the research could not find when NZEB will be implemented in Norway. Furthermore, there were limited research studies on the topic of NZEB in the Norwegian context since NZEB concept is new in Norway.

Chapter 7 Conclusion

In order to comply with the Paris Agreement, Norway is committed to a reduction target of greenhouse gases by at least 50 per cent and towards 55 per cent compared to 1990 levels by 2030 (KLD, 2020). This reduction target is huge. Since the building sector contributes to 36 % of the emission in Europe and Norway, NZEB can play a significant role in the reduction of greenhouse gases. EPBD recast directive for NZEB for the new building from December 2020 will play an important role in creating energy-efficient carbon-free building sector.

This thesis has examined the extent to which Norway is prepared for the implementation of NZEB until now. Based on the triangulation approach with the case study, document analysis and online survey the study found the government's current stand on NZEB, the issue with reinforcement of building codes and readiness of Norwegian building sector for NZEB implementation from December 2020 and thus, concludes that

There is no government policy in place yet to implement NZEB from 2020. Though there exist willingness for implementation there is no effort for inclusion of EPBD recast directive in the EEA treaty till now. Without clear legislation building codes are partially facilitating the NZEB or energy-efficient buildings. There exists technical barrier, financial barrier, information barrier and the fragmented interest of professional impeding the growth of NZEB. Furthermore, ambiguous stand by the government has created a dilemma among professionals thus limiting the competency of companies and institutions for NZEB. Consequently, the Norwegian building sector is not prepared for forthcoming regulation of EPBD recast for NZEB from December 2020. The future of NZEB implementation from 2021 in Norway is gloomy.

This study provides the reader with an insight into Net-zero energy building and its significance in the Norwegian building sector. By understanding the present act of ministries, national authority, and various professionals we can figure out the struggle the NZEB is facing for implementation. There is a need for drastic legislative changes and national strategies for the future of NZEB in Norway.

There are a few months left till December 2020 the present work calls for further research in when EPBD recast will be implemented in Norway and what will be a national strategy for implementing NZEB.

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Appendix 1: Survey Questionnaire from Google Form

This appendix provides the questionnaire that was made to gather the opinion of the professionals involved in the building sector.

Status of Nearly Zero Energy Buildings (NZEB) in Norway

This questionnaire has been developed for the fulfilment of Master thesis in City and Regional Planning at the University of Stavanger

I want to use this questionnaire as a tool for knowing how prepared the Norwegian building sector is for implementing the Energy Performance of Building Directive, 2010/31/EU for NZEB in Norway for new buildings from the 31st December 2020 and what are the challenges in integrating to renewable energy technology.

It will take approximately 2-4 minutes to complete.
The questionnaire is completely anonymous, and the results will be used exclusively for academic purposes.

Thank you for participating!

1. Are you aware that all new buildings even in Norway (EEA member) built from December 2020 according to the EU Directive 31/2010 shall be Nearly Zero Energy Buildings?

   Mark only one oval.

   ◯ Yes

   ◯ No

2. To realise the energy efficiency of a building (NZEB) in Norway, which strategy is mainly followed: Passive Strategies (NS 3700: 2013 for residential buildings / NS 3701: 2012 for non-residential buildings) or is combined with Active Strategies (Solar PV, solar thermal system, geothermal system)

   Mark only one oval.

   ◯ Passive Strategies

   ◯ Combined Passive and active strategies

3. Has there been an increase in renewable energy technology for Electricity Generation like Solar PV, Photovoltaic thermal hybrid solar collectors (PV/T) in the project you have been working in past

Mark only one oval.

- Solar PV
- Solar PV/T
- No

4. Has there been an increase in renewable energy technology for Thermal energy Generation (thermal heat) like Solar thermal, geothermal, heat pumps in the project you have been working in past

Mark only one oval.

- solar thermal
- geothermal
- heat pumps
- No

5. Are you prepared and have the necessary competence for integrating solar energy technology or Geothermal technology?

Mark only one oval.

- Solar techonology
- Geothermal techonlogy
- No

6. What are in your opinion the three most used criteria in the selection of building integrated renewable energy technology in Norway?

Check all that apply.

- [ ] Investment Cost
- [ ] Maintenance cost
- [ ] Operational problems
- [ ] Availability in Market
- [ ] Financial Incentives

7. How many BREEAM Excellent or Outstanding, plus energy or NZEB have you been involved in?

Mark only one oval per row.

	None	Less than < 5	greater than > 5
Breeam Excellent or Outstanding	◯	◯	◯
Plus Energy	◯	◯	◯
NZEB	◯	◯	◯

8. In your opinion do Enova Funding programme promotes NZEB?

Mark only one oval.

◯ Yes

◯ No

9. To analyze the status of NZEB in Norway, the interviewees are grouped so it's important to know which sector you are working in?

Mark only one oval.

- ◯ Architect
- ◯ Energy Advisor
- ◯ Construction Company
- ◯ Housing cooperative
- ◯ Solar companies
- ◯ Geothermal companies
- ◯ Kommune
- ◯ Statsbygg
- ◯ DIBK
