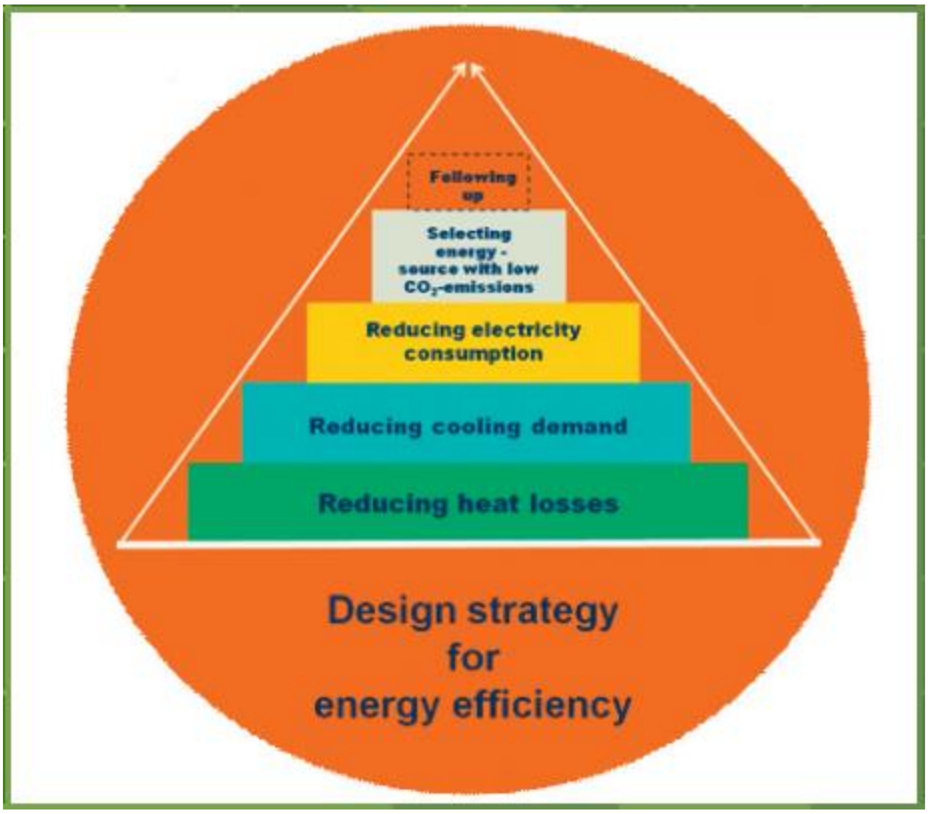
A Study of Energy Efficiency in the old residential houses in Norway.



Master Thesis

By

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ABSTRACT

The rapid and predicted warming of global average temperature to 1.5^0 C presents a challenge for the capability of the current and impending generations to ensure their necessities. This is extensively owing to industrialization that has impacted an environmental footprint globally. The ecological imbalances are fuelled by the synergies of high energy intensity, high energy consumption in all sectors (such as industry, transport, and buildings) of humans' daily life, and upward econometrics gross domestic product (GDP). Among all the energy-intensive sectors, the building is one of the biggest-consumed sectors of energy globally. Most of the stakeholders around the world are in the fight to reduce the emissions from the commercial, public, and residential buildings. Concurrently the Norwegian government has been implemented numerous policies to scale EE up in the residential buildings along with scaling the emission down to build the emission-neutral society by 2050, although the improvement level of EE in the residential buildings is not satisfactory. Therefore, the aim and purpose of this thesis are to identify the key barriers and presents possible solutions to improve the EE level in the old residential buildings in Norway. The thesis abductively analyses the barriers of EE through a qualitative thematic analysis of the key barriers and possible solutions. The overall objective of the thesis is to map the EE gap in the old residential buildings in Norway, which leads to creating the hindrances in the process of EE up-gradation in the existing building stock. The findings for the sluggish nature of EE up-gradation in the old building stock in Norway, are the insignificant financial assistance, lack of necessary information and cheap energy to be more important, and other common constraints as well.

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ABBREVIATIONS

CO_2 – CARBON DIOXIDE

EC – EUROPEAN COMMISSION

EEA – EUROPEAN ECONOMIC AREA

EE – ENERGY EFFICIENCY

EED – ENERGY EFFICIENCY DIRECTIVE

EETS – ENERGY EFFICIENT TECHNOLOGIES

EPBD – ENERGY PERFORMANCE BUILDING DIRECTIVE

ETS – ENERGY TRADING SYSTEM

EU – EUROPEAN UNION

FKR – FUNCTIONAL KEY RESPONDENT

GHGS – GREENHOUSE GASES

HVAC – HEATING, VENTILATION AND AIR CONDITION

IEA – INTERNATIONAL ENERGY AGENCY

IPCC – INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

LED – LIGHT EMITTING DIODE

Mtoe – MILLION TONNES OF EQUIVALENT

NZEB – NEARLY ZERO ENERGY BUILDING

KBN – KOMMUNEL BANKING

KWH – KILLOWATT-HOUR

PA – PASCAL

PCMS – PHASE CHANGE MATERIALS

PV – PHOTOVOLTAIC

SDGS – SUSTAINABLE DEVELOPMENT GOALS

SSB – STATISTISK SENTRALBYRÅ

TEK – TEKNICHAL REGULATION

TWh – TERAWATT-HOURS

VAC – VENTILATION, AIR CONDITIONING AND COOLING

1 Introduction

At present, due to the exponential advancement of science and technology in the world, which is led to variegated significant drawbacks, such as environmental contamination, energy shortages and most noticeably climate change[1] (Guo, Jiang, & Pang, 2019; Tian, Feng, Li, & Xu, 2019). Moreover, along with the global energy consumption and population multiplication, climate change is occurred by the extreme dependence of humankind's on fossil fuels to ensure the energy demand, which leads to dishevel the ecological balance through the discharging of greenhouse gases (GHGs)[2] (Moran, O'Connell, & Goggins, 2020). To more precisely, Anthropogenic activities are the key causes to increase the global emission, which impacts the whole balance of radiative energy, raising the average surface temperature and occurring many footprints on the global climate system (Tettey, Dodoo, & Gustavsson, 2019). The Intergovernmental Panel on Climate Change (IPCC) report recommends the rise in GHGs in the atmosphere is reshaping the world's climate[3] (Moran et al., 2020). And Climate change is being forecasted to impact adversely on the world unless appropriate alleviation measures are put into practice[4] (Moran et al., 2020). The Intergovernmental Panel on Climate Change (IPCC) also noticed a rise of about 1.0°C temperature globally, since the pre-industrial period because of anthropogenic activities[5] (Chen et al., 2019). They predict that if the ongoing trend carries on, global temperature will grow by an additional 1.5°C in the span of 2030 to 2052 (Chen et al., 2019). Several international agreements have been implemented to approach such a grave issue of climate change including the United Nations Framework Convention on Climate Change Treaty[6], the Kyoto Protocol, and the Paris Agreement (Moran et al., 2020). However, many sectors are responsible for the CO_2 emission, while the building sector is presented, both globally[7] and locally[8], as one of the most key sectors for energy use mitigation (Søraa, Fyhn, & Solli, 2019).

The buildings sector liable to consume about 32-36% of global energy consumption, consuming the equivalent of more than 35,000 TWh of electricity per annum and accounts for

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[1] Cited from(F. Li, Zhang, Liu, Xiao, & Wu, 2018)
[2] Cited from(IPCC, 2014)
[3] Cited from(IPCC, 2014)
[4] Cited from(IPCC, 2014)
[5] Cited from (First, 2019)
[6] Cited from (Secretariat, 1992)
[7] Cited from (Janda & Parag, 2013; Shove & Walker, 2007)
[8] Cited from (Aune, 2007; Solli & Ryghaug, 2014)

40% of total direct and indirect CO_2 emissions (Antony Froggatt, 2020; Bremvåg, Hestnes, & Gustavsen, 2020). 71% of all energy, in Europe, is calculated for space heating of residential buildings alone (Antony Froggatt, 2020). The object of decarbonization of the building sector is to be driven by the extensive renovation project of existing building stock (Antony Froggatt, 2020). And improving the energy performance of the building stock is difficult, more cost-effective, and environmentally friendly than extending capacity in the energy supply system (Bremvåg et al., 2020).

Regarding the buildings in EU, the building sector alone uses about 40% of EU's final energy consumption, simultaneously it is responsible to generate 32% of Carbon Dioxide emissions[9], residential sector comprises around 75% of the building stock and most of them (64%) are detached residents[10] (Bravo, Pardalis, Mahapatra, & Mainali, 2019; Danish, Senjyu, Ibrahimi, Ahmadi, & Howlader, 2019; Dubey & Dodonov, 2019; Hirvonen, Jokisalo, & Kosonen, 2020). To more precisely, the residential sector consumes around 66% of the energy and produces 64% of CO_2 in the buildings in the EU[11] (Y. Li, Kubicki, Guerriero, & Rezgui, 2019). And the energy demand will increase in approaching the future in the housing sector (Coma et al., 2019). Moreover, the building sector has left behind significant environmental impacts Regarding resource consumption, harmful emissions, and generation of waste (Allacker et al., 2019). Existing building stocks (those built on the 1950s and 60s), which presents a potential source to save energy and reduce emissions, will take a longer period for more than 50-100 years in the most developed countries[12], those buildings built before the implementation of current low energy regulation (Dubey & Dodonov, 2019; Fyhn, Søraa, & Solli, 2019; IEA, 2013; Krarti, Dubey, & Howarth, 2019). However, Directive 2012/27/EU emphasizes increasing the investment for the building renovations and has planned to renovate the whole existing building stock by 2050 (Bravo et al., 2019). And on November 2016 the Commission presented an overview to the EE Directive (EED), incorporating a new 30% of EE goal for 2030, along with the approval to present the update to Directive to ensure the new target is fulfilled (Haase, Lolli, & Thunshelle, 2020). The most recent revision of EPBD (2018/844/EU) urges to member states to step forward *"to achieve a highly energy-efficient and decarbonized building stock and to ensure that the long-term renovation strategies deliver the necessary progress towards the transformation of existing buildings into nearly zero-energy buildings, in*

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9 Cited from(Brambilla, Salvalai, Imperadori, & Sesana, 2018; M. M. Liu & Mi, 2017; UNECE, 2018)
10 Cited from(Marina Economidou et al., 2011)
11 Cited from(López-González, López-Ochoa, Las-Heras-Casas, & García-Lozano, 2016)
12 Cited from(Power, 2008)

particular by an increase in deep renovations"(Haase et al., 2020, p. 11). Hence, on one hand, existing technologies offer a big possibility to reduce the energy consumption in the buildings dramatically, but the majority of already-built houses retain the old-fashioned energy-intensive technologies which are the reason for the more energy consumption (Nezhnikova, Papelniuk, & Dudin, 2019). According to the International Energy Agency 2018, it is possible to save 25-40% of direct energy form the housing sector by installing cost-efficient technologies at the national level, while the amount of investment for EE is lower than the rational (Nezhnikova et al., 2019). *"Improving EE is one of the most cost-effective options for meeting growing energy demand in most countries. It contributes to energy security, energy-saving, a better environment, improved quality of life, and economic well-being"*[13] *(Dubey & Dodonov, 2019).*

Accordingly, energy-saving and the reduction of the carbon dioxide emissions are appearing as the most burning issue in the table of discussion among all the researchers and world leaders globally (Tian et al., 2019; Zeng, Liu, Feiock, & Li, 2019). Although it is presumed that significant progress has been made but there is still the noticeable potential of developing EE worldwide (Dubey & Dodonov, 2019). Therefore IEA (International Energy Agency) states that there is a massive potentiality to save the enormous amount of energy form buildings as well as to reduce GHG emissions (Nezhnikova et al., 2019). Moreover, EE and management, in the building, are considered as the most burning issue among researchers around the world (Danish et al., 2019). It is possible to lower GHG emissions through the renovation of the existing building stock, which is a widely accepted measure to combat the global temperature (Chen et al., 2019). It is also stated that, renovation of the existing building stock results in 50% of the energy-saving[14] which is shown in Figure 1.1 below (Chen et al., 2019). However, this thesis will show the importance of the renovation regarding the EE improvement of existing residential houses in Norway.

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[13] Cited from(UNECE, 2017, p. 10)
[14] Cited from(Patiño-Cambeiro, Armesto, Bastos, Prieto-López, & Patiño-Barbeito, 2019; Rosenow, Eyre, Sorrell, & Guertler, 2017)

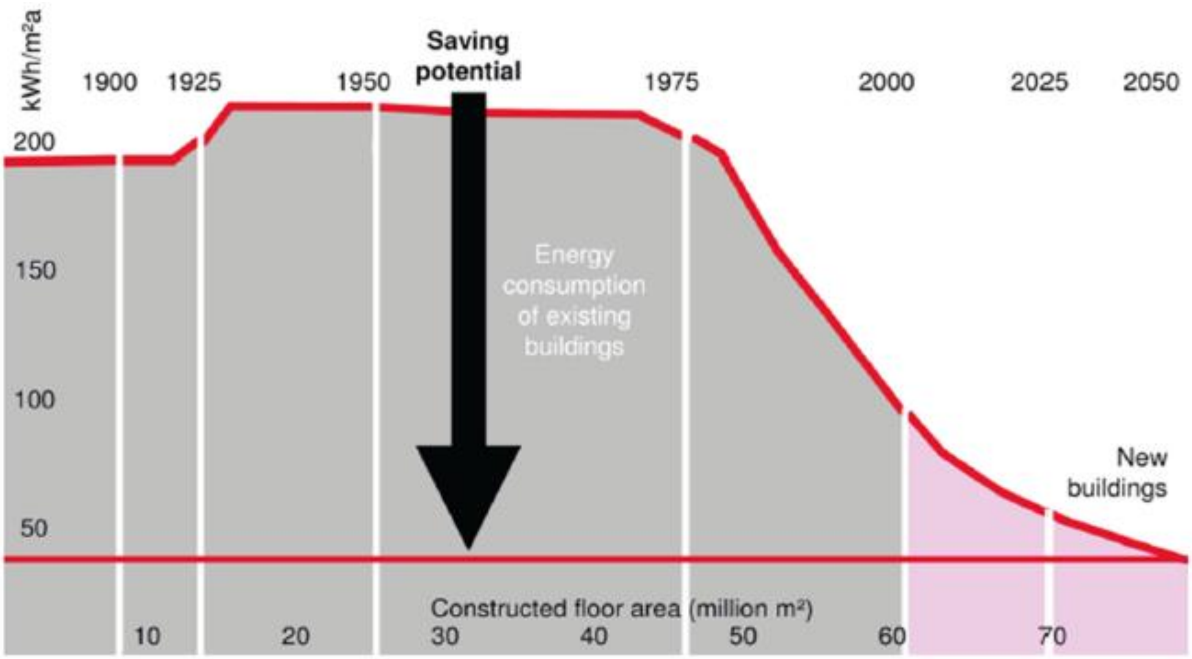

Figure 1.1. Construction work (in million m² floor area) and specific energy use (for heating and hot water)
Source: (Haase et al., 2020)

There is a tremendous economic and population growth, in Norway, along with the expansion of petroleum extraction, since 1990, which resulted in the use of a massive amount of fossil fuels and production of the enormous amount of CO_2 (regjeringen, 2020c). In June 2017, the Norwegian Parliament endorsed an Act connecting to Norway's climate targets (Climate Change Act), which points to become a low-emission society by 2050, to reduce GHG emission through the scientific knowledge (Regjeringen, 2019, 2020c). However, recently Norway has presented an enhanced climate target under the Paris agreement, Norway's new and strengthened goal is to lower the emissions with a minimum 50%, and towards 55% by 2030 relative to 1990 levels (regjeringen, 2020a). Norway also is committed to fulfilling the EU goals to reduce emissions by at least 40% by 2030 relative to the level of 1990. Norway is trying the lower the emission but not fast enough (regjeringen, 2020a).

The sustainable development goals (SDGs) were fixed in September 2015 and designed a plan for attaining the goals of sustainable development by the year 2030 (DNV, 2018b; Sustainalytics, 2019). The green bonds present the following SDG targets: (mentioned those point which is related to the buildings).

Use of Proceeds Category	SDG	SDG target
Green buildings	7. Affordable and clean energy	7.3 By 2030, double the global rate of improvement in energy efficiency
Green buildings	11. Sustainable cities and communities	11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries
		11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
Green buildings	12. Ensure sustainable consumption and production patterns	12.2 By 2030, achieve sustainable management and efficient use of natural resources

Figure 1.2. Alignment with/contribution to SDGs
Source: (DNV, 2018b; Sustainalytics, 2019)

In this SDG targets, it is presumed that EE will be doubled by 2030 compared to the global rate as well as sustainable consumption and production of energy will be confirmed within the same period (DNV, 2018b).

As it is shown in the over-mentioned table the Norwegian government has predicted to reach the level of overall EE to twofold by 2030 relative to the global standard, consequently, it is very key for the government to reduce the energy consumption from housing sector along with the gradual degeneration of CO_2 emission as well. Therefore, buildings (particularly the old houses in Norway) must be pointed carefully to implement the deeper renovation in buildings. however, there are several obstacles to continue the renovation, this thesis will identify those hindrances.

In the course of the reduction of emissions, households can play an important role to make the transition to a low emission society (Enova, 2018). Most of the Norwegian residences (around 80% of the buildings) are old houses, and it is believed that they will sustain for a long time (Enova, 2018). Out of the total 1.2 million Norwegian single-family houses, 0.5 million were built on throughout 1946-1980, which have a very low standard of energy installations that results in the production of CO_2[15] (Enova, 2018; Gullbrekken & Time, 2019). Furthermore, 30% of Norwegian residential buildings are comprised of detached houses built between 1950 and 1990, these building stock needs very deep renovation (Heide, Georges, Lien, & Mathisen,

[15] Cited from(Risholt, 2013)

2019). Furthermore, buildings are responsible to consume about 40-50% of total stationary energy in Norway, hence it is very important to consume the energy efficiently (energifaktanorge, 2019; Enova, 2019a; Haase et al., 2020)[16]. Although renovation is continuing each year while renovations regarding the improvement of EE are half of the total renovation in whole Norway, and yet there is a big gap to improve EE in the residential buildings (Enova, 2019a; Heide et al., 2019). To more precisely, this building stock is in such a stage where substantial renovation is mandatory (Gullbrekken & Time, 2019). Every year, Norwegians (63% of people spend for painting, 40% of people lay a new floor, 30% of people do electrical work and 28% of people do plumbing renovation) spend the most of the money for the home renovation to upgrade the living rooms, baths, and kitchens, to more precisely the house owners mostly spend money to upgrade the baths and kitchens (Irene Mårdalen, 2019). Norwegian spends around 94 billion NOK for the house renovation every year (Fyhn et al., 2019; Irene Mårdalen, 2019). Bjørn-Erik Øye 'market research company Prognosesenteret' stated that people want to be environmentally aware while renovating, but it is difficult to unearth what is the meaning of environmentally friendly to the house owner. He further stated that *"if you want to upgrade the energy standard of your home, you get different answers depending on who you ask. Currently, there are no objective bodies that consumers can turn to. They depend on the various commercial players,"(Irene Mårdalen, 2019).* Moreover, according to Byggemonitor, Norwegians tend to have no substantial plant while continuing renovation projects, the majority of people do it as they are willing to, and not because they have to (Irene Mårdalen, 2019). Furthermore, around half of the investment in the renovation has been going for nothing, and the rest performs for the aesthetic reasons (Irene Mårdalen, 2019). However, it is important to note that, the level of EE has been improved significantly in the new buildings, whereas the project of retrofitting or renovation of old houses are not pointed perfectly in line with those existing regulations (forskning, 2019; Fyhn et al., 2019).

In the existing building stock, the technical sides of the building have the largest potential to increase EE (13.4 TWh) through the intense retrofitting[17](Fyhn et al., 2019). At the same time, recently the government has published a low emission strategy for 2050 and was emphasized to reduce the emission of the order of 90-95% compared to the reference scenario year 1990

[16] Cited from ((M Economidou et al., 2011)
[17] Cited from(Enova, 2012b)

(regjeringen, 2020c). Norway is obliged to reduce GHG emission equivalent by 30% in line with the Kyoto Protocol, compared to the level of emission in 1990 (regjeringen, 2020c).

The building is one of the biggest sources of GHGs emission, in line with the goal of the Norwegian government to build low emission society, renovation of old houses to increase the level of efficiency as well as to eradicate all the constraints toward the renovation are highly time-justified to reach the outlined goals, which is the main focal point of this thesis.

This Introduction section will be the predecessor of the problem statement of the master thesis research and the identification of the research problem are derived from the background of this research.

1.1 Problem statements and research question

The problem statement for this thesis is constructed based on the introductory paragraph. However, after an in-depth discussion of different scholarly articles, books, and Norwegian government documents, it is obvious that a certain EE gap is being existed in the residential building sector in Norway (Heide et al., 2019). To more extensively, an existing building in Norway reflects a greater challenge, as these buildings exist for the longer period as well, so the energy performance of the existing building stock will present building practices and quality in construction at the time of construction, that can remain many decades back in time (Haase et al., 2020). Apart from this, existing buildings may also have been the necessity to do the maintenances of various scope and quality over the whole period of their lifetime (Haase et al., 2020). And it has been recognized that parts of existing buildings stock have used very sub-standard energy measurements which leads to having poor energy performance. A partly or comprehensive renovation is the key opportunity to upgrade the energy performance of those buildings (Haase et al., 2020).

To more precisely, around all the Nordic countries are facing the EE problem in the old houses, especially those built in the 1970s and 1980s (Y. Li et al., 2019; Mahapatra et al., 2012), in Norway, the dwellings from the 1980s are more energy-intensive compared to the new housing stocks and those houses needs a massive renovation to increase the EE and sustainability by decreasing the emission (Enova, 2018; Ryghaug & Sørensen, 2009). This sentence has cemented the idea of the problem statement of this thesis that there is a definite EE gap in residential buildings in Norway, that gap is being created owing to the number of constraints regarding the renovation of old residential buildings for improving the level of EE along with the reduction of CO_2 emissions.

Although Norwegian people tend to renovate their house once in a year, while aesthetic purpose turns out to be the leading cause for the renovation (Fyhn et al., 2019; Irene Mårdalen, 2019). However, the Norwegian government has been implemented numerous agenda or policies to reach the climate goal and keep emission neutral by 2030, residential buildings are one of the key sectors which can contribute to fulfilling the climate goal of the Norwegian government through the reduction of energy consumption and the up-gradation of the level of EE (Enova, 2018; Klimakur, 2020; regjeringen, 2020a, 2020c). The problem statement of this thesis is delineated based on the overmentioned discussion, which is, Norway has started to implement the policies for the development of EE in buildings (particularly the old buildings) since the 1970s, while the measures, such as retrofitting, renovation or replacement of all technologies, have been in effect to improve the level of efficiency, but not significant to notice (Fyhn et al., 2019; Gullbrekken & Time, 2019; Heide et al., 2019; Irene Mårdalen, 2019). Therefore, numerous scholars have identified several barriers to upgrade the efficiency level, followed by a clear efficiency gap in the buildings. Subsequently, the building is one of the important sectors to contribute to reaching the climate goal by increasing the energy-efficiency as well as decreasing the level of emissions. Therefore, it is obvious that there is an EE gap in the old building in Norway. So, this thesis attempts to identify the facts that lead to slower this EE up-gradation in the old buildings in Norway, to more precisely the hindrances in the process of promoting the level of efficiency. However, based on the introductory paragraph and problem statement, this thesis will answer the following key research questions and sub-research questions:

 What does hamper the speed of the process of energy efficiency (EE) in the old buildings in Norway?

- *What are the barriers to improving the level of EE in the existing residential buildings in Norway?*
- *How can these barriers be overcome to raise the level of EE in the old residential buildings in Norway?*

1.2 Structure of this thesis:

This thesis has designed this thesis with multiple chapters from the introduction to the conclusion.

Chapter One: Introduction of the thesis, has simply reflected on the climate change, GHGs emissions globally and particularly contribution of the building sector to scale up the emissions form the perspective of Norway and globally. This chapter has tried to prove the EE gap in the Norwegian existing houses, based on this statement, problem statement of this thesis has been stated, which has paved the way to construct the research questions.

Chapter Two: In the Background part, the thesis presents a global overview of the energy consumption, CO_2 emission, and the harsh response, and then this thesis focuses more precisely on the average energy consumption and emission equally, followed by the scenario of the sustainable housing sector. Afterward, this thesis narrows down more explicitly to the Norwegian housing sector. Moreover, this thesis briefly presents Norwegian energy agreement and energy policy, Norwegian energy consumption and production, and the challenges for the Norwegian authority to achieve the global promised regarding emission. I have ended with a low emission scenario.

Chapter Three: In the theoretical part, starting with the introduction of the theories, followed by the justification of employing these theories in this case. The thesis analyses the generic barriers regarding the upgradation of EE in the old residential buildings in Norway as well as presented several common solutions to overcome those barriers.

Chapter Four: This chapter addresses the methodological and research design approach. The chapter presents the philosophical assumption that is interpretivist and qualitative approach for the research design. To more precisely, the thesis will follow the abductive method to present result. Data collection is qualitative through semi-structured with key interviewees, data analysis and reduction are completed applying NVivo qualitative software. The issues concerning validity and reliability of this thesis are also presented in this chapter.

Chapter Five: The chapter presents the data and results collected and interpreted in chapter three. The presentation of data is done applying word cloud frequency query results and the thematic analysis for each of the key barriers and solutions regarding the improvement of EE in the old housing stock in Norway.

Chapter Six: “Findings and Analysis” presents a comprehensive analysis with several argumentation pros and cons of this paper’s topic. I have analyzed the findings step by step from the over-mentioned theoretical perspective, to answer the research questions aptly as well as to evaluate the collected data competently from the perspective of the upgradation of EE in the old houses in Norway.

The final chapter: “Conclusion” this thesis reiterates some of the key issues of this paper, by which the reader can perceive a clear motive of the paper. And this thesis also brings some suggestions to improve the EE in the existing residential houses/buildings in Norway.

2 Background of the study

2.1 Overview of the international community for energy efficiency (EE)

In 1987, United Nations Brundtland Commission has emphasized to change the existing the current energy policies to save the energy and they also started to reduce the energy consumption by at least 50% within 40-50 years, with the beginning from 2008 as a base year and focused on the concept of sustainable energy to a wider extent (Aall, 2011; Holden & Høyer, 2005). Since buildings are the biggest source of energy-consumer globally and energy demand will increase with time in approaching years. 'EE' is the focus of attention of all EU's energy policy. Buildings responsible for 40% of total energy consumption globally and about 75% of them are used inefficiently (Sesana & Salvalai, 2018).

According to IEA (International Energy Agency), EE is the core issue of any planning to ensure secure, sustainable, and comprehensive economic development (IEA, 2019b). Moreover, it is one of the most cost-effective means to improve the security of energy supply as well as to scale down the emission from the energy system (IEA, 2019b). Global energy outlook 2019, has presented two scenarios Stated policies Scenario and Sustainable Development Scenario (IEA, 2019b), it has shown in Figure 2.1 (below). In Stated Policies Scenario, a quarter of primary energy growth augments from 2018 to 2040 with the average growth rate of 1% per year along with the doubling of energy consumption and economic growth (IEA, 2019b). While according to the Sustainable Development Scenario, the demand for primary energy reduces by 25% compared to the Stated Policies Scenario (IEA, 2019b). This is because of the improvement of EE regarding energy consumption, which paves the way to save 60% of energy (IEA, 2019b). Around 50% of EE derives from the industry sector along with the massive contribution from the transport and building sector as well (IEA, 2019b). An acute growth of EE is the key measure that helps the world to reach the Sustainable Development Scenario, which is shown in figure (IEA, 2019b). Finally, "EE is the Primary "Fuel" of choice in most regions because of its cost-effectiveness" and it presents very lucrative payback although having many impediments (IEA, 2019b).

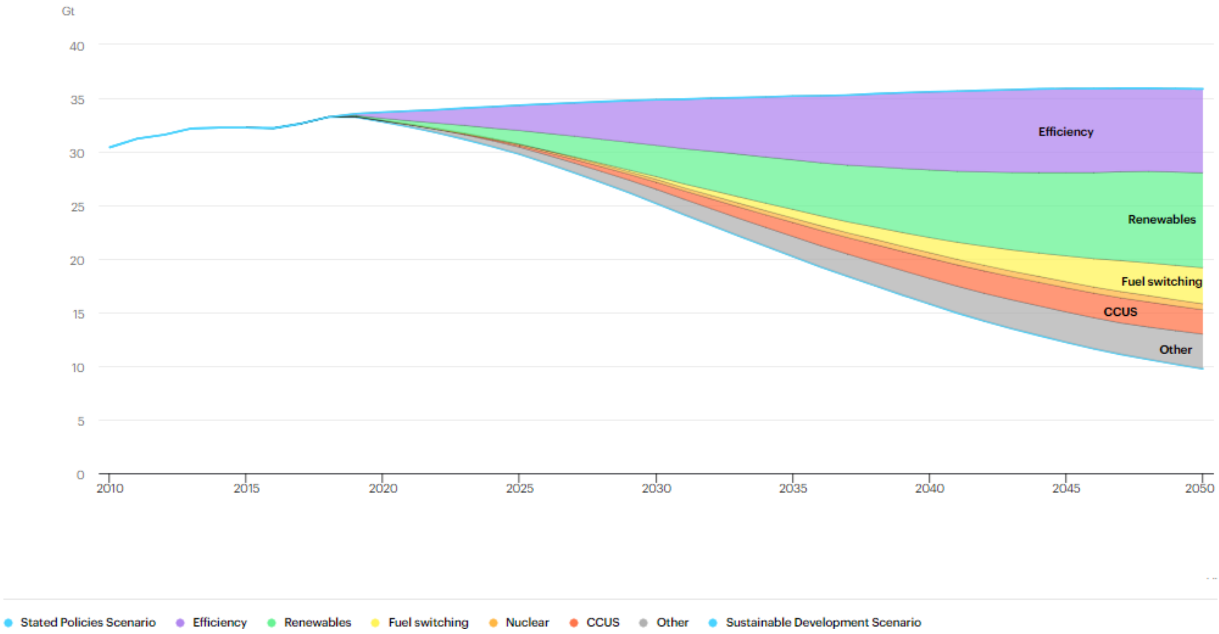

Figure 2.1. CO_2 emissions reductions by the measure in the Sustainable Development Scenario relative to the Stated Policies Scenario, 2010-2050
Source: (IEA, 2019b)

Apart from that, IEA has marked that the rate of EE was very low in 2018 since the beginning of the decade, it is portrayed in Figure 2.2 (below). However, they emphasize to member states to increase investment (IEA, 2019a). And focused on the digitalization of the EE and improving its value as well, which can remove the barriers (IEA, 2019a). At the same time, it is mandatory to bring a significant change in the energy system, along with the adding of the bigger shares of intermittent generation to the electricity system (IEA, 2019a). In this process, digitalization is improving the demand-side EE more valuable than in the past, this is because of digitalization not only presenting the end-use efficiency but also providing other services as well, such as flexible load, accordingly it increases the efficiency of the overall system (IEA, 2019a). Moreover, end-users enjoy the most important system benefits, as digitalization enable him to measure and to evaluate all the aspects more quickly and promptly (IEA, 2019a).

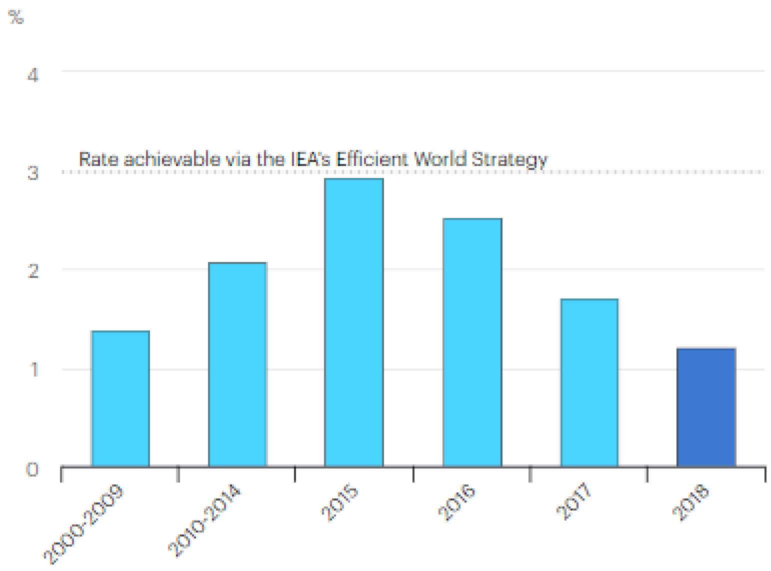

Figure 2.2. Global improvements in primary energy intensity, 2000-2018
Source: (IEA, 2019a)

Apart from this IEA recommended the policy which smoothens the adoption of the digital technologies for EE while the policy is regarding the adoption of EE technology is deficient (IEA, 2019a). IEA has selected a set of crucial policy to remove the barriers of the adoption of digital technologies for increasing efficiency (IEA, 2019a). which are mentioned below:

- *Improve access to energy-related data*
- *Ensure adequate protection from cybersecurity and data privacy risks*
- *Strengthen trust in digital technologies*
- *Ensure energy markets value the services provided by digital EE*
- *Ensure equitable access to digital technology and infrastructure*
- *Increase digital skills and plan for job market transformation*
- *Minimize negative environmental impacts*
- *Encourage technology and business model innovation*

Source: (IEA, 2019a)

2.2 The Norwegian Government plan for the building sector in tandem with the EU

European Union Directive 2002/91/EC (European Commission, 2002) regulates the energy consumption of buildings, Norway, as a member of the European Economic Area (EEA), must conform to the directions of European Union. Norwegian authority integrated the Directive "European Union Directive 2002/91/EC" in Norwegian legislation through the modernize of the technical regulations (TEK) of the Planning and Building Act (Ministry of the Environment, 2008) that operates the energy requirements for new and renovated buildings.

Norway has been committed to joint fulfilment of the 2030 target; Norway will cooperate with the EU for the reduction of non-ETS emission (regjeringen, 2017). The commission suggests that Norway would be imposed a target to reduce the non-ETS (emission trading system) of 40% below the 2005 level in 2030 (regjeringen, 2017). The continuation of that agreement, the use of mineral oil to give the base-load capacity for heating in the residential buildings, and peak-load capacity for the commercial buildings are forbidden from 2020 (regjeringen, 2017). To some extent, the government is designing a plan to ban the use of mineral oil for heating in a farm building and temporary buildings as well (regjeringen, 2017). The government is reviewing the potentiality to decrease the emission from the use of natural gas for heating buildings (regjeringen, 2017). In 2015, the number of non-ETS (emission trading systems) from the heating of building was 1.2 million tonnes CO_2-eq, now the government is planning to reduce, the amount of the non-ETS emission from heating, to 0.5 million tonnes by 2030 (regjeringen, 2017). At present, buildings currently are responsible to consume around 40% of net domestic energy consumption in Norway, while the amount of emission from this sector is only 2%. The government is committed to bringing the emission down to 0.7% by 2030. Although it is said that increasing EE will not impact extensively to reduce greenhouse gas emission as the greater part of stationary energy use come from the renewable sector (regjeringen, 2017). However, according to the white paper on Norway's energy policy (Meld. St. 25(2015-2016) that, the efficient and environmentally friendly energy consumption will play a vital role to reduce the emission for the period till 2030 (regjeringen, 2017). For that purpose, Enova provides a massive amount of funding for both the existing and new buildings, including from the support for conceptual studies to building new technologies (regjeringen, 2017). The new regulations came to force for the buildings on the 1st of January 2016 and expected to develop the level of EE in new buildings by around 20-25%. At the same time determining the amount of energy reduction in the existing building by 10 TWh by 2030 (regjeringen, 2017).

The amending directive (2018/2002) focuses on the Clean Energy for all European packages, and the main target of this amended directive is to achieve an EE target for 2030 of at least 32.5% (commission, 2019). to more precisely, the energy consumption should be not exceeded the limit not more than 1273 Mtoe (million tonnes of equivalent) of primary energy and no more than 956 Mtoe of final energy (commission, 2019).

And very recently the EE Directive 2012/27/EU (EED) initiated the concept of deep renovation which denotes that *"refurbishment that reduces both the delivered and the final energy consumption of a building by a significant percentage compared with the pre-renovation levels, leading to a very high energy performance" (Haase et al., 2020, p. 12).* Initiating a deep energy renovation points to the adoption of an integrative approach for the whole building, which results in a more cost-effective process as well as an opportunity to save a significant amount of energy compared to the partial energy retrofit measures (Haase et al., 2020).

2.3 How to make a building energy efficient

The building sector demonstrates an extraordinary opportunity to improve EE comprehensively, both through the retrofitting\renovation of existing buildings and by imposing the standard energy efficiencies on newly constructed buildings (Dubey & Dodonov, 2019; Krarti et al., 2019). The demand of energy in the residential sector is increasing substantially due to the proliferation of the number of people in past three decades (Irshad, Habib, Saidur, Kareem, & Saha, 2019) and around half of the energy production over the world is consumed in the running processes of buildings, which results in approximately 60% of CO_2 production (Irshad et al., 2019)[18]. Buildings consume a significant amount of energy to provide the comfortable occupancy level, which necessitates space heating and domestic hot water preparation, ventilation and air condition/cooling, and electricity supply for lighting and other households' activities (Dubey & Dodonov, 2019). There are many cutting-edge technologies for building to lower the energy demand, CO_2 emission, and energy wastage while optimising the highest amount of thermal comfort along with making sure the resident security (Dubey & Dodonov, 2019). Currently, building-planning is being considered from the crucial point of view at the construction stage, which incorporates standard planning of eco-design, building orientation, efficient use of green plant systems for the roof and building façade, use of shading, installing natural lighting and cross-section ventilation (Dubey & Dodonov, 2019). Apart from this, many scientists and planners, taking those points in thinking, have researched globally to improve the energy effectiveness of the frameworks, redesigning the present structure by utilizing energy effective measures and assessing it technically and financially (Irshad et al.,

[18] Cited from(Huo et al., 2018)

2019)[19]. Apart from this there are several aspects to increase the level of efficiency, which is listed below,

2.3.1 Insulation of building envelop, airtightness, thermal bridging

It is evaluated that around 20-50% of reduction of energy consumption is possible through the implanting proper design of a building envelope (Harish & Kumar, 2016). The building envelop has the biggest influence on building energy performance; this is a key area to be considered of planning for EE measures for both existing and new buildings (Dubey & Dodonov, 2019). Regarding the purposes of the building envelop (security, comfort, shelter, privacy, aesthetics, ventilation), it is obligatory to optimize the design of the building envelop to match the residents' demands while lowering the energy usage and heat loss. The significance of thermal insulation (Dubey & Dodonov, 2019). Building envelops making use of the potential of phase change materials (PCMs), that lower the energy demand for cooling by 10% and 87%, consecutively improve environmental influence over the building life cycle[20](Danish et al., 2019). It is possible to improve the heat exchange capability and to lower the heat losses by developing the insulation (controlling exhaust/intake, etc), using shading (Danish et al., 2019).

Airtightness, and reducing thermal bridging in the building are similar for both hot and cold climates (Dubey & Dodonov, 2019). It is very usual to lose the heat through leakage during cold seasons which results in increased use of heating energy, it is also true in terms of using air condition in the summertime; in both conditions lead to more consumption and increased CO_2 emissions (Dubey & Dodonov, 2019). Most of the heat loss take happens through the walls, roofs, floors, and glazing, sealing joints, and thermal bridges (Dubey & Dodonov, 2019). Proper levels of insulation and the lowering of thermal bridging are key actions for upgrading thermal performance and cosiness, which also confirm the long-term building sustainability (Dubey & Dodonov, 2019). There are different types of insulation depends according to climate, building type, and usage (Dubey & Dodonov, 2019). Insulating of pipelines by covering with insulation materials lowers the heat losses in the pipelines, simultaneously continuing their better temperature, resulting in noticeable energy savings (Dubey & Dodonov, 2019). Temperature control in every room is very basic for energy consumption in an efficient

[19] Cited form(Sun, Gou, & Lau, 2018)
[20] Cited from (Konstantinidou, Lang, & Papadopoulos, 2018)

way (Dubey & Dodonov, 2019). So, radiator heating is marked to save the heat through the installation of thermostatic control valves on the radiator (Dubey & Dodonov, 2019).

2.3.2 Installation of modern windows with higher thermal features

Changing old-fashioned windows with modern technology insulation is more efficient than retrofitting them (Dubey & Dodonov, 2019). The latest windows are featured with multi-chamber glazing profiles, which is a more upgraded design. Based on the thermal and technical requirements, windows profiles can be ensured in line with the building regulation; acoustic insulation could be attached (Dubey & Dodonov, 2019).

2.3.3 Efficient heating, cooling systems, and domestic hot water supply

There are various types of heating system are available which is related to the energy sources, fuel prices, infrastructure, technological development, and pertinent energy policy (Dubey & Dodonov, 2019). Currently, most of the multifamily residents, public and private holdings, and commercial buildings are installing new engineering systems which include heating, ventilation, and air conditioning (HVAC), along with the hot water supply (Dubey & Dodonov, 2019).

Using the district heating systems requisites, a complex automated system in the buildings' heat supply systems, which includes the heat point and heat consuming systems. Installation of a district heating system is mandatory for many countries for new buildings and renovation as well (Dubey & Dodonov, 2019). To lower the energy intensity from mechanical equipment such as air conditioners, researchers point to the semiconductor materials along with the building materials (Irshad et al., 2019). Moreover, they also emphasize to install the PV (Photovoltaic) system which will convert incident solar radiation over the building into electricity and lowering the heating and cooling demand of buildings (Irshad et al., 2019).

2.3.4 Lighting System

Lighting consumes around 10-20% for residential and commercial buildings[21] still fluorescent lighting is available in many buildings around the world (Danish et al., 2019). But, currently, different kinds of light-emitting diode (LED) technologies with eco-friendly features are

[21] Cited from(Byun & Shin, 2018)

developed which will change the lighting industry toward increasing efficiencies[22](Danish et al., 2019). However, the changes are not much noticeable due to the high investment cost for the installation of LED lighting (Danish et al., 2019).

Upgrading of the existing lighting system in residential buildings is determined to replace the incandescent lamps with energy-saving option (Dubey & Dodonov, 2019). Generally, Multifamily residential and public buildings use either filament or fluorescent lamps or light-emitting diodes to be more common (Dubey & Dodonov, 2019). However, there are different types of measures to upgrade the light system to energy effective in buildings, such as the installation of a sensor-controlled lighting management system, using the motion and thermo service devices that identify the absence\presence of people (Dubey & Dodonov, 2019). In the case of building design, it is important to notice the building orientation and developed fenestration technologies, for instance, dynamic windows (Dubey & Dodonov, 2019; IEA, 2013). It is practicable to reduce 40% of energy consumption by 2050 through the upgrading lighting system in existing buildings (Dubey & Dodonov, 2019; IEA, 2013).

2.3.5 Energy monitoring and smart metering systems

Measuring components (smart meter), control and measuring system that measures the number of resources utilized, forms and presents the primary data about the quality and quantity of used resources, provides primary storage of all received information for every automation object (Dubey & Dodonov, 2019). Subsequently, all the data send to the computing components for the data processing, analysis, storage, and distribution of information (Dubey & Dodonov, 2019). The modern building is being featured with very upgraded engineering systems, which have dynamic operating system mode, those are not only allowed to consume less energy but also produce fewer emissions (Dubey & Dodonov, 2019).

2.3.6 Ventilation, air conditioning, and cooling (VAC)

Around one-third of heat loss, of detached single-family houses built before 1990, occur through infiltration and ventilation[23](Gullbrekken & Time, 2019). According to TEK17, the maximum limit of air infiltration is fixed to 1.5 air changes per hour at 50 Pa pressure variation (Gullbrekken & Time, 2019). The importance of building infiltration has resulted in a positive

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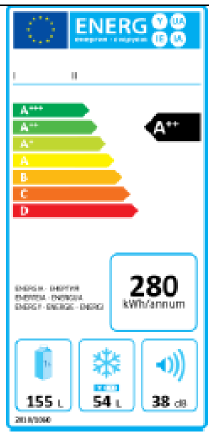
[22] Cited from(Ploch et al., 2013)
[23] Cited from: (Granum, 1990)

focus on air tightening, particularly as wind barriers (Gullbrekken & Time, 2019). An airtight wind barrier along with the airtight vapor barrier contributes to saving energy, simultaneously secure building from defects occurred by, for instance, convection of warm, humid indoor air through the structure[24](Gullbrekken & Time, 2019). A recent study shows that about 60% of the Norwegian detached houses have not brought any changes in the ventilation system while taking energy renovation, only 9% installed a balanced mechanical ventilation system (Heide et al., 2019). Due to the low electricity price, very few detached houses in Norway have a hydronic heating system form the period of 1950-1990 (Heide et al., 2019). Balanced ventilation with heat recovery is one of the key ventilation aspects of energy-efficient buildings. Efficient heat recovery consumes low energy, preheating of supply, or gives good thermal comfort (Heide et al., 2019).

2.3.7 Energy-efficient appliances (EE labeling)

Application of energy-efficient appliances labeling is a crucial step to the reduction of internal energy consumption along with the lowering CO_2 emissions (Dubey & Dodonov, 2019). However, home appliances consume an important amount of energy, the access of "A class" of EE of home appliances is not only leading the degrowth of emission but also experiencing the truncating of emissions (Dubey & Dodonov, 2019). In this term, the electrical appliances are being certified as stated by the ISO 9001 and ISO 14001 standards, which present no detrimental elements toward nature (Dubey & Dodonov, 2019). The figure will show the labeling of EE, certified by the European Union,

<table>
<tr>
<td>Home appliances of energy efficiency A class and higher can significantly reduce energy consumption. Labels typically include the following information:
• Title, model, producer;
• Class of energy efficiency: colour code with alphabetic reference (from A to G), which reflects the level of energy consumption;
• Level of annual energy consumption;
• Additional information regarding the type of appliance, e.g. the internal volume of the refrigerator in litres, the maximum speed of rotation for washing machines etc.; and
• Noise level expressed in Decibels.</td>
<td>
</td>
</tr>
</table>

Source: (Dubey & Dodonov, 2019)

[24] Cited from: (Gullbrekken, Kvande, Jelle, & Time, 2016)

2.4 A brief discussion of about residential sector of Norway

2.4.1 Typical houses with great energy savings potential in Norway

The total number of dwellings in Norway is approximately 2610040 in 2020, and the below mentioned Figure 2.3 (below) and Table 2-1 (below) shows the number of different types of houses in 2018, 2019 and 2020 (H. Tankovska, 2020). Figure 2.3 (below) and Table 2-1 (below) show that detached houses are the most common houses in Norway in 2018, 2019, and 2020. And the number of detached houses in 2020 is around 1.3 million, while the multi dwellings numbers around 640 thousand (H. Tankovska, 2020). The aggregate number of dwellings in Norway has grown from about 2.55 million in 2018 to 2.61 million in 2020. Moreover, the number of houses had increased by about 280 thousand units over the past decade, where the biggest rise shows in the number of multi-dwelling residents, and the increased with approximately 114 thousand units (H. Tankovska, 2020).

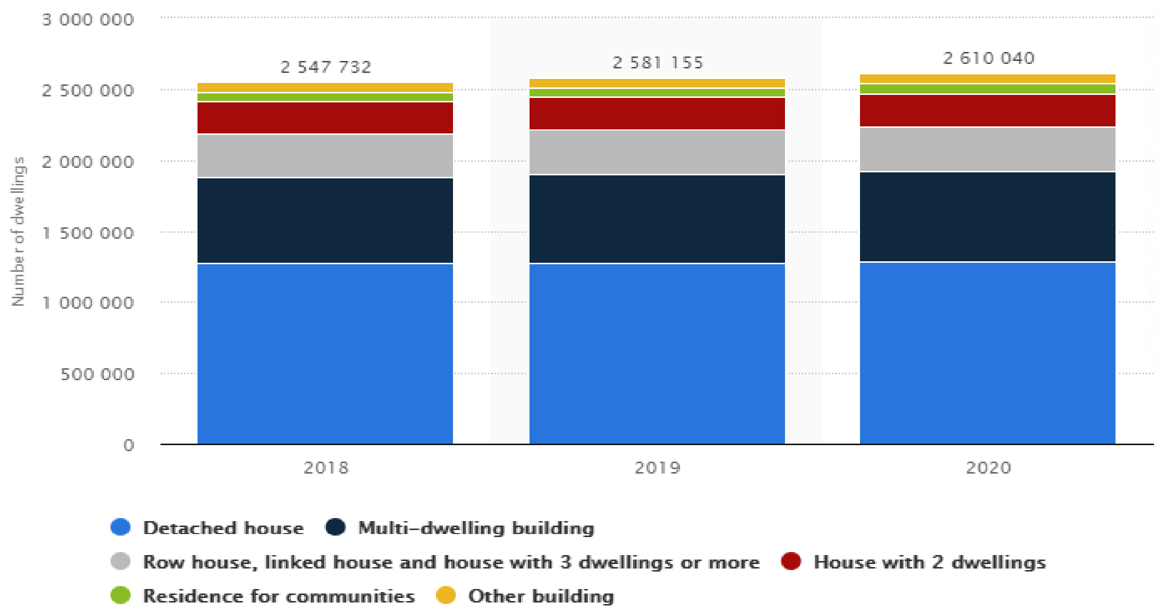


Figure 2.3. Number of residential housings in Norway 2018-2019, by type
Source: (H. Tankovska, 2020)

Table 2-1. Number of residential housings in Norway 2018-2019, by type

	2019	2020	Change	
			2010-2020	2019-2020
Total	2581155	2610040	286115	28885
Detached house	1276690	1281004	61101	4314
House with 2 dwellings	232948	235467	23871	2519
Raw house, linked house, and house with 3 dwellings or more	307910	311648	43827	3738
Multi-dwelling house	628145	643631	120639	15486
Residence for communities	61912	63309	22114	1397
Other buildings	73550	74981	14563	1431

Source:(SSB, 2020a)

Since the beginning of the construction period, one specified model for the single-family house is being followed in the Norwegian building stock. wood is the main construction material in Norwegian houses, since the construction of EKEBERG house in 1948 (Vanhoutteghem et al., 2009).

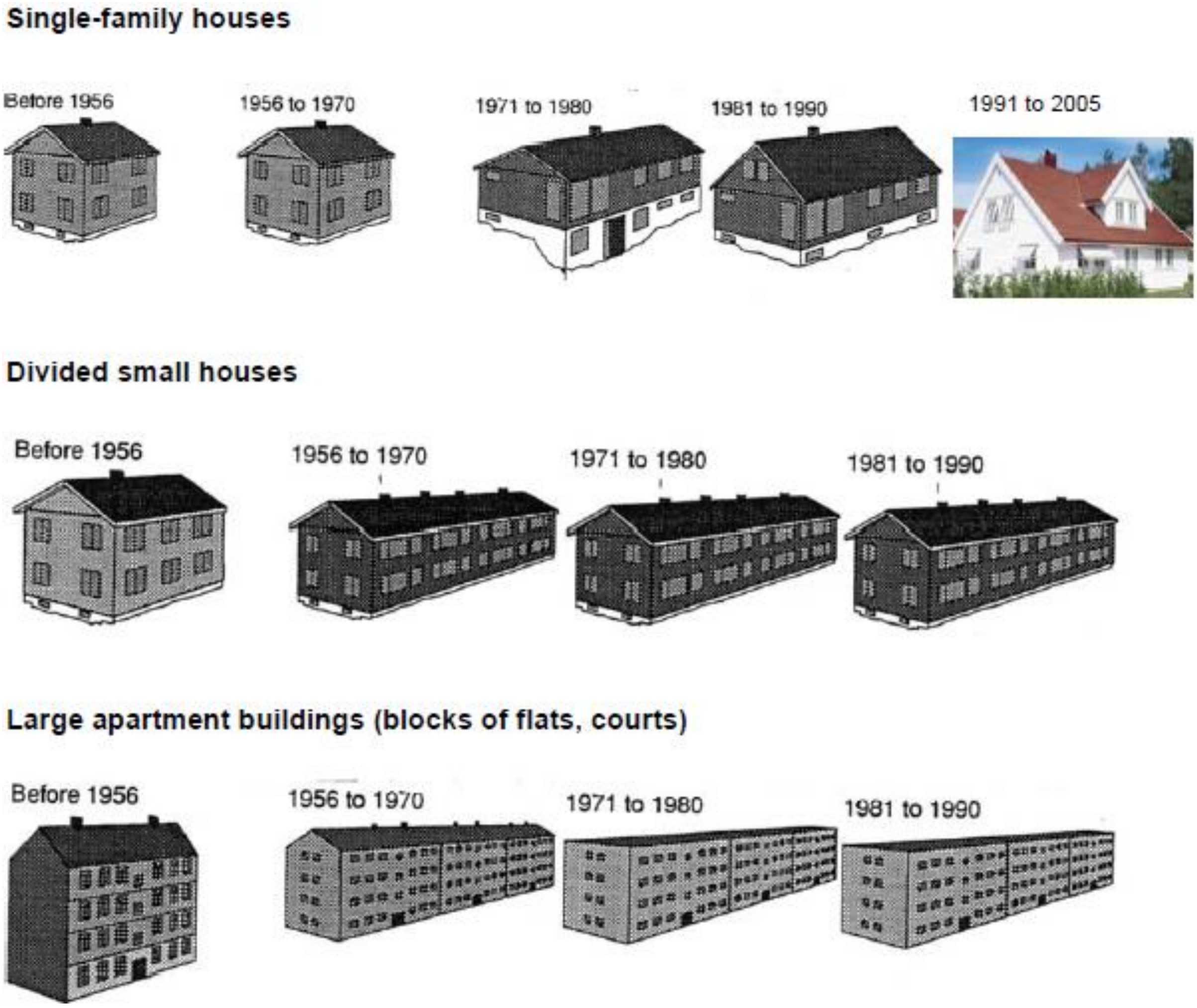


Figure 2.4. Stereotypes of small and large houses buildings, dependent on the year of construction
Source: (Thyholt, Pettersen, Haavik, & Wachenfeldt, 2009; Vanhoutteghem et al., 2009)

And since around 1955 onwards, light timber-framed constructions with the mineral wool have been the most prevailed construction formula of the single-family houses (Vanhoutteghem et al., 2009). In the beginning, 100 mm studs have been used in the walls and since the early 1980s, 150 mm studs and 150 mm thermal insulation has been introduced (Vanhoutteghem et al., 2009). Moreover, the thermal insulation of floors and roofs have been developed during the same period because of the economic growth and the strengthening of building regulations (Vanhoutteghem et al., 2009). The implementation of the New Building regulations on 1 July 1997, was the new turn for the thermal insulation level (Vanhoutteghem et al., 2009).

2.4.2 Number of houses and floor area

Around 90% of the existing Norwegian building stock has been built after the 2nd world war. The amount of dwelling units has been increased by 40% between 1982 to 2005, and the aggregated number of dwellings in Norway was approximately 2.2 million (Vanhoutteghem et al., 2009). According to the SSB, over the same period number of square meters per person has been increased by about 35% (SSB, 2012; Vanhoutteghem et al., 2009) The number of single-family houses are counted as 57% of the total number of dwellings, 21% of dwellings are belonged to the group “divided small houses”, which consist of a small house which vertically and horizontally divided, raw house and smaller terraced houses, and the rest of 22% of the dwellings are called as the apartment that comprises of detached blocks of flats and combined buildings (Vanhoutteghem et al., 2009).

The total heated floor in Norwegian houses has been increased by 16% from 1982 to 2005, reaching about 70 m2 per dweller in 2005. Figure 2.5 (below) delineates that the total heated area in a single-family house, among three types of houses, is reasonably more than double (Vanhoutteghem et al., 2009). The distribution of total heated area, calculated to be 230 million m2, that is pictured in the figure with the construction period of different types of buildings (Vanhoutteghem et al., 2009). In Norway, floor-heating is responsible to consume a massive amount of energy.

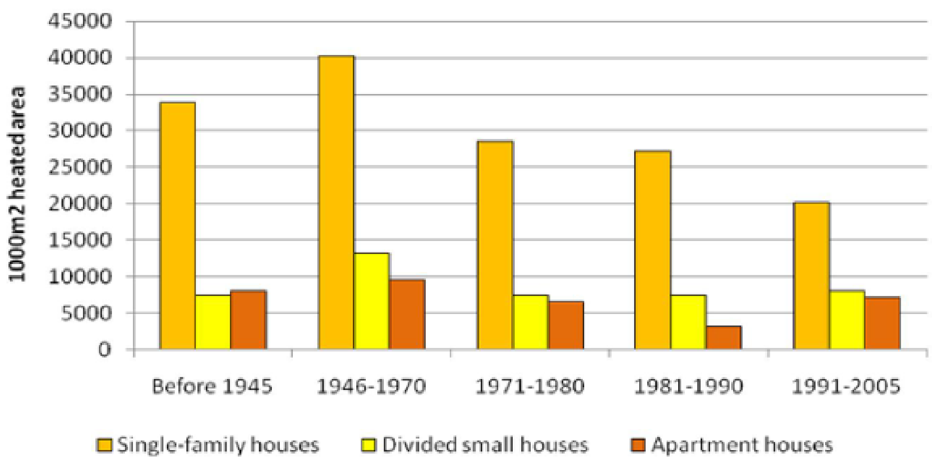


Figure 2.5. The total heated area, dependent on the type of dwelling and the year of construction[25]
Source: (Vanhoutteghem et al., 2009)

[25] I have contacted with SSB for the most update data, but they said that new data will take time to publish

2.4.3 Energy use

Energy consumption of the building relies on the extent to which EETs (Energy Efficient Technologies) are considered, from the building design to its construction, operation, maintenance and finally demolition and recycling, to precisely the whole life cycle (Yeatts, Auden, Cooksey, & Chen, 2017).

According to the IEA Energy Conservation in Buildings and Community Systems, the energy consumption of the building is propelled by six factors (Yoshino, Hong, & Nord, 2017): Climate, Building envelop, building equipment (energy service systems), Building Operation and Maintenance, Residents' behaviours and Indoor environment conditions.

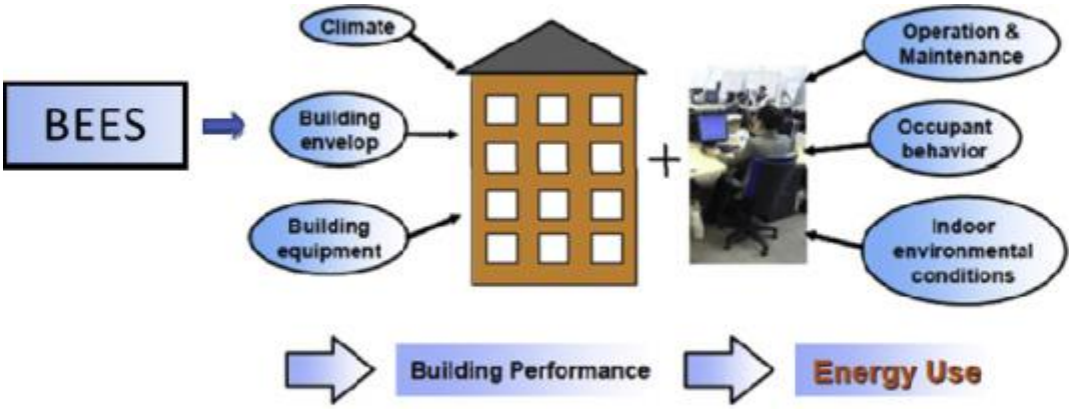


Figure 2.6. The energy consumption of the building
Source: (Wang et al., 2019)[26]

Table 2-2. Energy consumption in households

	2014	2015	2016	2017	2018
Electricity (GWh)	36 918	38 690	40 045	40 442	*40 537
Natural gas (GWh)	44	39	42	89	*9
District heating (GWh)	1 000	1 037	1 212	1 271	*1 284
Gasoline (GWh)	10 150	9 537	8 899	8 524	*8 096
Total energy consumption per household (kWh)	28 656	29 138	29 458	28 849	*28 362
Total energy consumption per person (kWh)	12 838	13 097	13 293	12 995	*12 903
Electricity consumption per household (kWh)	16 040	16 586	16 948	17 014	*16 825

[26] Cited from: (Yoshino et al., 2017)

Electricity consumption per person (kWh)	7 186	7 455	7 648	7 664	*7 655
Population	5137429	5189894	5236151	5276968	*5295619
Number of households	2301546	2332722	2362884	2376971	*2409257

Source: (SSB, 2019b)

The above-mentioned Table 2-2 (above) shows the ever-increasing growth of the use of electricity over the period, from 2014 to 2018 and onwards, along with the rise of the number of people and number of houses (SSB, 2019b). While the use of gas and gasoline shows a steady downward trend in the same period (SSB, 2019b). Total energy consumption in per person and per household (KWh) has experienced noticeable growth in 2015 and 2016, compared to other years (SSB, 2019b). Moreover, electricity consumption per person and household (KWh) has increased slowly over the whole period from 2014 to 2018 and will maintain steady growth in the future as well (SSB, 2019b).

Single-family houses and divided small houses consume around 85% of the average energy consumption, while the usage of apartment buildings is 15% (Vanhoutteghem et al., 2009). The single-family houses use around 30 TWh and the remaining building consumes around 44 TWh (Vanhoutteghem et al., 2009). The below-mentioned Figure 2.7 (below) has shown that the single-family houses built after the 2nd world War consume the highest amount of energy among all other types of dwelling stock (Vanhoutteghem et al., 2009).

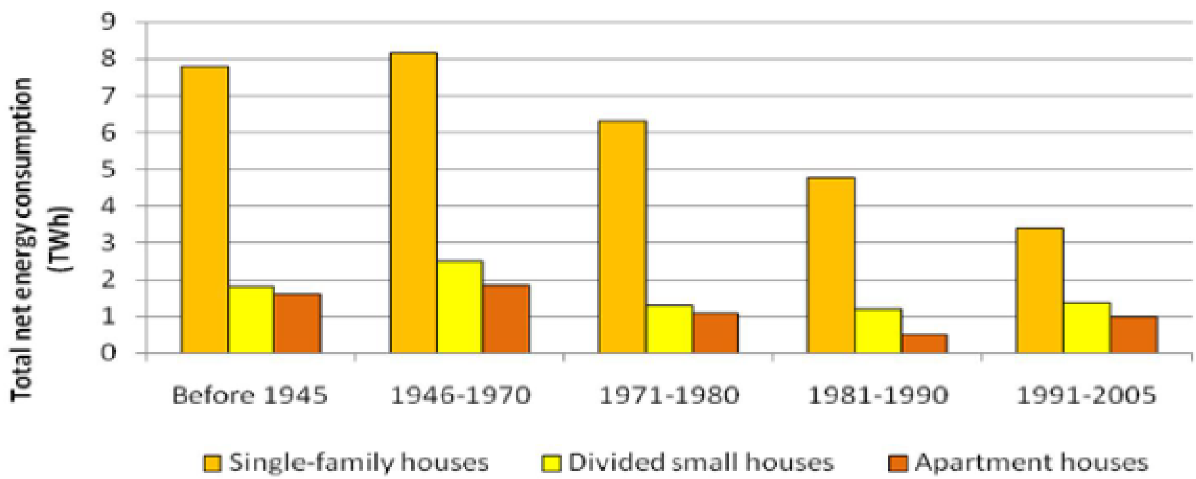


Figure 2.7. Total useful energy use, dependent on the type of dwelling and the year of construction[27]
Source: (Vanhoutteghem et al., 2009)

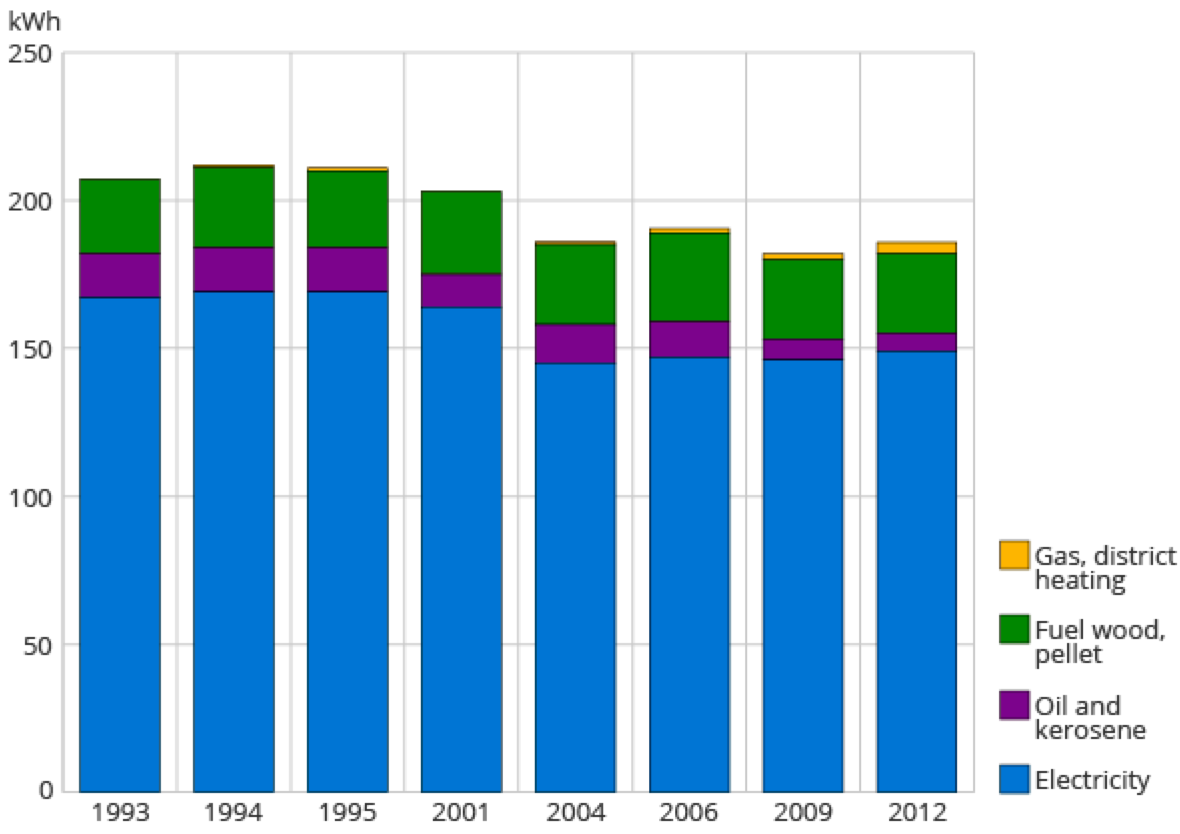


Figure 2.8. Energy consumption in household per m^2 dwelling area from 1993 to 2012[28]
Source:(SSB, 2014)

According to the above-mentioned Figure 2.8 (above), the overall energy consumption in households per m^2 dwelling area has decreased steadily over the period (SSB, 2014). Electricity is the biggest usage energy while the least amount of people consuming gas and district heating in several years among all the periods. Around 44% of total detached houses use a heat pump in 2012 that leads to a decrease the energy consumption (SSB, 2014).

Moreover, houses with the heat pump consume less energy in comparison with the houses without a heat pump (SSB, 2014). For example, households with a living area of more than 150 m^2, the usage of energy are on average 3900 (KWh) lower for the houses with the heat pump (SSB, 2014). Energy consumption deceased in recent years because 36% of households have implemented different measures to decrease energy usage, and of these, 80% of

[27] I have contacted with SSB for the most update data, but they said that new data will take time to publish
[28] I have contacted with SSB for the most update data, but they said that new data will take time to publish

households stated that the reduction of the energy cost helps them to reduce consumption (SSB, 2014). Moreover, about 40% has used more insulation to the houses and 61% had replaced the windows with better insulation (SSB, 2014).

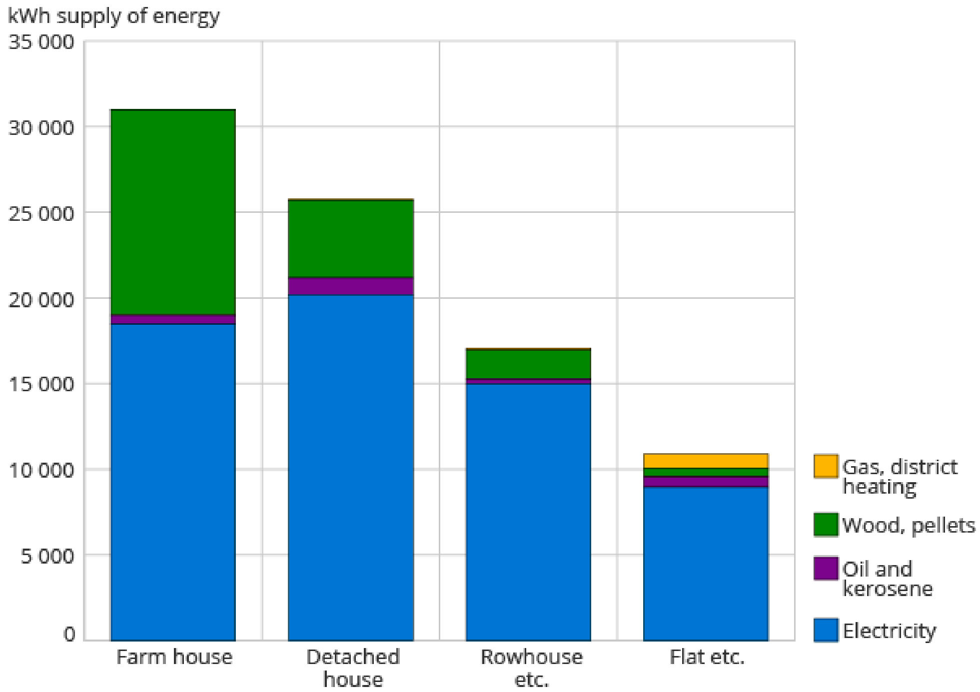


Figure 2.9. Average energy consumption, by household type
Source:(SSB, 2014)

According to Figure 2.9 (above), the farmhouse is the biggest energy consumer, and the energy consumption of flats is the lowest quantity (SSB, 2014). Most of the electricity is used by the detached house and farmhouse consume the highest quantity of wood and pellets (SSB, 2014). Moreover, gas and district heating are used by the flat alone (SSB, 2014). And detached houses are consuming the is more than twice compared to the apartment buildings (SSB, 2014).

2.4.4 Heating system

At present, between 50 and 80% of energy consumption in homes relates to heating (Enova, 2019a), to some extent 60% of total energy is consumed by the space heating and cooling systems, which poses the biggest potentiality in terms of energy demand reduction, develop energy security and reduces the CO_2 emissions (économiques, 2013).

Norway is one of several countries where electricity is the prime heating source (SSB, 2014). 73% of households use the electricity-based heating system, to some extent 48% of people use an electric space heater, 7% use electric floor heating system and 21% of households use the air-air heat pump of central heating with the electricity (SSB, 2014). Fuelwood is the main source of heating system of 12% of households (SSB, 2014). Around half of the farmer stated that wood is their main heating source and their usage of wood correspond to around 11-12000 KWh per year (SSB, 2014).

In Norway, there are various kinds of heating systems are used. Around 70% of the buildings use the electric heating systems, where some use the only heating system or other use the combination of different heating systems (Vanhoutteghem et al., 2009). Around 12% of people use the hydronic heating system and most of the hydronic system is being used in new houses that run by electricity (Vanhoutteghem et al., 2009).

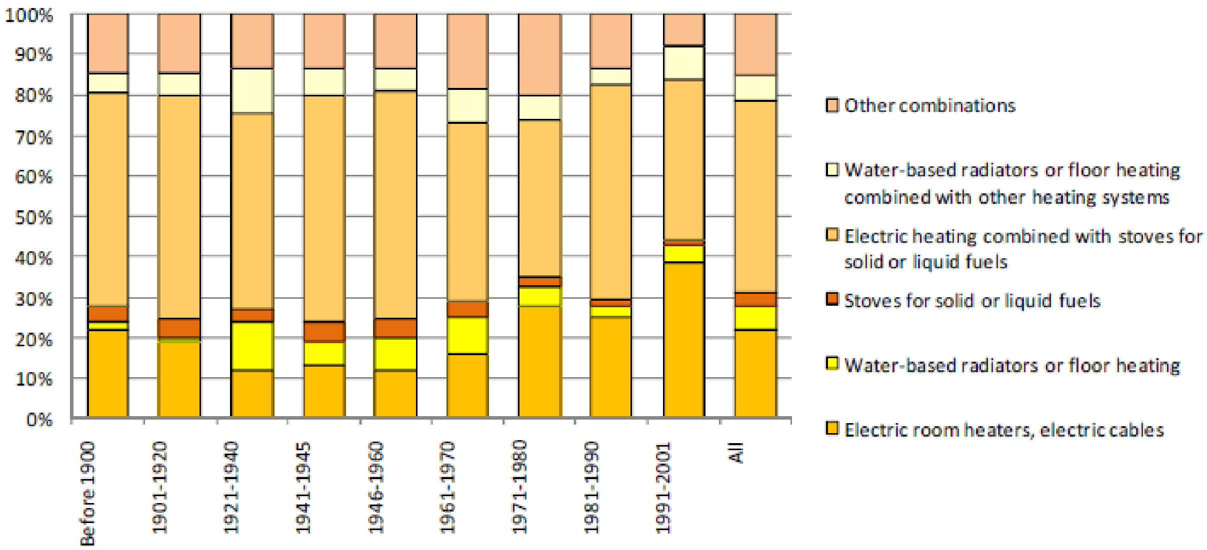


Figure 2.10. Heating systems in the Norwegian dwelling stock, by the year of construction[29]
Source: SSB. (Thyholt et al., 2009)

2.4.5 Ventilation and thermal insulation

The Norwegian government is implementing strict building regulations regarding the technical sides of the building since 1950 (Gullbrekken & Time, 2019). Many revisions have been made, in recent decades, about the necessity of heat insulation of building parts. However, the condition for the air change rate of the building envelope has been reduced from 4 to 1.5 h-1 (at 50 pa pressure difference) (Gullbrekken & Time, 2019). Heat recovery of the ventilation air included in the requirement in 2010 (Gullbrekken & Time, 2019). According to Myhre (1995),

[29] I have contacted with SSB for the most update data, but they said that new data will take time to publish

the prime aim of the Norwegian building regulations of 1949 was to present an adequate indoor climate[30], moreover, Norwegian building regulation 1965 hardly included the matter of thermal upgrading[31](Gullbrekken & Time, 2019). However, thermal insulation level conditions were rigidified in 1985 (Gullbrekken & Time, 2019).

How the level of insulation approved by the Norwegian Building Research Institute have upgraded slowly from 1952 to today, which is presented in Table 2-3 (below)

Table 2-3. Technical minimum demands for energy performance/thermal insulation given for building envelope parts according to the Norwegian building regulations throughout the studied years. TEK97 means 1997 and so on

Building part		1949	1965	1985	1987	TEK97	TEK07	TEK10/TEK17	
							*	*	**
Wall	[W/m²K]	0.70–1.05	0.46–0.58	0.35	0.30	0.22	0.18	0.18	0.22
Window	[W/m²K]			2.7	2.4	1.6	1.2	0.80	1.2
Door	[W/m²K]			2.0	2.0	1.6	1.2	0.80	1.2
Roof	[W/m²K]	0.70–1.05	0.41–0.46	0.23	0.20	0.15	0.13	0.13	0.18
Basement walls	[W/m²K]	1.16–1.86	1.57–2.33	0.8	0.8	0.22	0.18	0.18	0.22
Floor towards external air	[W/m²K]		0.41–0.46	0.23	0.20	0.15	0.15	0.10	0.18
Slab on ground	[W/m²K]			0.3	0.30	0.15	0.15	0.10	0.18
Window area	[m²/ m² heated area]			0.15	0.2	0.2	0.2	0.25	0.25
Air change rate, n_{50}	[1/h] at 50 Pa			4	4	4	2.5	0.6	1.5

*Energy measures method.
**Minimum requirements for the building part, which imply stricter requirements for other building parts to fulfil the overall energy norm.

(Gullbrekken & Time, 2019).

2.4.6 CO_2 Emission

According to the SSB (Statistisk Sentralbyrå) 52 million tonnes of greenhouse gas has been released from the overall Norwegian territory in 2018 (SSB, 2019a).

[30] Cited from: (Myhre, 1997)

[31] Cited from: (Granum, 1989)

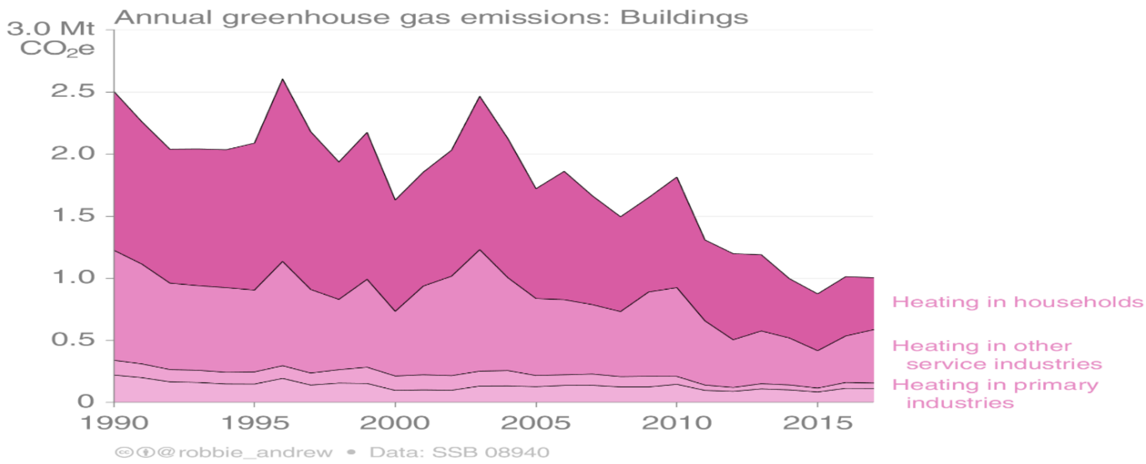


Figure 2.11. Annual Green House gas emission: Buildings in Norway[32]
Source: (CICERO, 2019)

Figure 2.11 (above), shows that the average household CO_2 emission has dropped to twice 2015 as it was in 1995 (CICERO, 2019). Since 1995 the heating is the biggest producer of CO_2 in the residential sector (CICERO, 2019). The residential sector has reported producing around 1.4 Mt in 2015. According to the Survey of SSB (Statistisk Sentralbyrå) 0.4 million tonnes of greenhouse gas have been emitted from the heating sector in households in 2018 (SSB, 2019a).

It is presented in Table 2-4 (below) that oil and gas extraction is the biggest sector of CO_2 emission among all the indicators in the table while heating is considered as the lowest producer of CO_2 in 2018 (SSB, 2020b). The growth rate of overall CO_2 emission from 2017 to 2018 is -0.9%, at the same time very lowest growth rate of CO_2 emission is presented in the heating sector which is -15.9% (SSB, 2020b).

Table 2-4.Emission to air

Emission of greenhouse gases (Mill. Tonnes CO_2 equivalents)		Change in percent (%)	
	2018	1990-2018	2017-2018
Emission from Norwegian territory	52.0	1.1	-0.9
Oil and Gas extraction	14.2	73.1	-1.0
Energy supply	1.8	326.3	-2.7
Heating in other industries and households	0.8	-69.4	-15.9

Source:(SSB, 2020b)

[32] I have contacted with SSB for the most update data, but they said that new data will take time to publish

2.5 Government action plan to make the residential sector more energy efficient

Collaboration and cooperation among the institutions is the key point of Norwegian authority to lower the emission in the broader sense (regjeringen, 2010). The state policy should spar complex technological and institutional changes for enhancing the EE and annihilating the imbalance of microeconomic interests at the national and international arenas (Arpan, Xu, Raney, Chen, & Wang, 2018). Moreover, it is a universal truth that harmonization among the existing actors is crucial to combat worldwide factors such as GHG emission.

The government needs to cater to a standard policy, strong institutions, and competent public services to secure the growth of the private sector, they are also mandated to improve and sustain the institutions which implement, supervise, and control these policies (Krarti et al., 2019). The private sector is key to economic growth, but it cannot run and does not act alone, the public sector should design a balanced strategy, the "Technology push and Market pull" tactics,[33] (Krarti et al., 2019). The UN's Sustainable Development Goals target 7.3 (SDG 7.3) is to "make twofold the worldwide rate of improvement in EE by 2030"[34](Krarti et al., 2019).

2.5.1 Norwegian energy efficiency policy

The Norwegian approach to EE has been featured by the country's relatively rich supply of energy (Aune, 2007; Godbolt, 2015; Ryghaug & Sørensen, 2009; Sørensen, 2007). After the so-called oil crisis in 1973, the reformed government policy was based on the perception that to save energy was not an end-user in itself; rather, the goal was to improve the profitability of the production and use of energy (Ryghaug & Sørensen, 2009). And the result was that policymakers featured the EE issue to emphasize economic facets rather than energy conservation: EE measures should be profitable (Ryghaug & Sørensen, 2009).

Thus, the dominant energy policy in Norway has mainly relied on the idea that energy should be harnessed in an economically optimal way (Ryghaug & Sørensen, 2009). This strategy is called the 'energy economizing' (in Norwegian: 'Energiøkonomisering' abbreviated ENØK). The official discussion of ENØK focuses on the following issues, (Ryghaug & Sørensen, 2009)

- Utilization of the produced energy in Norway and distributions of that energy will be the most efficient way within the agreed frames of profitability.

[33] Cited from (Brocato, 2010)
[34] Cited from (UNECE, 2017, p. 1)

- Reduction of costs when trading one energy carrier for another (substitution).

In terms of materialization, ENØK has been presented in two ways: as a governmental policy suggesting incentives to stir EE activities and as a suggested strategy to be implemented by pertinent actors to enhance EE within their domain (Ryghaug & Sørensen, 2009). In terms of building industry, ENØK has reflected a governmental propose to be connected to the EE as well as some incentives to instigate such activities, apart from this being an overall strategy for doing EE (Ryghaug & Sørensen, 2009). However, based on the above discussion about ENØK, the content of ENØK was unclear as government policy as well as a strategy to be followed by the downstream actors (Ryghaug & Sørensen, 2009).

Norway has focused on the economically optimal uses of energy in ENØK more than public energy conservation efforts in the majority of the other countries, while this Norwegian policy is not much different compared to the EE policy of other countries (Ryghaug & Sørensen, 2009).

The factor of EE is very ambiguous in the definition of ENØK, as EE is not possible to optimize energy use and energy costs at the same time (Ryghaug & Sørensen, 2009). This perception made ENØK into a strategic formula that could be discussed to point that one should look for ways either to lower energy costs or to save energy (Ryghaug & Sørensen, 2009). In terms of implementation, the first interpretation has attracted the policymakers, placing EE so-to-speak in the iron cage of economics (Ryghaug & Sørensen, 2009). Nevertheless, as pointed above, a competing engineering interpretation has also pointed to the policies on the development and implementation of technologies to achieve energy conservation (Isachsen, Rode, & Grini, 2011; Sørensen, 2007) .

Within the area of the building industry, the ENØK strategy of the policymakers has not been diffused as thought (Ryghaug & Sørensen, 2009). Rather, what has been spread is an ambiguous notion that one should be concerned about energy, mostly a motivation to build for growing the EE but without increasing the construction costs (Hubak, 1998; Moe, 2006) (Ryghaug & Sørensen, 2009). Hubak (1998) mentioned an example about a discussion with heating and ventilation (HVAC) engineers who argued that suggest technological solutions that would help to energy conservation without including too much to building costs, according to the ENØK (Hubak, 1998; Ryghaug & Sørensen, 2009). However, they said it was struggling to get such proposals accepted (Ryghaug & Sørensen, 2009).

While HVAC engineers stated that, while they could serve fairly accurate assessments of costs, they lacked the obligatory information to provide the strong calculations of future economic profits for the builder or owner (Ryghaug & Sørensen, 2009). This made it difficult to construct scenarios that would be significantly attractive to other actors (Ryghaug & Sørensen, 2009). To be practical, ENØK could not be materialized as it was impractical for the actors connected to calculation what would be economically optimal solutions (Ryghaug & Sørensen, 2009).

The dominant EE strategy in Norway ENØK only narrowly has influenced the practices in the building industry (Ryghaug & Sørensen, 2009). This is because of the underlying and misleading idea that actors should accept so-to-speak a co-optimization of EE and economic outcomes in their decision making (Ryghaug & Sørensen, 2009).

Norwegian authorities have emphasized primarily on the general principles of ENØK, presenting a strong a belief that relevant actors, for instance in the building industry, will respond according to ordinary economic theory to price signals and other financial instruments, thus making mind to scale up the energy standards when price increase, although this perception is flawed (Ryghaug & Sørensen, 2009).

2.5.2 Technical Regulations

TEK 17

Buildings are responsible to consume about 40% of total energy in Norway, hence it is very important to consume the energy in an efficient way (energifaktanorge, 2019). Buildings standards have a prolonged history in Norway, since the implication of energy requirements for buildings in 1949 (energifaktanorge, 2019). The ministry of local government and modernization is liable to fix the requirements of the Technical Regulations on buildings (energifaktanorge, 2019). The Technical Regulations address primarily to new buildings along with the renovation of an existing building (energifaktanorge, 2019).

Norwegian building code has continuously emphasized the EE issues of the buildings over the long period, which is resulted in the reduction of the energy demand since the ELDRE (First Norwegian building code) (DNV, 2018a). The Technical Regulations to the Planning and Building Act (TEK) have emphasized the changes in energy consumption and reduction of the demand in the building (regjeringen, 2010). In the first update in 2007 (TEK10), the issue of EE in the building sector has been considered from a stricter point of view compared to previous regulations (Ministry of Local Government and Regional Development, 2007). The

TEK10 has not brought a lot of changes but it banned to install the fuel oil boilers (Ministry of Local Government and Regional Development, 2010). Moreover, since 2010 the energy labeling of buildings must be attached in terms of selling or renting the house (Norwegian Water Resources and Energy Directorate, 2011).

The most recent TEK17 is very much like TEK10 in terms of conditions such as use the EE, reduction of the emission of CO_2, and the reduction of the energy demand (regjeringen, 2010). To more precisely, there was massive importance to install more renewable energy sources in big buildings in TEK10 (regjeringen, 2010). Moreover, environmental taxes have been implemented to lessen the detrimental emissions to the air and the water along with the degeneration of the amount of waste (regjeringen, 2010). These legal elements lead to implement several implications in terms of certification or different labeling in the building and energy sector.

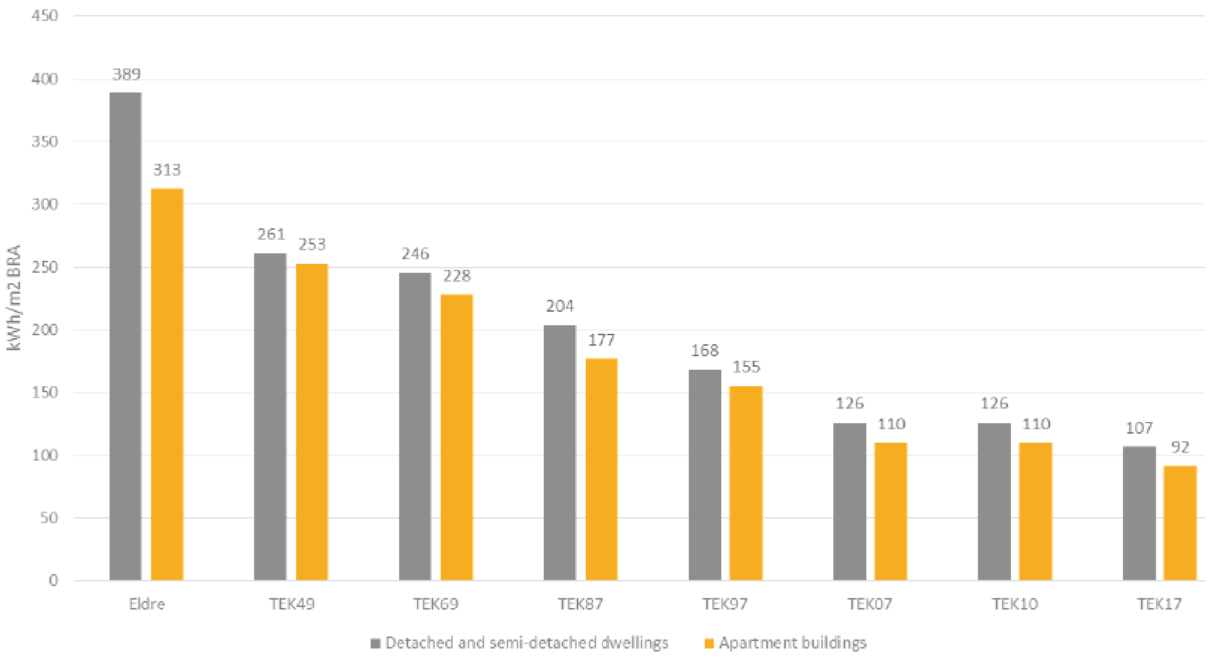


Figure 2.12. Development in calculated specific net energy demand based on building code and building tradition (Multiconsult, simulated in SIMIEN)
Source: (Multiconsult, 2019)

Figure 2.12 (above) shows that Energy demand has reached to less than half, 107 and 92KWh/m^2 in a detached house and apartment buildings consecutively, in TEK17 (DNV, 2018a; Multiconsult, 2019). According to the DNB criterion, the buildings which are being built according to the regulations of TEK10 and TEK17, are qualified for Green Bonds since they are the top 7% of the most energy-efficient building in Norway (DNV, 2018a; Multiconsult, 2019). Moreover, the energy reduction rate is around 15% form TEK07 to

TEK17 and around 25% of the reduction rate has been reported between TEK97 and TEK07 (DNV, 2018a; Multiconsult, 2019). The below-mentioned Table 2-5 (below) will show the difference between TEK10 and TEK17 (DNV, 2018a; Multiconsult, 2019),

Table 2-5. Specific energy demand calculated for model buildings

Building code	Specific energy demand apartment buildings (model homes)	Specific energy demand other dwellings (model homes)
TEK 10	110 kWh/m^2	126 kWh/m^2
TEK 17	92 kWh/m^2	107 kWh/m^2

Source: (DNV, 2018a; Multiconsult, 2019)

The average net energy demand should not be crossed the level of energy requirements, which is listed in Table 2-6 (below)

Table 2-6. Energy Budgets

Building category	Total net energy requirement [kWh/m^2 heated gross internal area per year]
Small houses and leisure homes with more than 150 m^2 of heated gross internal area	100 + 1,600/m^2 heated gross internal area
Block of flats	95
Kindergarten	135
Office building	115
School building	110
University/university college	125
Hospital	225 (265)
Nursing home	195 (230)
Hotel building	170
Sports building	145
Commercial building	180
Cultural building	130
Light industry/workshop	140 (160)

Source: (dibk, 2017)

In the over mentioned Table 2-6 (above), it is delineated the energy requirement of different types of houses. The next table will present the energy-saving measures in small houses and blocks of flats.

Table 2-7. Energy-saving measures

	Energy-saving measures	Small house	Block of flats
1.	U-value outer walls [W/(m² K)]	≤ 0.18	≤ 0.18
2.	U-value roof [W/(m² K)]	≤ 0.13	≤ 0.13
3.	U-value floors [W/(m² K)]	≤ 0.10	≤ 0.10
4.	U-value windows and doors [W/(m² K)]	≤ 0.80	≤ 0.80
5.	Proportion of window and door areas of heated gross internal area	≤ 25%	≤ 25%
6.	Annual mean temperature efficiency ratio for heat recovery systems in ventilation systems (%)	≥ 80%	≥ 80%
7.	Specific fan power (SFP) in ventilation systems [kW/(m³/s)]	≤ 1.5	≤ 1.5
8.	Air leakage rate per hour at 50 Pa pressure difference	≤ 0.6	≤ 0.6
9.	Normalised thermal bridge value, where m² is stated as heated gross internal area [W/(m² K)]	≤ 0.05	≤ 0.07

Source: (dibk, 2017)

In this Table 2-7 (above) all the indicators are same between small houses and flats, but normalized thermal bridge value, where m^2 is stated that as heated gross internal area [w/(m^2k)] between the small house and flat is 'less than or equal to' and 'greater than or equal to (dibk, 2017).

Moreover, the minimum requirements for EE are shown in Table 3-8 (below),

Table 2-8. The minimum requirements for EE

U-value outer walls [W/(m² K)]	U-value roof [W/(m² K)]	U-value floors on ground and facing open air [W/(m² K)]	U-value windows and doors, including frames [W/(m² K)]	Leakage figures at 50 Pa pressure differential [air change per hour]:
≤ 0.22	≤ 0.18	≤ 0.18	≤ 1.2	≤ 1.5

Source:(dibk, 2017)

Blocks of flats with the central heating system and non-residential residents must have dedicated energy meters for heating and hot water (dibk, 2017).

Pipes, ducts, and equipment that are connected to the heating system in the building must be insulated (dibk, 2017). And the thickness of insulation should be economically optimal, it must be accounted for based on the Norwegian standard or like the European standard (dibk, 2017). The use of fossil fuel in the heating system is not allowed and the heated area of a building will be the gross internal area of more than 1000m2, which will have various heating sources along with the adoption for use of low heating-temperature heating solutions (dibk, 2017).

2.6 Measures of ENOVA for the residential houses

Enova, a public enterprise owned by the Ministry of Petroleum and Energy (Søraa et al., 2019). Enova was established in 2001 to drive the transition to more environmentally friendly consumption and energy generation in Norway (Søraa et al., 2019) (Olaussen, Oust, Solstad, & Kristiansen, 2019). Enova’s measures include full renovation support and support for energy-saving measures – such as the implementation of heat pumps, solar energy utilization, and balanced ventilation – as well as monetary support for energy consultation and renovation (Søraa et al., 2019). Further, Enova, in collaboration with the building industry represented by “the low-energy programs”, set up a course to educate and certify energy consultants (Søraa et al., 2019). Enova has different schemes based on construction year, which is discussing below,

2.6.1 Measures of ENOVA for the houses before 1960 (Translated from Norsk):

The older house, the bigger consumer. Enova will not provide support for all energy measurements (Enova, 2019b). Enova focuses on the re-insulation of a home as it provides you lower energy costs and better living comfort (Enova, 2019b). Re-insulation is well matched for the houses built in the 80s or earlier (Enova, 2019b). When owners in the process of renovation or up-gradation, it is cost-effective to re-insulate at the same time (Enova, 2019b). There are some positive impacts of re-insulation homes, (Enova, 2019b)

- *you reduce the house's heat loss and energy consumption.*
- *you get a better indoor climate and increased living comfort.*
- *you can combine the re-insulation of exterior walls with the modernization of the home.*
- *the house can get a better energy label, which in turn can increase the value of the home.*

How do homeowners should know to re-insulate?

The year of the construction of the houses is the best indication to re-insulate. If the house was built before 1955, it is frequently leaky with little or no insulation (Enova, 2019b). At that time, it was also common to fill floor dividers and roofs with shavings or clay. Through the re-insulation, it is possible to save several thousand kWh\y (Enova, 2019b).

If the house was built after 1955, there is probably mineral wool in the walls and ceiling\attic. The thickness of the insulation is far less than today's requirements (Enova, 2019b). Regarding the comfort, environment, and economy, it is sensible to re-insulate the attic in particular (Enova, 2019b). This is because of the insulation has probably been pressed and deformed (Enova, 2019b). The houses from the 70s, 80s, and 90s generally have 10 to 20 CM thick insulation, which is considerably less than today's requirements (Enova, 2019b).

The economic benefits of re-insulation: (Enova, 2019b)

- *The re-insulation of roofs (from 10 to a total of 30 CMs), 23 kWh/m^2 insulated area, or NOK 2,300 / year at 100 m^2.*
- *The re-insulation against cold basement (from 10 to a total of 20 CMs), 15 kWh/m^2 insulated area, or NOK 1,500/year at 100 m^2.*
- *Exterior re-insulation of the exterior wall with new wind seal (from 10 to a total of 25 CMs, leakage rate improved from 6.0 to 2.5), 39 kWh/m^2 insulated area, or NOK 2,900/year at 100 m^2.*
- *The U-value for building components provides the standard of thermal insulation, the lower the U-value the better.*

Table 2-9 below shows the requirements of U-verdi have changed over time, (Enova, 2019b),

Table 2-9 The development of U-values

Utvikling av u-verdi	U-verdi tak	U-verdi gulv	U-verdi yttervegg
Byggeforskriftene 2017	0,18	0,18	0,22
Byggeforskriftene 2010	0,18	0,18	0,22
Byggeforskriftene 1997	0,15	0,15	0,22
Byggeforskriftene 1987	0,2	0,3	0,3
Byggeforskriftene på 1960- og 70-tallet	0,41	0,58	0,46
Byggeforskriftene på 1940-tallet	1,05	0,93	0,93

2.6.2 House built between 1960 and 1987 (Translated from Norsk)

The houses from this period have 3 times as high an energy need for heating as today's modern homes (Enova, 2019c). House built in the 60s are often insulated with 6-7 CMs thin glass cotton, while others have no insulation at all (Enova, 2019c). In the 70s and 80s, it got popular to insulate more, and houses from this time often have featured 10-20 CMs of insulation, which is better, but not equivalent to the level of modern standards (Enova, 2019c).

Post-insulation is often implemented as a part of a lager upgrade, but also individual measures. Re-insulation gives higher temperature on surfaces such as walls and windows, so it is possible to remove the cold drafts. And the room temperature can be reduced without the comfort doing so (Enova, 2019c).

Lower energy windows/fluorescent window

Windows is a typical house make up just 5-10% of the total exterior, surface, the windows can reduce as much as 40% of heat loss, and heat loss depends on the quality of glass, size of the window, the airtightness and the insulation (Enova, 2019c). The energy savings from the up-gradation of windows varies from home to home, according to the requirements of TEK17, energy-saving will be mentioned below, (Enova, 2019c)

- *Per m2 window: 40 kWh / year, or NOK 40 / year.*
- *For the entire home (27 m2 window): 1,080 kWh / year, or NOK 1,080 / year.*

2.6.3 The contribution of ENOVA in 2019

In 2019, Enova paid out a total of NOK 334 million in support to *20789* energy measures in Norwegian homes (Enova, 2019a). Both figures are noticeably high. Phasing out 2848 old oil furnaces is a part of the picture as well (Enova, 2019a). We are noticing a slow increasing interest in scaling up the energy measurements of existing buildings (Enova, 2019a). Moreover, Enova has also provided the grant to 733 homeowners to hire expertise to construct an energy plan for their renovation project (Enova, 2019a). Enova has also contributed to improving both the scope and quality of the energy upgrades (Enova, 2019a). A change is creating in the market, while there will be a call for extra measures to ensure further development and that the impact in the market is permanent (Enova, 2019a). 20000 of individual measures in Norwegian homes are also being supported, to invest for energy smart solutions in their homes (Enova, 2019a). In the case of removing oil tanks, Enova provides the grants to 5400 homeowners to remove the oil tanks along with purchasing another renewable heating system, such as a heat pump (Enova, 2019a).

2.6.4 Financial instrument

The polluter pays (Green taxes) is the core issue of the Norwegian policy framework on climate change (regjeringen, 2020c). In the white paper on the 2030 climate strategy (Meld St. 41 (2016-2017) the government emphasized the cost-effective solution to reach the 2030 target (regjeringen, 2020c). Consecutively, they impose a tax for the non-ETS emission, in addition to this, increment the support for the R&D project to develop climate-friendly technologies (regjeringen, 2020c). Emissions from heating from households and industrial buildings are also obliged to pay the CO_2 tax, which equivalent to 2% of the total national emissions (regjeringen, 2020c). The main goal of the government to designing stricter rules to stimulate the house owner or industry owner to use different heating systems (as the fossil-based heating system is banned from 2020) as well as to reach the 2030 target (regjeringen, 2020c). Moreover, the government expects that it is possible to mitigate 1.105 million tonnes (2017 white paper on long-term perspectives for the Norwegian economy, presented in NC7/BR3) CO_2 in 2020 and 2030, and the biggest contributor to the reduction will be the transport sector (regjeringen, 2020c). Many policy instruments have already been implemented by the Norwegian government to control emissions such as support for R&D, taxes, regulations (regjeringen, 2020c). In 2016, the Solberg Government launched a financial support scheme, which is called Klimasata, to reduce the emission at the local level and speed up the transition to a low emission society (regjeringen, 2020c).

KBN (Kommunel BANKING) has provided low-rate green loans for the investments that contribute to mitigating the climate problems of the future since 2010 (KBN, 2020). KBN's green loans are financed by the Green Bonds (KBN, 2020). Figure 2.13 (below) has shown the Green project portfolio, where is presented that the highest amount of loan has been allotted for the buildings which are 58.9%, whereas the least amount of investment has been reported in EE, renewable energy and, climate change adaptation.

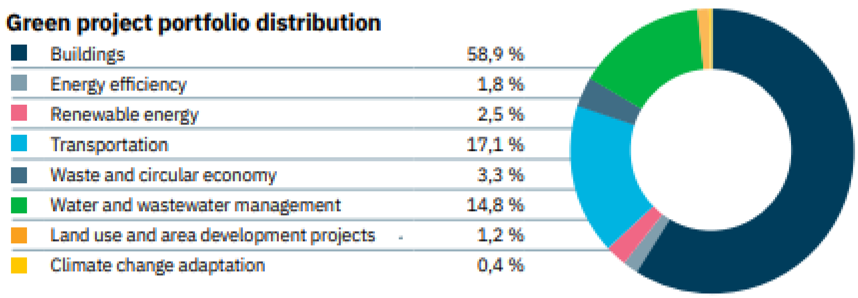


Figure 2.13. Green project portfolio distribution
Source: (KBN, 2020)

There is a significant growth of green loan in the last several years, in 2019 the green lending portfolio has been risen by 3.7 billion NOK. which is shown in Figure 2.14 (below).

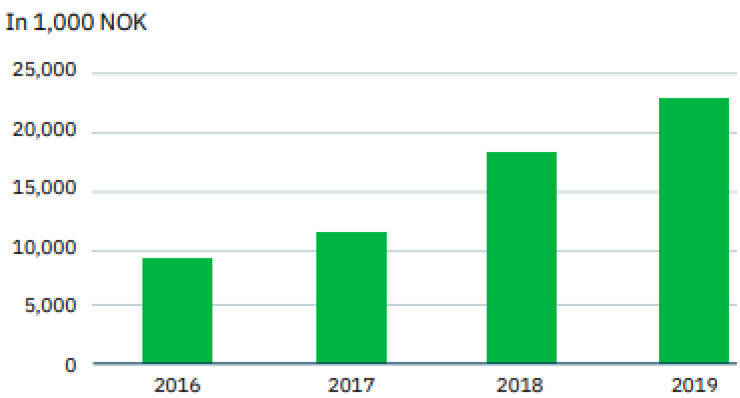


Figure 2.14. Outstanding Green Loans

Source:(KBN, 2020)

There is 25% of the reduction of energy consumption has been noted through the KBN's investment project relative to the previous investment as well as phase-out of fossil energy sources (KBN, 2020).

2.7 The climate agreement regarding the building sector

Very recently, Norway has presented an amplified climate target under the Paris agreement (regjeringen, 2020b). The new target is to decrease the emissions with a minimum of 50%, and towards 55% by 2030 compared to the level of the year 1990 (regjeringen, 2020b). Norway is one of the first countries that presents an enhanced target under the Paris agreement (regjeringen, 2020b). Norway agrees to meet the strengthened target in affiliation with the European Union (regjeringen, 2020b). Norway has already committed with the EU to reduce the emissions minimum of 40% by 2030 compared to 1990 levels (regjeringen, 2020b). Moreover, they are a few focus points, such as,

- *Importance to the energy-efficient building through the supervision of Enova*
- *Stop using of oil-fired of heating*
- *The transition from fossil fuel to renewable sources of energy for the heating*
- *The low-energy program*
- *Monitoring od inspection of the building project*
- *Energy conservation*
- *Energy check and climate standard for the state procurements*

  Source: (regjeringen, 2010)

2.8 Building renovation scenario in Norway

According to the Gram-Hansen, energy retrofitting of private dwellings is the very challenging areas of energy policy due to this task is completed by the homeowners themselves, without having enough knowledge about energy retrofitting, despite having several policy incentives regarding the energy retrofitting, for the homeowners but they appear Stubbornly resistant to improving their homes, EE[35](Fyhn et al., 2019).

[35] Cited from (Wilson, Crane, & Chryssochoidis, 2015)

Norwegian authorities have a 40 years history of EE policies, while social sciences research has presented that these measures have had very low success in consumption of energy in the buildings as a whole[36], private dwellings to more precisely[37](Fyhn et al., 2019). However, it is noticeable that the rate of EE for new buildings has improved over the decade while retrofitting of existing homes are not properly identified with the demarcation of those regulations (forskning, 2019; Fyhn et al., 2019). Even though Norway spend around ninety-four billion NOK per year to renovate the houses, which is subject to improve the aesthetic aspects rather than the energy/emission reduction (Fyhn et al., 2019). Private dwellings, which constitute around 80% of all homes, reflect the biggest category of building-related energy consumption (Fyhn et al., 2019). Norwegian authority emphasizes improving the level of EE in the existing building stocks through retrofitting/renovation to contribute to the climate change mitigation policy[38](Fyhn et al., 2019).

Therefore, this thesis has selected the matter of the importance of EE of the old houses, the necessity of improvement of the overall level of efficiency is distinct in the old buildings, which is built on since the 1950s and those are very energy-intensive and produced a remarkable amount of CO_2. Moreover, Norwegian authority is working since the 1970s to improve the efficiency level, while the improvement of the project is not up to the mark, due to some constraints regarding different actors in these surroundings.

According to the key actors of Norwegian energy policy, it is mandatory to retrofit holistically to get a higher level of EE and the holistic method is shown in Figure 2.15 (below) which is designed by the Housing bank[39](Fyhn et al., 2019).

[36] Cited from (Karanfil, 2009)
[37] Cited from (Enova, 2012b)
[38] Cited from (Arnstad, 2010)
[39] Cited from (Dokka & Hermstad, 2012)

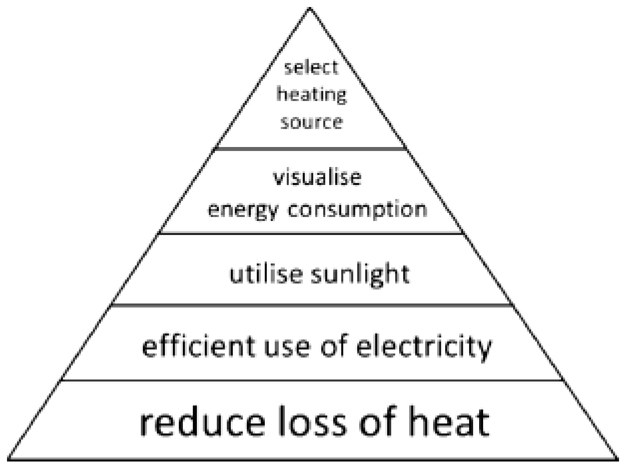


Figure 2.15. Kyoto pyramid[40]
Source: (Fyhn et al., 2019)

It says that insulation and work on a building envelop are much more crucial than the installation or use of some technologies in the building (Fyhn et al., 2019). If someone plans to retrofit, it should be started from the base of the pyramid by the lowering of heat-loss, which is the foundation for other measures, and that is performed by increasing insulation and strengthening of tightening (Fyhn et al., 2019). The second step indicates to use the electricity efficiently as much as they can. In this way, it should run until reaching the top with choosing the right heating source and it is very important to follow the steps orderly to retrofit the house (Fyhn et al., 2019). For example, if some install the new heating system without improving the insulation, which results in less-optimal impact (Fyhn et al., 2019).

Residential buildings in Norway are mainly detached wooden houses, about 60% of detached houses were built between 1960 and 1990[41](Gullbrekken & Time, 2019). The building envelops and technical systems of that period are maintained with the substandard EE measures relative to the level of today, which presents a potential source to save energy through renovation[42](Gullbrekken & Time, 2019). In line with the European Union Directive 2010/31, the Norwegian government has announced that all new buildings should be built with the standard of nZEB level by 2020 (Gullbrekken & Time, 2019). It is important to concentrate on the existing building stock regarding save energy. It is possible to save up to 8 TWh through the renovation of detached houses built before 1990 (Gullbrekken & Time, 2019).

[40] Cited from (Dokka & Hermstad, 2012)
[41] Cited from (Statistisk, 2010)
[42] Cited from(Risholt, 2013)

According to Risholt (2013), a big number of single-family houses have been renovated in the last couple of years, but people are emphasizing the aesthetic matter rather than the efficiency issue due to lack of proper instructions[43](Gullbrekken & Time, 2019). Two possible measures for renovating to zero energy standard are suggested, firstly emphasize to the façade solution, that incorporates improving the thermal properties of walls, windows, doors, installation of balanced ventilation and renewable energy production on-site, and the second option is to upgrade the building envelop to passive house standard, installation of ventilation and renewable energy production on-site (e.g. BPIV) (Gullbrekken & Time, 2019).

Only half of the renovation of buildings has performed energy renovation[44](Gullbrekken & Time, 2019). A building envelops have a life cycle of 30-50 years, where it is mandatory to replace when necessitates, if we replace the cladding without attaching insulation, we, therefore, may result in "energy lock-in" (Gullbrekken & Time, 2019).

Hence, In Norway, the old buildings will consider a large share of building stock for many years, for Norway share will be around 50% in 2030 (H. Li & Nord, 2019). Space heating is used in those buildings, which are designed with supply temperature would be presumed to occur discomfort for the residents (H. Li & Nord, 2019). It is possible to lower the supply temperature to less than about 60°C for over the whole year, through the replacement of existing windows (H. Li & Nord, 2019).

The overmentioned paragraph shows the urgency of the renovation of old houses which is much important to increase the level of efficiency, to reduce the GHG emission along with the completion of government climate target. However, this is the justification of choosing the topic of "EE in the old houses", so this thesis will find out the ways to improve the level of efficiency in the buildings to reach the government's climate target.

2.9 The Norwegian reference scenario in terms of EE

"*Scenarios are descriptions of journeys to possible futures. They reflect different assumptions about how current trends will unfold, how critical uncertainties will play out, and what new factors will come into play*"[45](Schanes, Jäger, & Drummond, 2019).

[43] Cited from(Risholt, 2013)
[44] Cite from (Risholt, 2013)
[45] Cited from (UNEP, 2002)

In Table 2-10 (below), it is showing the projections of the number of population and number of households and the persons per household, it is conspicuous that, the number of households and the household area is bigger than the population growth (NTNU, 2015). Moreover, the per dwelling and per person will also expand, whereas the number of persons per dwelling will continue to fall (NTNU, 2015).

Table 2-10. Key statistics and assumptions used in the projection of residential energy

	Starting year	Starting value	2030	2050	Yearly growth 2010-2050
Population (mill.)	2010	4.858	6.037	6.681	0.80%
Households (mill.)	2010	1.587	1.982	2.197	1.08%
Persons per household	2010	2.24	2.07	2.00	-0.28%
Share of multifamily houses of new dwellings	2000-2013	55.9%	56%	56%	
Area per new dwelling (m^2/dwelling) - single family house - multifamily house - average	2009-2013	 163.8 93.0 133.0	 164 93 133.0	 164 93 133.0	
Renovation rate (% per year)			2.0%	2.0%	
Demolition rate (% per year)			0.3%	0.3%	
Alternative population projections: - Low LLML - High HHMH	 2010 2010	 4.858 4.858	 5.607 6.553	 5.646 8.393	

Source:(NTNU, 2015)

The concerned development of both historical data from 1970 to 2012 and projection 2012-2050, with 2010 as the base year is shown in Figure 2.16 (below)

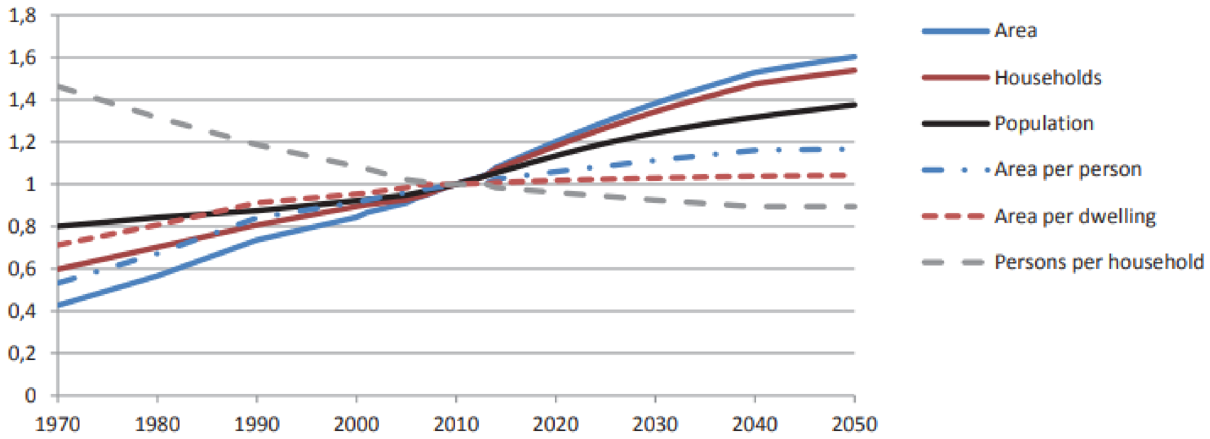


Figure 2.16. The relative development of key parameters of residential projection; statistics 1970-2012, projection 2012-2050; 2010=1
Source:(NTNU, 2015)

The demand of residential energy service from 2010 to 2050 has been depicted in Figure 2.17 (below) the reference path consists of EE improvements from renovations and predicted impacts of the directive of energy labeling of appliances and lighting (NTNU, 2015). The energy service demand will grow from 44 TWh in 2010 to 51 TWh in 2030 along with 55 TWh in 2050 in the reference path(NTNU, 2015). EE lowers the demand by 7 TWh in 2050 in the reference path relative to the Frozen efficiency path. The dwelling area increase from around 263 mills. m2 in 2010 to about 420 mills. m2 in 2050, with a yearly average increase of 1.2% (NTNU, 2015). if the population projection apart from pursuing the middle path of statistics Norway will increase according to the high and low projections, the demand for the energy service is accounted as 24%higher or 25% lower than the reference path in 2050 (+13 TWh to -8 TWh in 2050) (NTNU, 2015), that is shown to the right figure,

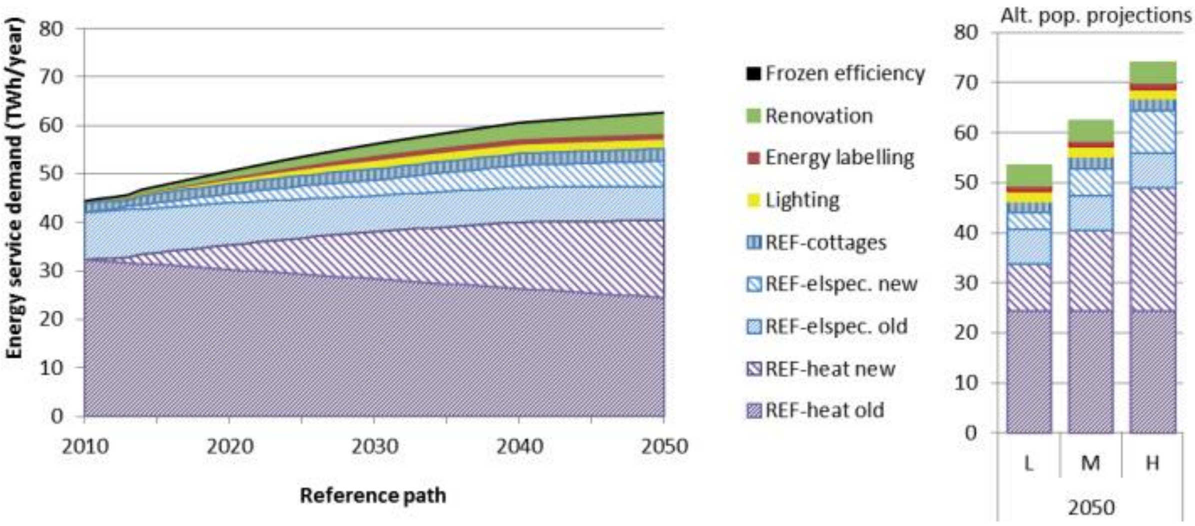


Figure 2.17. Residential energy service demand 2010-2050 for the reference path to the left and with alternate population projection on the right L=Low, M=Medium, H=High population growth (TWh\year)
Source:(NTNU, 2015).

Over the whole background presents a detailed picture of the Norwegian building sector, energy consumption, GHG emission, Norwegian government planning and policy reports and targets, and the EE scenarios. This background part will pave the way to formulate the theory, based on the findings in the introductory part and background part in details. The focus of this thesis is to answer the question “how to improve the level of EE in the existing residential buildings in Norway” in response to this question, this thesis will unearth the key barriers regarding the EE improvement in the existing residential building stock in Norway and presents some possible solutions to overcome those barriers.

3 Theoretical framework:

Efforts to improve the EE in the home have waxed and waned over the decades since the oil shocks in the 1970s when the financial incentives increased significantly to lower the energy consumption (Wilson et al., 2015). subsequently, policy implementations regarding the EE are again ascendant, induced by climate mitigation and energy security targets (Wilson et al., 2015). Therefore, the embark of the theoretical framework will analyze the concept of EE and EE gap in the buildings, which is the precursor of the creation of barriers. The concept of EE is widely discussed among the scholar from time immemorial in environment and energy sector, however, the explanation of EE is varied from country to country, while scholars, environmentalists, and governments are agreed upon to improve the level of EE. Since global warming is bringing the different types of threats for human civilization, so it is crucial to reining in the control of emission. I have already analyzed the importance of the EE and EE gap in buildings form global and local (from the perspective of Norway). Moreover, the thesis has shown a clear scenario about the building sector where the majority of houses in Europe are energy-intensive and emitting noticeably, distinctively a gap to improve the efficiency level in the building sector. To improve the efficiency status in the buildings needs to implement an in-depth renovation, to pour money, and to change in the lifestyle. However, most of the countries are constructing new policy instruments, an extraordinary agenda, and announcing climate policy targets to deal with this significant issue, the scenario, in effect, is not seemed much expected. Consequently, there are several constraints that retard the improvement of EE in building to be more précised.

The rise of energy consumption has resulted in the continuous increase of energy demand, the principal factors of energy consumption are industrialization and development in all aspects of human civilization (Amoruso, Donevska, & Skomedal, 2018; Gupta, Anand, & Gupta, 2017). The alternate sources of energy particularly renewable sources are getting developed and reinforced the existing energy system, but it will need a long time to depend completely on the renewable sources of energy production (Alam et al., 2019; Gupta et al., 2017). In the present context, the importance of efficient consumption of energy is considered as a comprehensive and plausible solution to the crux of increased energy consumption (Amoruso et al., 2018; Gupta et al., 2017). The stemming challenges in the way of energy conservation or EE are a significant number (Gupta et al., 2017). There is numerous research work have been completed on the various factors which are blocking the progress of EE measures as well as several obstacles has been diagnosed by many researchers from time to time (Gupta et al., 2017).

However, all these barriers and measures are either not identified in proper manner or are highly localised. A very scanty attempt has been made to reflect this issue in a holistic manner (Gupta et al., 2017).

3.1 What is energy efficiency (EE)?

EE currently is a burning issue in the public agenda of most developed countries. The significance of EE as a policy matter is connected to commercial, industrial competitiveness, and security benefits, along with important to environmental positive outcomes such as emission cuts (Patterson, 1996). EE is a very generic term, there are no evident and clear quantitative measures of 'EE'(Patterson, 1996). Rather than this, it is key to rely on several parameters to measure changes in EE. In general, EE refers to produce the same amount of services or useful output (Patterson, 1996). For instance, if a house is insulated, heating, and cooling use less energy to achieve a satisfactory temperature (BGS, 2020). Patterson (1996), also stated that EE is the outcome of the same among of useful work (output or service) by utilizing relatively less amount of energy (Gupta et al., 2017; Patterson, 1996). In that definition points to the adoption of measures that result in the consumption reduction of energy (Gupta et al., 2017). Efficient energy use is gained byways of more efficient technology or process, energy-efficient buildings, industrial processes, and transportation might lower the world's energy demand by 2050 by one-third as well as pave the way to rein in emissions globally (BGS, 2020). The focus of this thesis is to describe it from the residential perspective, which refers to the renovation or refurbishment (regarding increase the EE) and changing the old technologies in the old buildings, as around two-thirds of the buildings in Europe account as old building stock, which represents a massive potential to improve the EE in the old building stocks. In Norway, 98% of electricity is produced by renewables (hydro and wind power), which is almost emission free production of energy (Bye, Fæhn, & Rosnes, 2018). Reduction of energy related emissions can be achieved by energy appliances switching, changing of other appliances for energy, lowering the production in energy using industries and/or final consumption (Bye et al., 2018). Around 80-90% of houses are being featured as old building stock, that provides an immense opportunity for the Norwegian government to improve the EE in the old residential buildings through renovation or changing the outdated appliances (Bye et al., 2018). However, despite having an immense potentiality in the old building stock, yet there is an evident gap, exists in the process of up-gradation of EE in the old residential building in Norway buildings (Bye et al., 2018). Norway is a very small country, a massive amount of energy but with quite long, cold, and dark winter (Godbolt, 2015). Electricity is very cheap and this energy is considered environmentally friendly (Godbolt, 2015). EE policy of Norway has been featured by the domination of the economic approach, rather than technical efficiency (Godbolt, 2015; Karlstrøm, 2012). Furthermore, this has been placed in policymaking concerning households, in which people has been motivated to take their energy consumption in economic point of view and to be inspired to save money through energy savings. in line with this, EE has primarily been thought a behaviour that ought to be handled by economic rationality (Godbolt, 2015). This thesis has discussed the Norwegian energy efficiency policy in the background section, the energy efficiency policy (ENØK) had not diffused properly in the building industry and had created an ambiguity among the stakeholders (Ryghaug & Sørensen, 2009).

Over more than three decades, the Norwegian government has implemented variegated policies or strategies to improve the EE in the building design, while the achievements may be pointed as modest at best (Ryghaug & Sørensen, 2009). Why that so? The fact of EE of buildings needs to be perceived as connected to a complex socio-technical system where different actors work at the centre point of industry, market structures, institutions of governance, innovation systems, evaluation practices, supplier-users chains, designer and engineering practices, etc (Ryghaug & Sørensen, 2009). Therefore there are several possible points of failure or gap, and the challenges in presenting a comprehensive analysis solution are alarming (Ryghaug & Sørensen, 2009).

Many scholars and publications have shown that the existence of a “gap” between potential cost-effective EE measures and measures implemented the so-called “EE gap” or “energy paradox” (Thollander, Palm, & Rohdin, 2010). Moreover, “the ratio of Maximum quantity of energy services obtainable to the quantity of final energy consumed is EE” (Greening, Greene, & Difiglio, 2000; Gupta et al., 2017; Herring, 2006; Patterson, 1996). However, different scholars have presented various definitions of EE. Giacone & Manco (2012) state that the efficiency can be viewed as useful work done while the lack of efficiency is wastage regarding the other types of energy other than as expected during the planned process (Giacone & Mancò, 2012; Gupta et al., 2017). Subsequently, energy can be harnessed in the right way which is controlled by the proper systems and procedures it needed, which leads to the research on the systems and processes for EE[46](Gupta et al., 2017).

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[46] Cited from(Hu & Wang, 2006)

There is the number of parameters for energy use measure buildings, but one of the most prevalent parameter for energy use measure is energy use intensity (EUI) which is given by US government (EIA, 2015), apart from this there are also different models(simplified engineering methods, statistical methods and, artificial intelligence methods) to measure the energy use in buildings (Greening et al., 2000; Gupta et al., 2017). However, it is important that the evaluation of these parameters has not been influenced the energy consumption to some extent (Gupta et al., 2017; Zhao & Magoulès, 2012) Building sector has a vast impact on the environment if analyzed from head to tail of a building (Gupta et al., 2017). The potential benefits of EE in buildings are significant but it is frequently obstructed by the different types of barriers, structural, economic, social, and behavioural barriers, which impede the adaption of EE measures in buildings (Gupta et al., 2017; Hesselink & Chappin, 2019). However, renovation or retrofitting is a very complex process, and there several barriers that impede the building renovation project to improve the level of efficiency (Alam et al., 2019; Marquez, McGregor, & Syme, 2012).

The "efficiency gap" is an issue that has been discussed by the scholars around a decade, which can be defined as "the slower than optimal adoption of energy-efficient technologies"47(Hesselink & Chappin, 2019). Furthermore, the efficiency gap as the hypothetical EE level which can be acquired through solving all the barriers which hinder EE adoption (Hesselink & Chappin, 2019). Since the 1970s there is a noticeable gap between the potentially profitable EE progress and the effective implementation of measures (Cagno, Worrell, Trianni, & Pugliese, 2013). As Jaffe and Stavins (1994) stated that "low uptake of EE, a long-standing paradox known as the EE"[48](Giraudet, 2020). In the beginning, this problem has been identified through unusual high implicit discount rates in terms of buying the EE products, which results in that consumers give away general profitable investment opportunities (Giraudet, 2020; Train, 1985). Most recent researches have shown that the EE gap suggests the energy savings measured after investment underperform those predicted by engineers' simulations before investment"[49](Giraudet, 2020). Apart from these, the gap from the consumer perspective, which represents the individual's costs, on the other hand, there is an efficiency gap regarding the societal outlook, that reflects both private and external costs (such as the environmental costs to energy production) (K. C. a. K. Palmer, 2020). Society might

[47] Cited from(Jaffe & Stavins, 1994)
[48] Cited from(Jaffe & Stavins, 1994)
[49] Cited from(Fowlie, Greenstone, & Wolfram, 2015)

be enjoyed the benefits of the investment from EE improvements when the aggregated cost of an EE investment is lower than for an alternative investment (K. C. a. K. Palmer, 2020). For instance, in some situations, it could seem more logical for the society to reduce the energy consumption rather than invest in a new gas plant that will result in bigger merged economic and environmental costs for society (K. C. a. K. Palmer, 2020). Therefore, minimizing the gap of EE is not only beneficial for the private consumer perspective but also the society as a whole (K. C. a. K. Palmer, 2020).

Three broad categories are presented to analyze the EE gap, market failures which bar the investment form social aspect, non-market failures that limit investment without influencing the social welfare, and behavioural barriers create the irrational basis for the investment along with the vague implications for social welfare (Gerarden, Newell, & Stavins, 2017; Giraudet, 2020). Recently information problems have also been identified as a key cause for the EE gap[50](Giraudet, 2020). Barriers of EE is followed by the “EE gap” or “energy paradox” which will be discussed in the later sections (Thollander et al., 2010).

3.2 Identification of barriers to energy efficiency (EE) in buildings

“A barrier to EE is a mechanism that inhibits investment in technologies that are both energy-efficient and cost-effective for the potential investor in such technologies”(O'Malley, Scott, & Sorrell, 2003, p. 15). In scientific literature, a diverse set of Barriers that hammers or hinders the progress, movement or development of something, in the respect to the EE and extensive literature survey along with the stakeholder feedback, several barriers have been identified (Gupta et al., 2017; Hesselink & Chappin, 2019). Barriers exist which are slowing the extension of energy-efficient buildings. It is widely acknowledged that readily available and financially sustainable technology could significantly improve the EE of buildings, but the possibility is not yet be understood. Perceiving the barriers which are controlling the implementation should try to identify holistically which is pictured in Figure 3.1 below mentioned,

[50] Cited from(Howarth & Andersson, 1993)

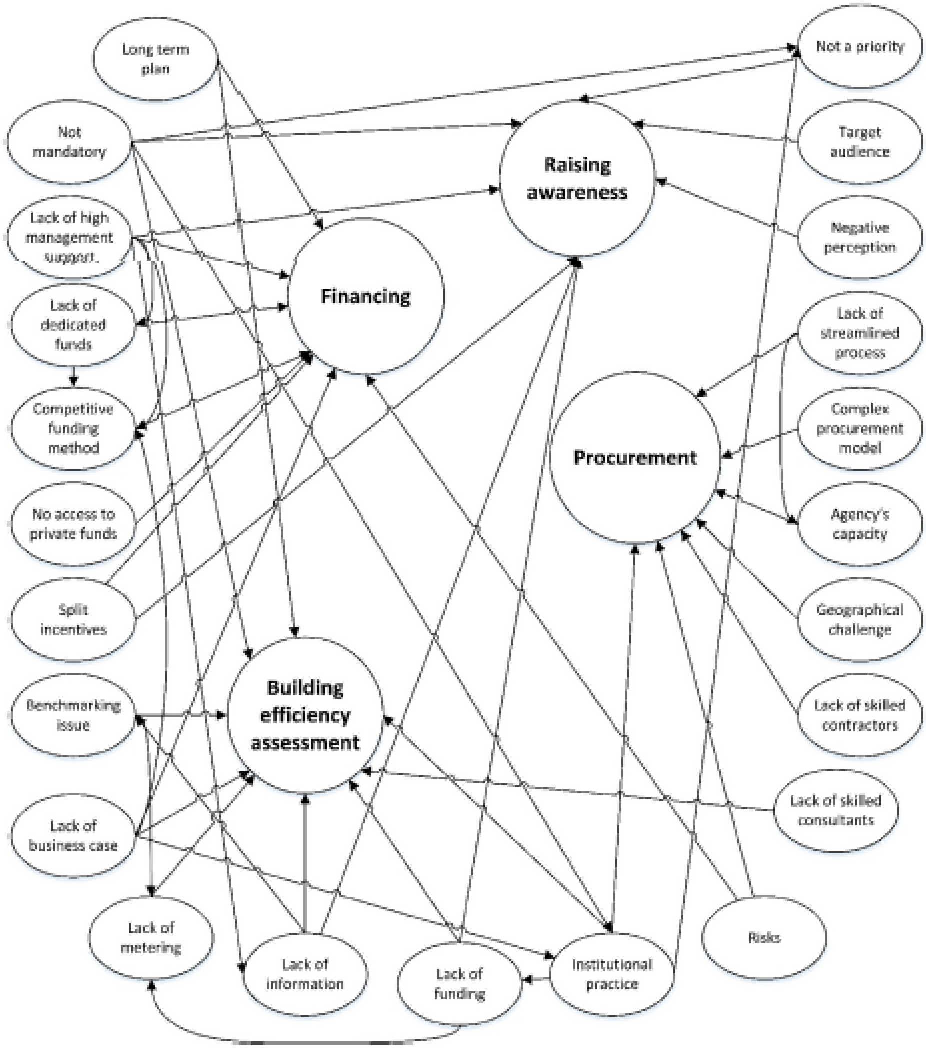

Figure 3.1 Barriers to the building energy efficiency(EE)/ energy retrofitting
Source: (Alam et al., 2019)

3.2.1 The economic perspective:

Economic and financial barriers are a very crucial group of barriers that which hinder the progress of EE in buildings, to analyzed the impact of economic barriers are classified into different categories such as Scarcity of Financial Means, Absence of Lucrative, Poor Arbitrage, Inadequate Monetary Assessment, and Limitations in Financial Provisioning, which is described to some length below (Gupta et al., 2017):

The non-market failure

Heterogeneity, although the technologies for the EE can be cost-effective on average for the particular class of users, the class itself forms of distribution of consumers, some of them might afford economically to purchase the technology, whereas others encounter the difficulties to purchase the cost-intensive technologies to improve the level of EE (Alam et al., 2019; Cagno et al., 2013; Jaffe & Stavins, 1994). Credit constraints are another sample of market failure which may reflect the EE gap (K. C. a. K. Palmer, 2020). If customers cannot buy the cost-intensive appliances which would result in the energy savings in the long run and customers cannot secure the credit of that investment (Gillingham & Palmer, 2014; K. C. a. K. Palmer, 2020). Subsequently, in this type of situation buyers do not act rationally which leads to loss aversion which means an overweighting of losses over gains (K. C. a. K. Palmer, 2020). A purchaser could be disinclined to buy an appliance with a high upfront investment, even if the benefits will overweight rather than investment in the long run, despite this consumers are very aware of the immediate monetary loss (Greene, Evans, & Hiestand, 2013; K. C. a. K. Palmer, 2020).

Hidden cost, cost of EE products, EE projects, or measures are significant factors, frequently has viewed a sheer inconsistency in real and perceived cost, the involvement of hidden costs in the EE projects is obstructing to develop the EE products or technologies (Cagno et al., 2013; Gupta et al., 2017; K. C. a. K. Palmer, 2020). In retrofitting project, the real energy cost and saving cost may differ from the estimated savings, because of not providing proper guidelines about several key parameters during design, construction and operation stages (Alam et al., 2019; Hou, Liu, Wu, Zhou, & Feng, 2016; Thomas, Gokarakonda, & Moore, 2018). For instance, the interruption in the production process is not being considered while planning which results in the increment of costs (Gupta et al., 2017; K. C. a. K. Palmer, 2020).

Access to capital, lack of financial means is the most key parameter that hindering the process of EE, want of enough funding, scarcity of capital for EE projects, lack of access to capital to accomplish the renovations and insufficient availability of resources and inefficient infrastructural support, these lead to creating the financial scarcity (Gupta et al., 2017; Haase et al., 2020). Despite having less investment, in many circumstances investments and benefits are not distributed proportionately among the parties that influence investment decisions (Hesselink & Chappin, 2019; Schleich, Gassmann, Faure, & Meissner, 2016). For instance, one of the key causes for the steady pace of the EE process in the buildings is the lack of incentive and a proper financial model and only a small budget has been allotted to support energy savings in Norway (Aasen, Westskog, & Korneliussen, 2016).

In some circumstances, building owners do not have enough financial capability to invest for the renovation of their buildings (Alam et al., 2019; Amoruso et al., 2018; Castleberry, Gliedt, & Greene, 2016; Marquez et al., 2012). In Norway, the EE concept is growing among the people, but the lack of economic incentives, the higher cost of appliances, and applications along with the long-term investment return stop people to start the renovation in their home (Amoruso et al., 2018).

Lack of funding opportunities or inability to save investment on justifiable conditions is one of the most cited constraints to go for the investment in EE measures51, which influences all types of ownership from the landlords to the tenants (Haase et al., 2020). The absence of financial structures or competitive funding methods to effectively perform, adapt, and maintain EE projects is a key issue (Gupta et al., 2017; Palmer, 2020).

Absence of lucrative, profitability of the EE program is a massive concern, because of the trend of less profitability with a massive investment employed (Gupta et al., 2017). Payback and up-front investment costs are key facts that oblige owners, public and private institutions to think twice before taking the investment decision (Haase et al., 2020). The technologies installed for EE, the renovation of old buildings, structures, and processes are costly which resulting in the reduction of profitability (Gupta et al., 2017). Moreover, Lack of suitable financial modeling and other studies such as lifecycle costing or payback period, which often presents an unstructured scenario of profiting of such projects (Gupta et al., 2017; Hesselink & Chappin, 2019; Moglia, Cook, & McGregor, 2017). Several studies have presented that, cost-effective ways are not always followed regarding the improvement of EE of a building, because of the technical shortcomings, behavioural constraints related to the information, authenticity of information and conflicting motives among the group of owners (Backlund, Broberg, Ottosson, & Thollander, 2012; Berg & Donarelli, 2019; Thollander et al., 2010). At the same time, a lack of proper understanding of energy and economic saving through achieving the EE for a long period also creates a foggy landscape of profitability (Alam et al., 2019). Owners generally prefer to get quick benefit rather than waiting for the longer-term benefit, apart from these they more focus to reduce the expenditure on renovation maintenance and new equipment's cost over the long-term benefits of energy-saving. over the (Alam et al., 2019). Moreover, in many situations, house owners can prioritize other things rather than the issue of EE, due to lack of the proper long-term public policy (Hesselink & Chappin, 2019). Owing to the cheaper electricity, the potential savings from the EE measures are being faded in face of the benefits

[51] Cited from (Nye, Whitmarsh, & Foxon, 2010)

from other investments (Alam et al., 2019; Caputo & Pasetti, 2017; Paiho & Ahvenniemi, 2017).

Poor Arbitrage, an inefficient risk assessment regarding the financial risks blocks the adoption of EE measures. In both cases, high discount rates for the EE and the rejection of the energy-efficient technologies manifest the risk factors (Cagno et al., 2013; Gupta et al., 2017). Lack of researches on the profitability of EE, incompetency of results involved with economic benefits of EE process, wrong evaluation of auditors of financial outcomes, catering the inconsistent assessment of the financial risks to green building adoption which impact badly the EE programs as well (Gupta et al., 2017). Moreover, another crucial issue is split incentives where investors do not receive the proper profit that is fixed before the investment (Alam et al., 2019; Amoruso et al., 2018; Caputo & Pasetti, 2017; Hesselink & Chappin, 2019; Hirst & Brown, 1990).

The market failure

Spilt incentives, also named as misplaced incentives, which is pointing to the appropriation of the benefits, which is considered as a key hurdle to progress EE projects (Alam et al., 2019; Cagno et al., 2013) (Young, 2013). The most referred example is landlords and tenants in the housing market (O'Malley et al., 2003). The house owners of the buildings do not want to invest for the renovation to reduce the energy consumption along with the up-gradation of energy performance and level of comfort, since the savings or outcomes would be enjoyed by the tenants (O'Malley et al., 2003; K. C. a. K. Palmer, 2020). And simultaneously tenants are not willing to invest in raising the level of EE in the buildings as they might move out before benefiting fully from the cost savings as generally payback period of the EE investment is longer (O'Malley et al., 2003). It occurs while the tenants who are liable to pay the energy bill are not the same entity as those finalise the decision for the capital investment such as landlords or building owners (O'Malley et al., 2003; Young, 2013). The principal agent problem can be particularly occurred when the rental market cannot clear the differences in energy costs to consumers (K. C. a. K. Palmer, 2020). From the theoretical sense, it is permissible for the landlords to raise the rent if they invest in energy-efficient appliances as tenants would be benefitted from the lower electricity bills (K. C. a. K. Palmer, 2020). In this perspective, tenants will not understand the energy savings advantage due to the lack of proper knowledge and will decide the rent elsewhere because of high rent price, which leads to discouraging the landlords to invest for EE (K. C. a. K. Palmer, 2020). The misplaced incentives are also analyzed as a form of market failure resulting from incoherent information (O'Malley et al., 2003). One side might have related information on the costs and benefits of EE investment, while the other party does not get the information (O'Malley et al., 2003). If there might have no information complexity, both the landlords and tenants would be able to sign the contract to share the cost and benefits of the investment (O'Malley et al., 2003).

Adverse selection, misconceived knowledge on energy pricing, on market demand, on market size, the quality and effectiveness of the products create an ambiguity about the EE products as a whole (Cagno et al., 2013). Adverse selection occurs during the transaction between two parties, to some extent when one party does not have the proper information about that product before entering the contract to sell or buy, this impacts negatively the decisions of buyers or sellers (O'Malley et al., 2003). For instance, despite having the standard products, while having the ambiguity in information, buyers cannot choose the right one as information is not clear to them (O'Malley et al., 2003).

Moreover, the possibility of adverse selection will rely on the nature of the goods or services. According to Golove and Eto (1996), the market for energy services is highly diverse (Golove & Eto, 1996; O'Malley et al., 2003). At one point, we have energy supply (KWh) and on the other part, we have EE investments, for instance, insulation (O'Malley et al., 2003). But in between, some products use energy (e.g. appliances) and products that impact the use of energy (e.g. building material) (O'Malley et al., 2003). These services, in most cases, are purchased directly or through intermediaries such as construction firms or maintenance firms. In the intermediate cases, EE is a secondary matter of the product and service and comparatively invisible frequently (O'Malley et al., 2003). As Hewett (1998) opines that, most of the EE products and services have the features that buyers con not instantly ensure their real quality despite having previous experience with their purchase (Hewett, 1998; O'Malley et al., 2003). The ever-changing nature of the information of the products makes consumers perplexed to choose the right choice (O'Malley et al., 2003).

Apart from these, Slow market adoption of energy-efficient products, deficiency of steering mechanisms, partialized reasoning about EE, and absence of business case understanding are key barriers(Gupta et al., 2017). Hence, buyers currently, are prepared to buy the products with the visible benefits such as prefer to choose the cheaper appliances rather than the expensive one, while not intended to spend relatively bit more amount for the EE products that are featured with the long term benefits (Alam et al., 2019; Cagno et al., 2013; Gupta et al., 2017).

It is very evident to notice that there is price competition in the market regarding the products of EE or buildings (Amoruso et al., 2018; Gupta et al., 2017).

There is substantial demand-gap of energy-efficient products, scanty of customer's interest in EE products, uncertainty in demand of energy-efficient products are very usual in the market of EE programs (Gupta et al., 2017; Hesselink & Chappin, 2019; Pelenur & Cruickshank, 2012).

3.2.2 Government or procurement perspective:

Government barriers is another types of barriers which also impede the progress of EE measures, to present the in-depth analysis of government barriers it is classified into different sections such as lack of financial motivation, bridals in hierarchical inspiration and functional congruity, the difference in the plan of action for energy and environment integration, inappropriate antecedences, absence of standards and references, and strong authority, those are explained below; (Gupta et al., 2017).

Shortage of financial motivation, scarcity of financial incentives, or no-incentives or spilt incentives are the key constraints to promote the EE measures (Giraudet, 2020; Gupta et al., 2017; Hesselink & Chappin, 2019; Nezhnikova et al., 2019). It is very prevalent to not distribute the financial incentives in a suitably manner or not pointing to the cause of the problem that influences EE, as well as a high upfront investment, make house owners reluctant to start renovation project (Gupta et al., 2017; Hesselink & Chappin, 2019; Pelenur & Cruickshank, 2012). Lack of funding and intention to the maintenance and improvement of communal areas of the building are a very common problem (Berg & Donarelli, 2019). Lack of maintenance urges the owner to do partial renovation (Berg & Donarelli, 2019). And If the government pays a decisive promise to policies which spar the sustainability (both incentives and requirements) which can cater a long-term rosy impact on building owners' inclination to upgrade their houses (Alam et al., 2019; Caputo & Pasetti, 2017; Paiho & Ahvenniemi, 2017).

Bridles in hierarchical inspiration and functional harmony, EE measures incorporate many stakeholders, all of whom have vested but not noticeably related to the interests and it generally includes, apart from the buyers and sellers, users of energy-consuming assets and as buying costs can be important credit providers, so in this context who is accountable, if the investment of service cannot meet the expectations (Giraudet, 2020). The absence of proper leadership in governmental and political parties are an important constraint to impede the EE project

(Bjørneboe, Svendsen, & Heller, 2018; Cagno et al., 2013; Gupta et al., 2017). For instance, Norway has implemented the EPC (energy performance contract) since 2003, but the guarantee offered by the EPC is necessary for its approval at the political level in all our case municipalities (Aasen et al., 2016). Politicians are always trying to create a competitive environment in influencing policy outcomes and being elected (Aasen et al., 2016). Apart from this, the long-term apprehension of the political parties to ensure the legitimacy in policies might play a role (Aasen et al., 2016). When the consideration comes to invest in energy savings measures, the politician must think about the risk of failure and a possible reduction in their competitiveness vis-à-vis other political parties (Aasen et al., 2016). Politicians do not have much knowledge about EE issues and they always consider firstly about their benefit from that service (Aasen et al., 2016). So, this conflict of interest has hampered the growth of the EPC and EE process (Aasen et al., 2016).

Moreover, the shortage of collaboration among different departments, agencies of stakeholders limits the activities regarding the progress of efficiency (Bjørneboe et al., 2018; Cagno et al., 2013; Gupta et al., 2017). Professionals from different background are got involved for the settling the energy usages in the buildings, in many cases, there are no concerned-professionals has expertise in the sector of buildings' EE, while they are concerned to ensure the EE that denotes the coordination challenge (Alam et al., 2019). Furthermore, political stability, organized government pattern, and viable making platform are key pillars to improvement. Energy consumption in buildings during design, construction, and operation stage is impacted by various professionals (Bjørneboe et al., 2018; Cagno et al., 2013; Gupta et al., 2017). In most aspects, the presence of expert professionals for the EE project is significantly low on a given project, but the responsibility for achieving EE is spread among them, thus indicating a collaboration challenge (Alam et al., 2019; Amoruso et al., 2018). In a multi-owner building, where the majority of all the building owners must take part to approve a decision and make a financial contribution, in some cases it can create complexity to invest for the energy savings investment (Alam et al., 2019; Paiho & Ahvenniemi, 2017).

Differences in the plan of action for energy and environmental integration, sustainability has a strong affiliation with the energy use and efficiency, environment, and other linked issues such as climate change or carbon credit, where the government can play a vital role to substantiate this linkage (Amoruso et al., 2018; Gupta et al., 2017). Lack of integration of energy and environmental factors while the policy is pictured, ambiguity on future energy process and fiscal policies, inadequate national policies and regulations, absence of strong authority of environmental enforcement, and competencies to acknowledge the demand for social regeneration can create the hurdles (Amoruso et al., 2018; Gupta et al., 2017).

Lack of standards and references, the government must have time-justified standards and references for the wider implementation to lead the EE (Alam et al., 2019; Amoruso et al., 2018). This is because of being outdated of the previous standard with time, however, governments must have the time-justified standards to adopt the updated changes (Alam et al., 2019).

Lack of strong authority, if the government shows the strong commitment to rules and regulations that will drive sustainability (both incentives and requirements), and also this can pave the way to make a prolonged-possibility on the building owners' intention to improve the level of efficiency (Alam et al., 2019). Having all the polices and a strong leadership or administrative basis, the expected result of the development of EE would not be achieved unless the policies are not materialized efficiently (Alam et al., 2019; Gupta et al., 2017). Moreover, deficiency of assessment and monitoring criteria, nonconformity of rules and regulations are also significant to address (Alam et al., 2019; Gupta et al., 2017). Apart from this, people have an intention to stick with the status quo rather than thinking to change for rational reasons and the convenience, since they try to avoid the hidden cost related to this project (Hesselink & Chappin, 2019; Moglia et al., 2017). In the case of a multi-owner building where the majority or all the property owners can involve in the decision-making process and make a financial contribution, it can be complex to carry on the investment for energy savings (Alam et al., 2019; Berg & Donarelli, 2019). The Norwegian housing stock is primarily private property, around 80% of Norwegian households belong to their house or apartment, and one-fourth of all dwellings are in multi-occupancy buildings (Berg & Donarelli, 2019; sentralbyrå).

Inexperience untrained persons, it is observed that there is an uncovered mistrust toward professionals, along with the lack of competent EE professionals which lead to creating confusion in investing in deep renovation (Haase et al., 2020). Moreover, individual homeowners and end-users find it difficult to find the experts and professionals to design the standard guidelines to go for the renovation (D'Oca et al., 2018; Haase et al., 2020). And the decision for the renovation is the biggest decision for some house owners, after purchasing their homes, so they want to get some guarantees that it is certain to increase the energy performance and overall comfort level, and reduce the energy-related expenses (Haase et al., 2020). proper training is key to deal with the new technologies such as technology for EE, as it is very general to encounter with new technologies, products, or methodologies to perform the work (Bjørneboe et al., 2018; Gupta et al., 2017; Hesselink & Chappin, 2019). So, without having the proper training, it is significantly difficult for the implementation, maintenance, and support (Bjørneboe et al., 2018; Gupta et al., 2017; Hesselink & Chappin, 2019). All the employees in this chain such as contractors, consultants, engineers must be trained properly to avoid the problems (Bjørneboe et al., 2018; Gupta et al., 2017; Hesselink & Chappin, 2019). For instance, a huge number of Norwegian buildings are maintained by the non-professionals, who are liable for any sort of maintenance and any climate adaptation of their properties (Berg & Donarelli, 2019). The shortage of competence in both the contractor market responsible for the suitable installation of energy savings measures along with the services of professionals (Alam et al., 2019). Controversial suggestions from professionals in terms of selecting the best method to renovate the buildings, frequently, create the ambiguity among the users over the installation of EE measures (Alam et al., 2019; Bjørneboe et al., 2018; Caputo & Pasetti, 2017).

3.2.3 Knowing and learning or Raising awareness barriers

Lack of cognizance, there are immense discussion and research has been done for the energy and EE issues yet there is a substantial deficiency to spread the proper guideline and the importance about the issues of the global climate crisis, benefits of EE in buildings (Alam et al., 2019; Gupta et al., 2017; Hesselink & Chappin, 2019). Often building owners and residents have dearth knowledge about the outcome of their actions on energy consumption and emission, and some owners have the perception that the investment for EE would not yield a return (Alam et al., 2019). However, Scanty of education about energy consumption and its impact, less-delivered information about the proper assessment of EE measures, and substantial deficiencies about the policies make this project stalemate (Alam et al., 2019; Gupta et al., 2017; Hesselink & Chappin, 2019). For instance, recommendations, in Norway, has been provided to improve the energy performance of the building or apartments, but provided recommendations are very general rather than précised and in some cases, the cost-effectiveness, technical adaptability, and historic features are not taken into consideration during providing the information (Berg & Donarelli, 2019). Although some house owners are cognizant about the fact of EE in the building, while they are not intended to go for the in-depth renovation to improve the efficiency level in their buildings unless the existing equipment is gone out of work or there is an apprehension to lose the rental capacity because of having some constraints (Alam et al., 2019; Bjørneboe et al., 2018; Caputo & Pasetti, 2017).

Furthermore, 'consumer acceptance' of the new technologies is documented widely52, where it shows that users or house owners often suspicious about new technologies mostly owing to the lack of knowledge, their understanding, feelings, interpretation of information, and finally worries, risk, and difficulties which they might feel about using the new technologies (Haase et al., 2020).

Lack of cognitive decision-making approach, decision maker's rationality is constrained by the tractability of the decision problem, the cognitive limitations of their mind as well as the time available to make the decision (Hesselink & Chappin, 2019; Schleich et al., 2016). Perceived lack of empowerment or decision making in an organization, deficient and incompetent approach of top management, anxious of losing support by leadership or top management, variation in the perception of managers, risk and fears involved with implanting new technology or systems which bar the progress of EE (Amoruso et al., 2018; Gupta et al., 2017). In many countries, the process of deciding to go for the in-depth renovation of the building is remarkably slow (Berg & Donarelli, 2019). A major part of the existing building stock is composed of multi-apartment buildings, features with multiple owners and the decision-making process are very complex in obligatory cases (Haase et al., 2020). Kalmykova et al. (2016), has stated that taking the majority's decisions is mandatory to go for any major renovation or doing any changes53(Haase et al., 2020). And another impact, of making consensus among the owners of multi-apartment buildings, is the asymmetrical distribution of benefits and costs of an energy renovation/retrofitting to the individual apartments (Haase et al., 2020; Whiffen et al., 2016). Moreover, behavioural failure of attention from the consumer's point of view, that points to a buyer either ignoring or misapprehension information germane to the decision they are deciding, where they may make the irrational decision (K. C. a. K. Palmer, 2020). For instance, information about energy usage is available, but the buyer may prefer not to read or take into consideration it while finalizing the decision (K. C. a. K. Palmer, 2020).

3.2.4 Building efficiency assessment barriers

Like other barriers building efficiency assessment obstacles also impact significantly to create hindrances in EE programs.

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[52] Cited from (Whiffen et al., 2016)
[53] Cited from (Kalmykova, Rosado, & Patrício, 2016)

Ill-defined vision or lack of long term plan, well-defined vision is a prerequisite for the success of any organization, however, less focus on the implementation of EE, less-focus on the management's time and emphasize on EE measures, showing inefficiency in the materialization of the policy of EE and lack of constructing a shared vision for the adoption of efficient technology are some of the organizational barriers (Hesselink & Chappin, 2019; Schleich et al., 2016).

Torpidity in process and practices, for efficient procedures of an institution, all the process, and systems implemented in an organization that claims a set of robust and efficient regulations (Caputo & Pasetti, 2017; Gupta et al., 2017). Requiring longer time to the process, demanding much time to design and to implement an integrated system and long process for the approval for new technologies and recycled materials that slower the project of EE (Alam et al., 2019; Gupta et al., 2017). And the renovation process itself demands a longer period (Haase et al., 2020). Norway has started to provide the EPC (energy performance certificate) to the municipalities to save the energy in 2003, only 21 municipalities out of 421 municipalities this EPC have received from 2003 to 2010 (Aasen et al., 2016). According to Mørk (2013), less amount of investment and lack of awareness about EPC has obstructed the development of EPCs in Norway and Norwegian municipalities have a substantial lack of the capacity to launch and follow up EPCs (Aasen et al., 2016; T, 2013).

Process related risk, technical risks such as the risk of production interruptions, less compatible with the real process along with the dearth of cutting-edge technologies lead to the creation of barriers (Alam et al., 2019; Gupta et al., 2017).

Interruption to building operation, it is very general that different types of difficulties can be encountered during renovation, such as occupants need to be relocated, the building needs to be vacated which demand extra expenses for the owners (Alam et al., 2019; Bjørneboe et al., 2018). This issue is corroborated by the substantial number of literature and researches which has denoted that one of the key hindrances to renovation is the disruption induced to residents (Feige, Wallbaum, Janser, & Windlinger, 2013; Haase et al., 2020; Sovacool, 2014).

Lack of information, because of conflict of interest among technology providers backed by the feeble legislation, it frequently causes that users or people dealing with EE products or factors are shaded with the false or misleading information sources which lead them to make sub-optimal decisions based on the provisional and uncertain information (Cagno et al., 2013; Giraudet, 2020; Gupta et al., 2017; Hesselink & Chappin, 2019). Sustainability or environmental performance and maintenance are not generally understood well by many property managers, building owners and occupants, as a result of this, Hewett stated, product or service is purchased infrequently (Alam et al., 2019; Amoruso et al., 2018; Bjørneboe et al., 2018; Cagno et al., 2013; Hewett, 1998). In many cases, building owners or occupants have a very little perception about the results of their actions on energy consumption and emission (Alam et al., 2019; Amoruso et al., 2018; Bjørneboe et al., 2018). Several building owners also have the perception that the investment for EE would not yield a profit (Giraudet, 2020). Rather, the requirement of EE is treated as compliance and cost burden by some consumers (Alam et al., 2019; Amoruso et al., 2018; Bjørneboe et al., 2018; Giraudet, 2020). *"Information-related barriers concerning homeowners and construction services play an important role in Norway to provide enough knowledge and raise awareness for the cost-effectiveness of measures"* (Amoruso et al., 2018). Furthermore, the shortage of knowledge about the available solutions (related to the EE) is an important barrier (Abd-ur-Rehman & Al-Sulaiman, 2016; Calì, Osterhage, Streblow, & Müller, 2016; Haase et al., 2020).

In addition to this, even after EE has been raised on a certain level, there would occur the Rebound Effect, due to the lack of proper information (K. C. a. K. Palmer, 2020). The rebound effect points to the situation where improved EE can result in an increase in energy use owing to the cost of energy service curve down (K. C. a. K. Palmer, 2020). This rebound effect consequently counterbalances the saving through the EE improvements to some extent (K. C. a. K. Palmer, 2020). For instance, a household purchases an upgraded energy-efficient washing machine that cheap to operate, the household may turn out to be using the washing machine more often, which creates the offset of the associated energy savings (K. C. a. K. Palmer, 2020).

Lack of metering, monitoring, and auditing to trace the energy-saving opportunities are cost-intensive and needed investment (Alam et al., 2019). The majority of the existing building either has no metering devices or outdated metering systems which do not present the proper data to evaluate the building EE (Alam et al., 2019). Owing to the scarcity of funding or proper information, owners install the cheap and substandard metering system which shows the insignificant value for effective decision making (Alam et al., 2019). Moreover, it is very common that there are not enough competent and promised consultants that can be trusted to accomplish the robust assessments on the EE of the building (Alam et al., 2019). In some cases, few of the consultants are too oriented to own monetary interests rather than unearthing solutions which are very crucial for the efficient operation of the clients building stock (Alam et al., 2019). These perceptions result in the creation of ambiguity about the assessment report which leads to creating the hesitation among the building owners about the investment for the EE project (Alam et al., 2019; Curtis, Walton, & Dodd, 2017).

Institutional practice, which points to the agency's usual practice which trammels a building EE assessment (Alam et al., 2019). Mostly, a piecemeal approach is practiced in case of the installation of monitoring devices without an organized long-term data collection plan continuous data monitoring of changes in energy consumption back and forth of the EE intervention is mostly not taken into consideration a high priority by senior management (Alam et al., 2019). The low priority of EE assessments also poses as an obstacle to improving the consciousness for EE in the agency (Alam et al., 2019).

Lack of benchmarking, which denotes the different functional facilities under the various climate conditions that produce less accurate assessment of building EE (Alam et al., 2019). At the same time, the absence of any mandatory requirements of EE, as well as less accountability, demotivate the building asset custodians to start EE retrofits (Alam et al., 2019).

Lack of business case, another key constraint of EE is the agency's inability to design a retrofit business case which will ensure finance flow for this project (Alam et al., 2019). There is also a lack of guiding regulations on how a private or public sector can carry on the EE project (Alam et al., 2019). Furthermore, the collection of detailed information on a building from the early stage to the end is very difficult (Alam et al., 2019). Because of not having enough experts to provide the key information for benchmarking the building (Alam et al., 2019).

3.3 Strategies to overcome barriers:

Overcoming these barriers requisites substantial commitment and leadership from the city and state authorities along with the willingness to perform jobs through the collaboration between the national and local governments, building and home-owners, developers, financiers, the building trades, and industries, and energy utilities (F. Liu, 2014). However, there are many solutions to overcome the barriers to improve the EE in the buildings, several potential points presents in the below-mentioned graph,

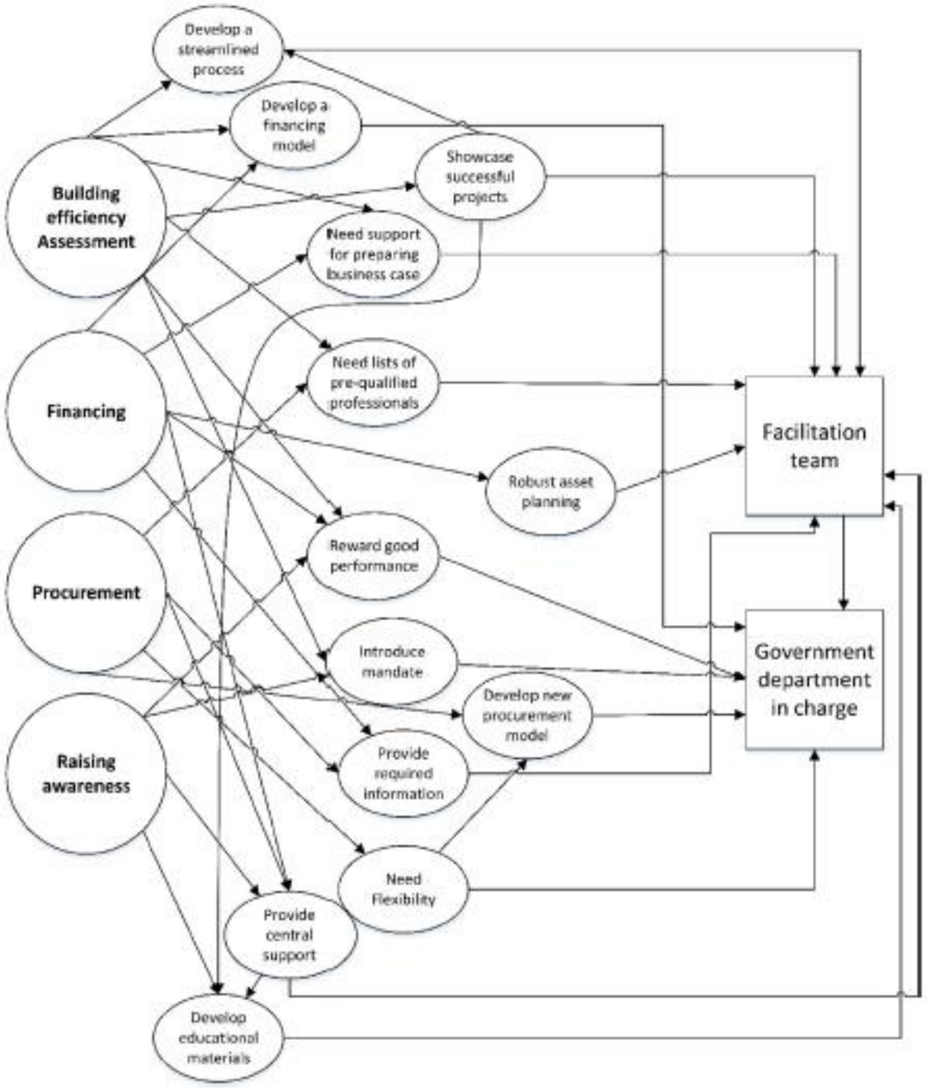

Figure 3.2 Strategies to overcome the barriers of EE in the buildings
Source: (Alam et al., 2019)

3.3.1 Strategies to overcome building efficiency assessment barriers

The most perfect strategy to overcome the barriers to building EE assessments is the design of a standard common assessment method and a comprehensive standardized certification process (Alam et al., 2019). It might also incorporate directions to ensure opportunity analysis and install EE measures (Alam et al., 2019). Subsequently, the creation of a framework of a financing model to buy and install monitoring devices (Alam et al., 2019). And it is important to emphasize the energy audit for the public agency and attaching the efficiency report at the entrance of the building (Alam et al., 2019).

A mingle of technology and engineering skills are key to receive the authentic information from the auditing; proper education or training facilities should be ensured for the professionals to produce the authentic report about the EE (Alam et al., 2019).

Apart from this, the public and private agency should be given the mandatory training and support to delineate a viable business case for the building efficiency assessment to evaluate the expenditure on building efficiency assessment and receive high management support (Alam et al., 2019). Moreover, this business case support is one of the key instruments to overcome the financing barriers which is described in the next section (Alam et al., 2019). The government should introduce a dedicated mechanism and a streamlined procurement process for EE projects so that all the departments or agencies can receive the required amount for their project (Alam et al., 2019).

3.3.2 Strategies to overcome financing barriers

Designing a financing model is the key to ensure simple access to the required investment for the EE upgrade (Alam et al., 2019). The investment model should be designed by the concerned body of the government which includes different types of economic support schemes for the owners of buildings (Alam et al., 2019). To some extent, the investment for the up-gradation of the EE, can be a form of allocation of a budget or a budgeting policy to provide support to the renovation program (Alam et al., 2019). Enova, In Norway, particularly provides all types of financial support for the renovation in buildings (Berg & Donarelli, 2019).

The next key task of the government to build an expert facilitation team to provide the support of different agencies and actors regarding the retrofit project planning, business case development, complex procurement process, discovering the skilled professional and ensuring important information and training (Alam et al., 2019). And the facilitation team will also support to get justified finance from the government budget (Alam et al., 2019).

Strong asset management is also a key instrument to build the proper plans which improve the EE of the building with the minimum costs (Alam et al., 2019). For instance, the empire state building in New York was retrofitted with around 13 million (only 14% increment of initial budget), the upgrade resulted in average yearly cost savings of USD 4.4 million that denotes that the payback period was only three years (Al-Kodmany, 2014; Alam et al., 2019).

3.3.3 Strategies to overcome procurement barriers

Before the financial allotment for the EE development, it is key for the city leaders to develop and present a clear overview of the key benefits, facts, and gaps available in raising the level of EE in new and existing buildings (F. Liu, 2014).

The government should construct energy regulated policies at the national and local levels, which points to the common inefficiencies in energy markets (F. Liu, 2014; K. C. K. Palmer, 2020). For instance, policies to reconstruct on-going pricing subsidies with determining social assistance modules, which need to implement the users of network-based energies be charged based on the metered consumption, that initiate incentives inspiring energy utilities to implement demand-side management activities (F. Liu, 2014; K. C. K. Palmer, 2020).

It is imperative to ensure the standard procurement documents, depth procurement guidelines, and simplification of the procurement process (Alam et al., 2019). The overmentioned facilitation team can provide extraordinary support to facilitate procurement services smoothly (Alam et al., 2019). Different types of solutions and receiving the various sorts of methods have been taken into consideration during the EE procurement which forms a flexible procurement process (Alam et al., 2019). For instance, allowing the actors to merge energy-efficient measures during the maintenance of equipment in an existing contractual arrangement (Alam et al., 2019). And procurement model should be renewed based on the situation, which not only focuses on the cheapest quote of purchase and installation but also emphasizes on the life cycle costing whole procuring the technologies for the EE (Alam et al., 2019).

3.3.4 Strategies to overcome the barriers to raising awareness

Researches on EE have shown that the concept of raising awareness plays a key role in the assessment and refurbishment side of EE in the building (Berg & Donarelli, 2019). Providing proper educational material for the concerned professionals and house owners related to the positive outcomes of EE is one of the key instruments (Alam et al., 2019). There are many ways to cater the proper information or education such as developing the website with the necessary information, reflecting the successful projects, making available the new research and findings along with the training programs supported by the government (Alam et al., 2019; Carlsson-Kanyama & Lindén, 2007).

Centralized high-level support is necessary to develop the educational instruments and also build the consciousness training program (Alam et al., 2019). Finally, the government should initiate the rewards programs to motivate service providers and service takers to participate in the process of the up-gradation of EE in the building (Alam et al., 2019).

4 Methodology and research design

4.1 Philosophical assumptions

Although philosophical assumptions usually keep hidden in the research, they impact the practice of research and need to be identified (J. W. C. Creswell, David J, 2018). There two frontline paradigms methodologies which are positivist and interpretivist approaches, under the shade of epistemological and ontological perspectives respectively (Bryman, 2016; J. W. C. Creswell, David J, 2018). Positivism is an epistemological approach that supports the application of the methods of the natural sciences to the research of social reality and beyond (Bryman, 2016, p. 28). According to the wills, "the basics concepts of positivism is that the implementation of the scientific method is the initial or only facet to unearth the truth about the world" (Willis, Jost, & Nilakanta, 2007, p. 33), although scholars have used it in a very different way (Bryman, 2016). On the other hand, "interpretivist perspective is catered to the researchers a hermeneutic tradition that tries to discover the meaning and perceive the extensive implication presented in data about people (Bryman, 2016). "Interpretivist subsumes various categories which incorporate different types of research approaches along with ethnography and case study" (Somekh & Lewin, 2005, p. 346). Moreover, interpretivist denotes to many specific and focused approaches such as ethnomethodology, social realism as a denial to the positivist and empiricism paradigms, and critical theory (Willis et al., 2007). Furthermore, Willis also stated that interpretivism is premised on the ideology which is opposite to a frequentative approach regarding the applicability of research methods and paradigms in social sciences for natural sciences (Willis et al., 2007). Blaikie points that, social reality is considered as a product of its inhabitants in interpretivism, it is a place which is explained through the meaning's participants produce and reproduce as an obligatory part of their daily activities together (Blaikie & Priest, 2010b, p. 99). Thus, this thesis will follow the interpretivist paradigm as a principal philosophy of science in the research process.

4.2 The aim of this thesis

This builds the foundation for the theoretical framework of the thesis and so it is mandatory to identify along with the research design, which incorporates inductive, deductive, and reproductive research design (Bob Brotherton, 2015; van Hoek, Aronsson, Kovács, & Spens, 2005). The thesis follows the interpretivist approach which is fundamentally qualitative and the make use of abductive research design. Kovacs states that abductive reasoning always accentuate on the perfect theories to an empirical observation, which is called "theory matching" or "systematic combining" (van Hoek et al., 2005). Therefore, this thesis looks forward to finding out the suitable theoretical framework of EE in the building sector in Norway and the bona fide empirical data through the scholarly article, structured and semi-structured interviews.

4.3 Research design and strategy

The use of interpretivist approach in this thesis is the basis for the research design and strategy which relates to this thesis's strategies to the data collection and discussion, validity and reliability in the research process to analyze the research questions for this thesis (J. W. Creswell & Creswell, 2018). Moreover, qualitative and quantitative are the two fundamental research methods and the basis of the data collection and analysis, contraction, ethical evaluation and decisive findings in the research process (Blaikie & Priest, 2010a; J. W. Creswell & Creswell, 2018; Punch, 2013; Silverman, 2010).

Creswell opines that qualitative approach is "one in which the inquirer often makes knowledge claims based primarily on constructivist perspectives (i.e., the multiple meanings of individual experiences, meanings socially and historically constructed. with an intent of developing a theory or pattern) or advocacy/participatory perspectives (i.e., political, issue-oriented, collaborative. or change-oriented) or both" (J. W. Creswell & Creswell, 2018, p. 18). Furthermore, Blaikie adds the comparison between the two philosophical approaches which is, qualitative points to the quantification of the statistical aspect of social phenomena, whereas qualitative approach is based on the empirical facets of social life, where social actors opinion and explanation are considered as key units and both approaches have drawbacks (Blaikie & Priest, 2010a). This is because of this thesis follows the qualitative research approach, that is based on the ontological interpretative or phenomenological metaphysical consideration which emphasizes on the concept that, *" the real world, and the phenomena and events that occur in this world, are created by the subjective thoughts, actions and interactions of people who inhabit it"* (B Brotherton, 2008, p. 36).

4.4 The perspective of choosing the research strategy (qualitative, to more precisely abductive)

This thesis covers what are the barriers regarding the renovation of old houses to improve EE. Building the research question is the most key part of the research, as Blaike (2010) states that comprehensive constructed question provides the basis to analyze the nature and the scope of the research, at the same time it helps to demarcate the boundaries to what extent a case is researched as well as providing a clear view of phenomena which is to be studied (N. Blaikie, 2010). In this thesis, research question has been formulated with the word “What” which implicates to the exploratory or descriptive studies, as Blaike claims that *“direct towards discovering and describing the characteristics of and pattern in some social phenomenon, for example (…) social groups and social processes”* (N. Blaikie, 2010, p. 60). Moreover, on the reflection of the research question proper” logic of inquiry is used as a starting point and a set of steps using which “what” questions can be answered” (N. Blaikie, 2010, p. 81). This thesis follows the abductive research strategy, which is mainly based on the bottom-up approach, which presents a *“descriptions and understanding that reflect the social actors' point of view rather than (..) researchers”* (N. Blaikie, 2010, p. 91). In abduction, it can begin with theory, make an observation and draw and inference about that observation connected with the theory, or it can start with an observation, state a theory, and draw a result (Seale, Gobo, Gubrium, & Silverman, 2004, p. 91). Either way, abduction connects an observation to a theory (or vice versa) and results in an interpretation (Seale et al., 2004, p. 91). In the abductive reasoning, a theory is applied along with observation, to create an interpretation of something specific, rather than to infer a generalization (Seale et al., 2004, p. 91). The most important aspect of the abductive research strategy is to explain the reality- based on the perceptions of informants rather than the personal view of research regarding the world view reflected by his informants (N. Blaikie, 2010).

According to Peirce, abduction on the one hand as a mode of inference with a defined logical form comparable to induction and deduction, and on the other hand as a more basic aspect of all perception, of all observation of reality (Danermark, Ekström, Jakobsen, & Ch, 2002, p. 102). The humanists and social scientists who have utilized the concept of abduction in recent years have further focused that abduction incorporates what has been called redescription or recontextualization (Danermark et al., 2002, p. 102). Abduction is neither a completely empirical generalization like induction, nor is it logically rigorous like deduction (Danermark et al., 2002, p. 103). In terms of the application of abductive inference in social science and interpret a phenomenon in the light of a frame of interpretation (rule), the frame of interpretation forms one of several possible frames and the interpretation of the phenomenon of several interpretations (Danermark et al., 2002, p. 103).

The decisive conclusion is one of many potential conclusions following from the fact that we connect various ideas and knowledge to each other (Danermark et al., 2002, p. 104) (Denzin, 1989, p. 100). A basic difference between deduction and abduction is that deduction proves that something must be in a certain way, while abduction presents how something might be (Danermark et al., 2002, p. 104) (Habermas, 1972, p. 113). Abduction is to move from a conception of something to a different, possibly more developed, or deeper perception of it (Danermark et al., 2002, p. 104). This occurs through placing and analyzing the originals ideas about the phenomenon in the frame of a new set of ideas (Danermark et al., 2002, p. 104). What was called the rule in the formalization above, is briefly this set of ideas, which is to apply to be able to perceive and explain something differently (Danermark et al., 2002, p. 104). In scientific work, this set of ideas may have the form of a conceptual framework or a theory (Danermark et al., 2002, p. 104).

Another way of expressing the abduction which is called redescription or recontextualization. To recontextualize refers to observe, describe, interpret, and explain a phenomenon within the frame of a new context, which is a central element is a scientific practice (Danermark et al., 2002, p. 104). The revolution of recontextualization is that they provide a new meaning to already known phenomena (Danermark et al., 2002, p. 104). This thesis follows the 'redescription or recontextualization' of various observations to establish the same phenomena with a different perspective. Subsequently, the barriers of EE in the old residential buildings in Norway has already been interpreted from a different point of views, so the motive of the thesis is to use the already-employed perspective from a different edge. Social science discoveries are associated with recontextualization to a greater degree (Danermark et al., 2002, p. 104). The social scientist does not discover new events that nobody knew about before. What is discovered is connections and relations, not directly observable, by which we can perceive and interpret already known phenomena in a novel way (Danermark et al., 2002, p. 104).

In the case of interpretation, several frames can be used to complement each other, in other cases they can be merged/integrated (Danermark et al., 2002, p. 105). In line with the previous sentence, this thesis resonates with the same idea to use several frames to support each other, the issue of up-gradation of EE in the residential buildings has widely discussed topic with a different point of views, in the world among the scholars. As Danermark states that the same phenomena can always be recontextualized in various modes without making it possible to say that one of these true than the other (Danermark et al., 2002, p. 105). And also abduction has been provided an independent status in the research process, as it gives a kind of knowledge that cannot be attained either through deduction or inductive generalizations (Danermark et al., 2002, p. 105). Social science analysis is likely a fact of applying theory, and frames of interpretation to achieve a deeper knowledge of social meaning, structures, mechanisms (Danermark et al., 2002, p. 105).

In terms of theory, it is now widely recognized that energy consumption patterns are a very intricate technical and socio-cultural phenomenon and to analyze this phenomenon, it must be presented from both engineering and social science perspectives (Crosbie, 2006). However, the methodological approaches are taken in household energy studies far behind the theoretical advances done in the last ten or fifteen years (Crosbie, 2006). The qualitative research approach has been used traditionally in the fields of building science, economics, and psychology, and dominate the household energy studies as well (Crosbie, 2006). While the qualitative ethnographic approaches to examine social and cultural events generally made use of anthropology and sociology are frequently ignored (Crosbie, 2006). It is problematic as quantitative approaches are unable to provide the "finely grained and detailed information" which is important for the examination of the socio-cultural impacts of household energy consumptions (Crosbie, 2006). To lower the household energy demand, it is key to find the methods of inspiring the adoption and use of EE technologies (Crosbie, 2006). Researches in household energy consumption socially and culturally provide the possibility to use the technically proved technologies into suitable social practices (Crosbie, 2006). For example, qualitative research has found "in Norwegian households" where it suggests that low energy alternatives to provide the same level of cosiness may present minimum part of the solution to lowering the energy demand to light and heat Norwegian homes (Crosbie, 2006). However, as the qualitative research approach of data collection may not provide the in-depth of data to unpack the socio-cultural form of household energy demand, the on-going dominance of these approaches in the household energy studies degenerates the effectivity of this work (Crosbie, 2006). Therefore, qualitative research methods are key to picture effective EE interventions (Crosbie, 2006).

A qualitative approach has been used to collect rich data (Cresswell & Plano Clark, 2011). Qualitative methodology, to be more précised, is very convenient to explore the barriers and facilitators to implementation (Landsverk et al., 2012) and allows programs to be researched to large extent (Chalkley et al., 2018; Proctor et al., 2009).

The qualitative research approach is the opposite research approach to the quantitative approach as such, its premises on the approach in gathering and analyzing data is different from the quantitative approach, however, both two approaches are not beyond criticism (Silverman, 2010). Blaikie states that the main idea in a qualitative study is the technical language of the researcher, where data is produced and reproduced by both researcher and social actors (N. W. Blaikie, 2010). Moreover, Blaikie also points that “languages are used to describe behaviours, social relationships, social processes, social situations, and in particular the meanings people give to their activities, the activities of others, and to objects and social contexts”(N. W. Blaikie, 2010, p. 204). On the other hand, Silverman points that, it is not allowed to present the technics used for the quantitative research which is mainly based on the numerical data that provides the statistical data, however, the main ground for the qualitative research approach is presented in the form of words technics which is as the main technique for collecting and analyzing data (Silverman, 2010; Yin, 2003).

4.5 Data collection

Qualitative research involving interviews and focus groups has become a popular way of collecting data in the social sciences (Mason, 1996). According to Blaike, primary data indicates the data which is collected, analyzed, and reported by the researcher himself, while the secondary data is the scholarly article or research which is not quite like the research problem to some extent (N. Blaikie, 2010, p. 160). For this thesis, primary data will be gathered through an open interview to capture comprehensive knowledge or ideas. While the scholarly article, Norwegian government reports (white paper, different reports on the climate of policy issues) will be the secondary data. However, this thesis will use both types of data for in-depth research. Although, A recent study shows that in-depth interviews and focus groups are susceptible to self-report bias, as participants in the research are overestimated the environmental friendliness of their lifestyles (Crosbie, 2006).

4.6 Interview Precondition

According to the Robson, collecting data is about using the selected ways of investigation, completing it organized means using these methods in a systematic, professional manner. Before the interview, there are some preconditions which include, fulfilling all the legal conditions for conducting scientific research through the Norwegian Centre for Research Data (NSD), which offers a legal basis for the researcher in Norway. Secondly, preparing an interview guide protocol based on the interview questions, which provide the interviewer to record the time, date, place, and functions of the respondents. Finally, inviting respondents via email meeting invites the application of Microsoft office 365 along with the date, time, and place. These preconditions have been presented in McNamara (2009). It is key to get the consent of interviewees for their voluntary participation and a paper of consent has been signed by both interviewees.

The interview was started with the formal introduction, the research topic, and regulations of NSD i.e. the participation is voluntary, and the withdrawal can be done anytime if the interviewee encounters any difficulty. It must be noticed before having the interviews that the data will be recorded until the submission of the thesis.

An interview guide steered the interview to facilitate the conversation, according to Kennedy, an interview guide is an organized set of questions to be requested to answer, which are penned down based on the research questions. In addition to this, the interviewer was gathered relevant knowledge in-advance about this topic through reading scholarly articles to explore the best possible response from the informant.

4.7 Interview

The interview is one of the popular means of data collection and has been extensively used in the built environment. It is easily demonstrated into different types and very useful for quantitative questions studies as well (Dadzie, Runeson, Ding, & Bondinuba, 2018; Kvale, 1994). A qualitative research interview is a type of discussion where interviewers receive information from the participants relating to the personal views about a specific area, generally regarded as the conversation with a purpose (Dadzie et al., 2018; Stake, Denzin, & Lincoln, 1998). Apart from this, kvale refers to that interview is a type of conversation, it is the art of questioning and listening (Dadzie et al., 2018; Stake et al., 1998). However, there are various types: structured, semi-structured, and unstructured54(Dadzie et al., 2018; Stake et al., 1998). The semi-structured interview is a process of interview where the questions are slightly structured, but participants have the freewill to provide the new ideas during the interview (Fontana & Frey, 2005). The semi-structured interview that presents a different approach compared to the other two types of interviews structured and unstructured methods (Dadzie et al., 2018). Moreover, the semi-structured are performed through face-to-face conversation, email, video conference, and the telephone (Denzin & Lincoln, 2011). In this thesis, the semi-

[54] Cited from: (Punch, 2013)

structured interview has been conducted. This is because of the availability of participants, the location, workload, and closeness to past documents for referrals (Opdenakker, 2006). To collect data for this thesis, two methods out of four proposed by Denzin and Linclon (Denzin & Lincoln, 2011) were used: face-to-face and Skype/Zoom video/audio conversation with the interviewees (Dadzie et al., 2018). The semi-structured interview is based on Patton's (Patton, 2005) general interview guideline (Dadzie et al., 2018). The interview guide is divided into two sections, one part covers the general perception of mass people for the energy consumption in their homes as well as CO2 emissions, government rules and police to improve the level of efficiency, the importance of renovation and alternative ways to improve the level of efficiency. And the last part particularly focuses on the barriers and possible solutions. The informants were selected through personal contacts or referrals, company websites, and professional associations as delineated in Figure 4.1 (below) (Dadzie et al., 2018). Moreover, an invitation letter was sent to possible interviewees with the interview guidelines in advance to prepare themselves before the formal interview (Dadzie et al., 2018). And those are referred by the other respondents were authorities to accept or ignore the invitation to participate in the interview process (Dadzie et al., 2018).

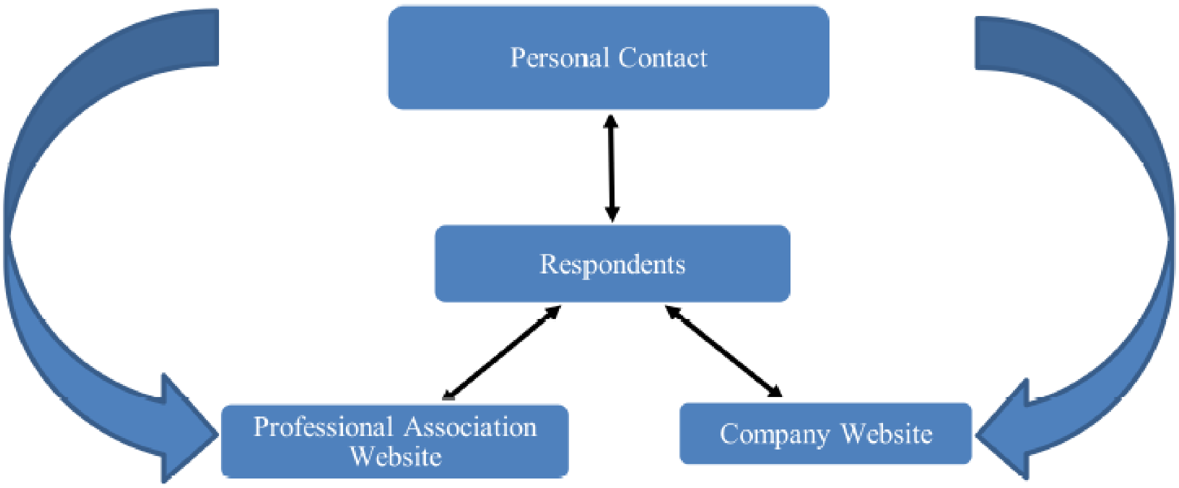

Figure 4.1 Respondent selection and survey distribution
Source: (Dadzie et al., 2018)

The interview process has been conducted with an open-ended section of the interview, which points to the background information of the informants and their previous experiences, and presents some projects related to the thesis topic. This step is very key to provide a strong basis to validate the interview process. The interview has been started with open questions that permit the respondents to expand their view and make a friendly environment. However, the interview guideline is not followed to the latter, as in the case of semi-structured interviews, interviewees are permitted to proceed on the conversation without strongly stick to

They are open-minded where the questions allow creativity and flexibility (Dadzie et al., 2018). This is because, it includes the use of open-minded questions or topics designed before data is gathered, therefore there is a gap of flexibility to some extent[55](Dadzie et al., 2018). Due to this semi-structured interviews are recognized as the most effective and convenient ways of collecting qualitative scientific data (Dadzie et al., 2018; Kvale & Brinkmann, 2009).

For this thesis, interviewees have been designed three categories, firstly the informants from the company and the researchers who have the connection this sort of project, secondly, the house owners who are the end-user of all types of energy, thirdly, professor or lecturer from the social science department who will be asked about the social aspects of improving EE in the buildings, as they have the academic knowledge about the issue of EE in the building.

In some cases, interviewees feel complexity as they are allowed to speak freely about a subject and response is to be more detailed way, and bringing the new topics as the discussion continues to go deeper (N. Blaikie, 2010).

4.7.1 A profile overview of interviewees

The thesis has chosen seven participants for the interview among many interviewees based on their practical affiliation with the issues of EE in the buildings, renovation of old buildings in terms of improving energy performance, energy performance and measurements of old buildings, financial aspects of EE project, research works about those issues and house owners of old buildings. The below-mentioned table presents the respondents.

Respondents	Code	The economic perspective	Government or procurement barriers	Knowing and learning barriers	Building efficiency assessments barriers	The means of overcoming barriers
Senior Researcher, (SINTEF Community)	FKR1	✓	✓	✓	✓	✓
Senior advisor, (ENOVA)	FKR2	✓	✓	✓	✓	✓

[55] Cited from: (Guest, Namey, & Mitchell, 2012)

Teamleder prosjektledelse, (BATE)	FKR3	✓	✓	✓	✓	✓
Avdelingsingenior, Energiavdelingen, (NVE)	FKR4	✓	✓	✓	✓	✓
Forskningsleder Energi og Inneklima, Bygninger og installasjoner, (SINTEF Community)	FKR5	✓	✓	✓	✓	✓
Driftsleder, (Jaderhus)	FKR6	✓	✓	✓	✓	✓
House owners	FKR7	✓	✓	✓	✓	✓

Table 4-1 Functional key respondents of this thesis

The overmentioned table shows the Functional Key Respondents (FKRs), the FKR1, FKR2, and FKR5 in the table rendered higher position and belonged the know-what, know-who and know-why of their institutions, FKR3 and FKR4 belong the know-how and know-what knowledge, and FKR6 features with the know-how knowledge. Hence the practical perception about the research issues of this thesis of all seven-respondent has been shown in the table. The key objective of this methodology in the choosing of the interviewees is predominantly for focusing the main research questions along with identifying the main barriers of EE in the old buildings in Norway and the ways to overcome those barriers through the corroboration of the theoretical framework.

4.8 Data analysis

Stake stated that qualitative data analysis emphasizes the separation of data into units, perceiving the components, and how those data can relate to each other (Stake, 1995). Blaikie and Priest said that gathered data from various data collection methodologies need reduction (Blaikie & Priest, 2019). Blaikie also stated that the process of data reduction changes qualitative data into quantitative data through coding or recoding process (N. W. Blaikie, 2010). This thesis will follow the framework analysis of Srivastava and Thomson (2009), as they pointed that "framework analysis is flexible during the analysis process in that it allows the user to either collect all the data and then analyze it or do data analysis during the collection process" (Srivastava & Thomson, 2009, p. 75). There are five parts of the data analysis framework according to Srivastava and Thomson (2009), which are Familiarization, identifying the thematic framework, Indexing, Charting and Mapping, and interpretation (Ritchie & Spencer, 1994; Srivastava & Thomson, 2009) which will be presented below.

4.8.1 Familiarization

Familiarization refers to the process during which the researcher becomes familiarized with the transcripts of the data collected (i.e. interview or focus group transcripts, observation or field notes) and gains an overview of the collected data (Srivastava & Thomson, 2009). Alternately, researchers are used to keeping busy listening to the audiotapes, studying the field, or reading the transcripts, in this process research will be conscious about the key ideas and recurrent themes and keep a note of them (Srivastava & Thomson, 2009). Because of collecting a massive amount of data, the researcher is unable to check all the materials (Srivastava & Thomson, 2009). So, it is key to choose a data set based on the data collection process (Srivastava & Thomson, 2009). In this thesis data reduction was launched through selecting the base themes and ideas in line with the research question and theory through using a qualitative research tool which is NVivo for evaluating data. All the data was sifted and sorted with the process of nodding of main themes and ideas in NVivo for every key sides of the barriers of EE in the building. The research questions (to some extent interview questions) have made the frame for the nodding process in NVivo.

4.8.2 Thematic framework

Thematic framework constructs based on the emerging themes or issues in the data set(Srivastava & Thomson, 2009). These emerging themes or issues have come to the light while researchers must allow the data to identify the themes and issues, and themes also have arisen followed be the taking note in the data familiarisation stage(Srivastava & Thomson, 2009). Ritchie & Spencer (1994) stated that the main issues, concepts, and themes have been demonstrated by the interviewees that are considered as the basis of the thematic framework which is utilized to sift or classify the gathered data (Ritchie & Spencer, 1994; Srivastava & Thomson, 2009). It is key to carry an open-minded interview session, despite having decisive priority issues. However, as the thesis has already determined the priority issues, that most likely will drive the thematic framework (Srivastava & Thomson, 2009). Subsequently, Ritchie and Spencer opined that the thematic framework is only tentative but it most like to be changed and refined in later stages (Ritchie & Spencer, 1994; Srivastava & Thomson, 2009). The data will be analyzed in this thesis through the qualitative data analysis tool NVivo, a thematic network analysis was taken to structure the thematic data for analysis (Corley & Gioia, 2004). The key themes will be selected based on the theoretical background to analyze the data thematically, and the theme will also be paired with the collected data from the interview.

4.8.3 Indexing

The third part of the data analysis is the indexing which refers to the section of the data that correspond to a theme and this process is utilized to all the transcribed part of collected data (Srivastava & Thomson, 2009). Bryman and Burgess (1994) stated that “the process whereby the thematic framework or index is systematically applied to the data in its textual form” (Bryman & Burgess, 1994, p. 180). The prime themes and concepts have been taken from the theoretical background in this thesis, which has been incorporated with the transcribed data from interviews to construct the indexes with the formulation of nodes by the qualitative data analysis tool ‘NVivo’ in order to stand the analysing issue for this thesis.

The gathered data from the process of nodding of transcribed interviewed data formulated the lowest order based on the interview questions from the interviewees, the first order codes which will be descriptive codes (Attride-Stirling, 2001; Essamri, McKechnie, & Winklhofer, 2019). Axial coding is used to create the second order themes, which follows the repetitive process to standardise the proper winnowing of the informant’s responds to form a comprehensive theme (Attride-Stirling, 2001; Essamri et al., 2019; Lawrence Neuman, 2014).

4.8.4 Charting

Those data have been indexed in the previous stage which is now organized in charts of themes, to some extent the extracted data from its main textual context and placed in charts which formulate the headings and subheadings that were taken in course of the thematic framework, or from a priori research inquiries (Ritchie & Spencer, 1994; Srivastava & Thomson, 2009). The key fact is that extracted data should be identified precisely in tandem with the case it came from(Srivastava & Thomson, 2009).

4.8.5 Mapping and interpretation

This stage indicates the main characteristics as laid out in the charts (Srivastava & Thomson, 2009). This analysis should cater to a schematic diagram of the event or case which showing the researcher in their explanation of the data set (Srivastava & Thomson, 2009). Interpretation in qualitative research studies points to the extraction of data out of codes and themes arena to a large extent (J. W. Creswell, 2013). it is a process that dawns with the construction of codes, the creation of themes for the codes, and subsequently the structuring of themes into larger units of abstraction to make sense of the data (J. W. Creswell, 2013). Ritchie and Spencer, this stage involves "defining concepts, mapping range and nature of phenomena, creating typologies, finding associations, providing explanations, and developing strategies" (Ritchie & Spencer, 1994, p. 186). In the mapping process, the gathered data through the interview were incorporated with the theoretical background, presenting the main concepts, mapping limit, and nature of phenomena, extrapolation of association, formulation of typologies, delineating explanations and presenting the barriers organized to pave the way to solve these constraints for the improvement of the EE level in the residential buildings.

4.9 Validity and reliability of the research process

Validity is one of the crucial parts of qualitative research and is based on determining of the qualitative research from the standpoint of the researcher, the participants of the reader's account[56](J. W. Creswell & Creswell, 2018, p. 199), and the term validity points to the trustworthiness, authenticity, and credibility (J. W. Creswell & Creswell, 2018, p. 200). Moreover, Creswell pointed that "means that the researcher checks for the accuracy of the findings by employing certain procedures, while qualitative reliability indicates that the researcher's approach is consistent across different researchers and different projects"[57] (J. W. Creswell & Creswell, 2018, p. 199).

This thesis will try to maintain coherence between interviewed data and secondary source of data such as a scholarly article with the main theme of this thesis as Creswell stated that Triangulate data sources by examining evidence from the sources and using it to build a coherent justification for themes, which claim the validity of data (J. W. Creswell & Creswell, 2018). The interviewees will be provided the organized and comprehensive guideline such as

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[56] Cited from (J. W. Creswell & Miller, 2000)
[57] Cited from (Gibbs, 2007)

topics theme, research questions, and methodological ground as if they can judge as to the topic and make a mind before providing information about the topic, as Creswell said that “Use member checking to determine the accuracy of the qualitative findings by taking the final report of specific descriptions or themes bank to participants and determining whether these participants feel that they are accurate” (J. W. Creswell & Creswell, 2018, p. 200). All the interviewees requested to provided proper interview guidelines before the interview as they can provide an in-depth analysis of that topic. Subsequently, it is possible to provide a detailed reflection.

Among the interviewees, employees from a private and public institution, house owners, university professors and are included, so it would be optimistic to gather multifaceted data about the improvement of efficiency level in the buildings. As black hinted that validity emphasized the cohesion between collected data and the main phenomena (Black, 1999).

Generally, reliability hints to the collected data in the research process are reliable, as Dumay & sandy 2011 noted that the researchers must identify properly any elements which can affect the research outcomes (Qu & Dumay, 2011). This thesis will very watchful to avoid the obvious mistakes during the transcription of data since Gibbs (2007) suggested that “check transcript to make sure that they do not contain obvious mistakes made during transcription” (J. W. Creswell & Creswell, 2018). Moreover, the research question has been constructed with a very clear view to avoid any confusion or misunderstandings.

The over mentioned discussion reflects on the methodological basis of this study, where it is mentioned that this research will follow the qualitative approach for this research. Moreover, it is shown that generally the issue of EE is mostly researched based on the quantitative approach, but in several cases, quantitative analysis cannot reflect the societal aspects of household energy consumption. The thesis uses the qualitative research method to unearth the barriers in terms of improving the efficiency level in the housing sector.

5 Data presentation and results

This chapter presents the collected interviewed data in tandem with the key research question, theoretical framework, and methodological framework; and interprets those data through visualization world cloud frequency results in NVivo and thematic perspective. The motive of data collection and presentation to show the EE gap in old residential buildings in Norway, that gap leads to create the different types of barriers regarding improving the energy measurements in the old buildings along with the ways to overcome the barriers to speed the process of EE up in the old buildings in Norway.

5.1 Presentation of results

5.1.1 Energy efficiency (EE) gap

This thesis has discussed the EE gap in the theoretical framework section to a wider extent. It is widely discussed that there is an evident EE gap exist in the old building socks not only in Norway but also over the whole Europe, which leads to creating several constraints/barriers to improve the EE level in the old buildings, overcoming those barriers will pave the way to rise the EE level. Some of the key respondents stated that,

"In Norway around 80% of residential buildings are old, and the energy measurements and performance are not up to the mark. And I think new houses consume half of the energy compared to consumption of the old houses. Consequently, there is an EE gap in the old building stock, which can be improved through the partial or in-depth renovation". FKR1 and FKR3

5.1.2 The economic perspective

Availability of the financial flow is the most important fact for any kind of project, subsequently most of the interviewees have shed light on the financial aspects as a key driver to raise the level of EE in the old buildings in Norway. Since financial availability is the most important aspect, the absence of proper financial flow interrupts the growth of EE very significantly, which is reflected by the functional key respondents in verbatim,

"Renovation rate of the old residential buildings in Norway follows a very flat trend last couple of years, compared to the urgency of renovation to improve the EE level. An economic perspective is one of the most key drivers to increase the EE rate through the renovation or refurbishment of the old residential building stock. However, the renovation of old buildings demands a massive amount of money in most cases, whereas the majority of the homeowners

cannot go for the renovation without the financial help from the public and private institutions". FKR2, FKR3 FKR4, FKR5 and FKR6

The word cloud frequency query results in Figure 5.1 below denotes the overall key themes form functional key interviewees are related to the economic barriers to the up-gradation of EE in the old building stock in Norway.

Figure 5.1 Functional Key Respondents word frequency query results for Economic barriers of EE up-gradation in the old residential buildings in Norway

The gathered themes have emphasized repeatedly by the interviewees, which are selected through NVivo data analysis tool. The selected themes about the economic barriers are mentioned below,

Lack of financial flow, Enova is the specialized institution of the Norwegian government, it has the responsibility to provide the loan or financial aid for the house owners who willing to renovate the house or replace the existing technologies to increase the efficiency. Enova's most of the financial schemes, regarding building renovation to improve the energy performance, are for the commercial buildings, the amount of Enova's allotment or loan schemes for the residential buildings are insignificant compared to the demand of the investment,

"I think, the financial schemes of Enova for the residential building renovation are quite low compared to the demand. Having said that, Enova currently is providing a good amount (about 100 thousand) of grants or subsidies for the small wooden houses' renovation, and recently they have provided grants for 300 houses as well. Although this amount is not enough compared to the practical demand for subsidies or incentives, I will say the Enova's grant schemes are growing day by day". FKR1 and FKR2

Most of the cases house owners do not want to go for the in-depth renovation, as all the measurements are very cost-intensive,

"In most cases, if the house owner is willing to do an in-depth renovation to increase the level of EE, lack of financial flow interrupts the process. Subsequently, house owners often prefer to go for the partial renovation". FKR4 and FKR2

"I think the most key barriers for the EE measurements is the lack of financial flow. And all kinds of measurements (such as insulation in interior and exterior and roof, changing heating system) and technologies related to the up-gradation of EE are cost-intensive, if you calculate the investment will take too long 30/40/50 years to make a profit". FKR5

There is a significant gap between personal economic level and societal economic level, which leads to discourage house owners to invest in the up-gradation of EE in their buildings,

"I think there is a gap between personal economical level and societal economical level, which is a key barrier that impedes going for the renovation project. So, the public or private authority must minimize this gap, if they want to improve the level of EE through renovation or refurbishment of the residential old building stock". FKR5

Poor selection, in some cases, shoppers are not being provided proper information from the seller about the technology which leads them to select the wrong one. And the overflow of the technologies and the price competition led purchaser to choose the cheap product as they are not being provided the right information about the quality and effectivity of the technology,

"I believe that energy-efficient technologies are available in the Norwegian market, but due to the lack of information or proper guideline, from both point views as buyers cannot provide the right information or sellers do not know much about these products, that lead to do the poor selection. But Enova is trying to spread information as far the demands which is not enough as it is the big market". FKR1 and FKR2

Long pay-back period, apart from that, the payback time for the investment of EE in the building is very long, so most of the cases private organizations do not intend to invest here as it is a very long term process to get the outcome. Therefore, government support is obligatory for the renovation project,

"I think house owners or private financial institutions might not want to invest as it has long a pay-back period, but in some situations, it is possible to make pay-back period shorter if house owners follow the cost-effective methods; and house owners have to know what they should change. However, house owners in many circumstances, do not go for the proper guidelines or do not do the proper assessment before investing in the renovation, therefore they lose a massive amount of money and payback will be longer". FKR1

Profit is the only motto of all types of financing institutions, public or private institutions regardless since the payback period of EE investment is very long. Therefore, private institutions and house owners do not want to invest in the renovation in terms of the up-gradation of EE in buildings, apart from these public institutions are also unwilling to go for this investment although they are provided financial incentives from the government…

"I agree with that as financing institutions tend to make more profit so they will go for those options where they have a chance to make more profit within a short time rather than investing in building renovation that has a long pay-back period. Overall, I believe that the economic aspect is most important to push more house owners to renovate their homes to improve the level of efficiency". FKR4

Lack of financial schemes, another important aspect of economic perspective is the lack of incentive schemes for the energy measurements for the old buildings...

"Government must ensure the reasonable incentive schemes to push more people along with the distribution of loans to upgrade the EE level. Since it is difficult for an individual house owner to invest that has a long payback time. Consequently, I think the government should employ proper regulations and right investment schemes along with catering sufficient information to put the people into the system as they are obliged to do so rather not pushing them by force". FKR4 and FKR2

And It is important to notify that the rate of old buildings' renovation is constant or follows the flat line. The masses do not choose the option of retrofitting as government or private institutions cannot present a standard business case that will ensure the flow of the investment and the cost-effectiveness. And it is important to collect detailed information about the house, although it is difficult, to sketch a standard case study to renovate the houses. And the government must have a time justified financial framework to push people for the holistic renovation or retrofitting of their houses

"I have worked with Enova regarding the financial issues for the residential building renovation project, so I think Enova's financial structures are quite good for the industrial and commercial buildings, but the financial schemes are very insufficient for the residential sector along with an inefficient business case for ensuring the financial flow for the old building stock". FKR5

Hidden cost, due to the absence of standard comprehensive research about the aggregated expenses for the renovation of buildings, makes it difficult for the house owners to avoid the uncounted costs during the renovation process,

"I think there are some economic barriers are manifested, such as long pay-back period, hidden cost, and dearth financial incentives schemes. it is a very challenging job to renovate the old building stock since it has a lot of variations in terms of construction year, buildings envelop, and technological variability. Before starting the renovation, a comprehensive assessment must be prepared to build an outlook for the customers. During the in-depth assessment, the real energy cost and saving energy cost might be incongruent to some extent.

since it takes a longer period, there is a possibility to increase the cost of the renovation. Therefore, this type of hidden costs trammels the pace of the EE project". FKR4, FKR2, and FKR1

The gap between supply and demand, in the Norwegian tech market (EE technologies), technologies are available compare to the customers, customers do not have much inclination to purchase those products, as they are not much aware of EE or global climate degradation to some extent,

"I think technology is available in the Norwegian market compared to the buyers who prefer to install new technologies to improve energy performance by replacing existing technologies or in-depth renovation. However, there is a trend in Norway to change the appliances yearly regardless of cost or EE concern. Therefore, there is a gap between supply and the demand for energy-efficient technologies in the Norwegian energy market". FKR4 and FKR2

Split incentives, there is a significant number of houses are being rented, where house owners might not invest for the energy measurements since it will be rented and the tenants will be benefitted from this up-gradation work, for instance, the consumption of energy will reduce as well as the level of comfort will increase, at the same time tenants will enjoy more than their spending. Whereas if house owners spend more money on the aesthetic aspects, that will increase the property value along with coupling the rent of the house,

"If house owners are uncertain to stay in this house for 30 years or longer period or it will be rented out, they don't want to do this investment, as it usually takes a long pay-back period or the benefits of investment for EE will be enjoyed by the rented people, such as tenants need to pay less electricity bill as energy consumption will bed decrease by renovating or installing new technologies". FKR5, FKR2, and FKR4

5.1.3 Government and procurement perspective

The word cloud frequency query results on the government and procurement perspective Figure 5.2 below points to the high word frequency key themes from the interviewees are extrapolated from NVivo in line with the interview questions. The goal and purpose of the word cloud frequency query is to attest the themes which are mentioned below,

Figure 5.2 Functional Key Respondents word frequency query results for government and procurement perspective

Absence of proper authority, as the thesis have stated earlier that the existence of policies or regulations is up to the mark to some extent, whereas the monitory body for the materialization of this rules seems fragile, as the Enova is the only body who is mostly recognized to monitor the issues of renovation and other works related to the process of EE in the buildings. The supervision sector of implementation of policies, funding or other monitoring is crucial as it is a massive area which consists of around 90% of the total number of houses in Norway are,

"Energy use in the Norwegian building mass follows the flat line or bit lower trend line over the last year. Since the ban of oil for the heating source, heat pump or electricity based heating system had to installed in old and new buildings phase by phase, renovation (with steady pace) of old houses to attach the better degree of insulation and later development in lighting system has contributing to raise the level of efficiency and to lower the CO2 emissions. The reason for

the slow pace, to implement the in-depth renovation, is the lower number of interventions for the existing buildings stocks along with the absence of proper authority to facile the process of renovation of old building stock". FKR4 and FKR2

"EPC (Energy Performance Certificate) is a contract form that is used by the Norwegian municipalities to improve the EE level in their municipality's buildings. The implementation phase of EPC is faltered as Norwegian municipalities have a very less financial flow to invest and inefficient administrative capability to address this issue properly. but the financial model in the EPC is very convenient to increase the investment in the municipality's buildings". FKR5

Absence of cooperation, cooperation, and collaboration among the private and public entities is crucial for such process like renovation of old buildings or replacing the old technologies in the old buildings, where public institutions, private firms, and the mass people are being merged to accomplish the process to upgrade the energy measurement of their buildings. According to the respondents, there are comprehensive policies and cutting-edge technologies for this project, while the process of implementation of the regulations is very sluggish which may reflect the absence of collaboration among the actors in the implementation page to push people to upgrade the energy performance of their houses,

"Old building stock is the massive area to deal with where private actors, public actors, and house owners (to some extent) are involved. So, it is key to have proper cooperation and collaboration among these actors to push more people to renovate their houses and to make it more cost-effective for the homeowners. I think there is a collaboration among all the key actors, but it should be stronger to reach the govt's goal to save 10 TWh/year through up-gradation the EE level of the old residential houses". FKR3, FKR2, FKR5, and FKR1

Lack of standards and references, the Norwegian government has determined the goals through EE improvement in the buildings, while the qualitative measures to achieve that goal seem flimsy,

"I think the Norwegian government does not have clear and concrete plans, references, and standards to achieve the determined goal of 10 terawatt-hours of energy saving through the up-gradation of EE in the old residential buildings. Moreover, the municipalities do not have the proper set up to give a standard guideline, to inspire people for EE. For instance, the

Norwegian government has initiated the EPC project for all the municipalities in Norway, but the rate of implementation of EPC is very low due to the absence of proper administrative authority and lack of standard and reference". FKR4 and FKR2

Unwilling to invest, as discussed earlier that, there is a lack of business case studies, economic models, research about the risk assessment for this investment. Therefore, even though masses willing to go for the in-depth renovation, they do not have the real scenario of the profit from this investment as the profit might come after 30 or 40 years of the investment. So, they need the time-defended design form the govt perspective to encourage themselves for the investment,

"I think, most of the renovation work is related to the increment of personal comfort or to increase the interior aesthetics, while renovation to improve EE is very low, cost-intensive along with the longer pay-back time are the key causes to follow a downward trend. Another fact we have registered many large buildings from the 70s or 80s for the renovation it is very difficult to inspire them for the renovation since they are staying in those houses only for 5-10 years, then they move to new houses. Therefore, they do not want to invest here which needs longer pay-back period, at the same time even though if they invest, they do for the aesthetic perspectives". FKR3 and FKR2

"Many house owners are capable to invest by themselves, but the long payback period discourages them to go for the renovation to upgrade the level of EE. Although Norwegian people spend millions of kroner to renovate their kitchen and toilet each year, since the benefits of these renovations are visible, take a short period and increase the comfort level. Moreover, it increases property value. I think an economic perspective is a key cause to scale the level of renovation down". FKR6

Lack of training for the professionals, EE up-gradation in old residential buildings is a very demanding task, as it is very diverse in terms of buildings' type, construction's year, used technologies, windows, and level of insulation. Moreover, modern technologies frequently update with new features. Wherefore, professionals must have sufficient competence about the properties of old building's appliances as well as ensuring continuous training to be cognizance about new technologies, *"I think, all the professionals have the basic skills about the renovation regarding upgrading the EE, we have different engineers from all types of disciplines for all departments who have the expertise in his area. Although, professionals might encounter difficulties to do pre-assessment regarding the existing technologies, building envelop, and renovation costs as different old houses have different energy measurements, windows, and insulation levels. And another key point is the nature of technology is dynamic and every day new technologies replace the old technologies, with new properties and features, where professionals need to know about the properties of those new technologies. Consequently, I think public and private institutions must have the system to train their professionals to enhance their skills and knowledge about the positive outcomes of the up-gradation of EE. So, they can also work as a medium to cater to the information among the homeowners as they have direct contact with the homeowners. And of course, new projects/new buildings get more priority to the company or engineers compared to the old buildings, which is very crucial to focus on". FKR3 and FKR6*

"Another important issue is that the used appliances in the house have an expiry time, when craftsman replace those appliances they must need to check the longevity of those appliances, for instance, a window can go for 10 years, so it has to be thrown after 10 years unless it is not usable. In some cases, due to the lack of professionalism of craftsmen, they replace mistakenly the used technology which can use more which is a total waste of money". FKR1

5.1.4 Knowing and learning or Raising awareness barriers

Figure 5.3 below word cloud frequency query results on knowing and learning or raising awareness barriers indicate the overall key themes from the functional key respondents' statements. The key themes are discussed below,

Figure 5.3 Functional Key Respondents word frequency query results for knowing and learning or raising awareness barriers

Lack of consciousness, this is the widely cited comment from the interview script that Norwegian people does not know much about the EE and CO2 emission, and they have some misconception, as Norwegian energy is emission-free energy so there is no point to produce CO2 form user perspective,

"Electricity is very cheap in Norway, so people do not have consciousness about the consumption of energy, quality of appliances, in some cases, either they are energy efficient or non-efficient and environmentally friendly or non-friendly. Moreover, these perceptions may influence the mass's decision to replace the existing technologies or to go for the renovation of their houses to some degree. And from a government point of view, there is a gap to make masses conscious about those issues properly. most people just follow what the government put upon to follow them. However, the government should construct a proper plan to push mass people". FKR3, FKR1, and FKR2

Norwegian people want to maintain a distance from these issues, as they do not have proper guidelines, but if energy prices would be higher, they obviously will care about these issues. A small portion of a political party does not believe in the climate change which impacts negatively,

"I think, Norwegian people, tend to modify the indoor set-up of their building every year, they do renovate from the aesthetic point of view without considering the EE fact. Simultaneously, they try to maintain a distance with environmental issues or a fact of EE. However, generally, they are less conscious about those issues, due to the prevalent perception of Norwegian energy is emission-free and very cheap. I deem that if electricity price is soared as a short-term basis rather than the improvement of the building envelop, which would result in a tremendous decrease in energy consumption". FKR4 and FKR2

"I think, The main reason for this less consciousness is that they energy price is in Norway is very cheap; and at the same time there is an informational difficulty, but if it is high people will take care of that. It does not cost anything to use energy in Norway. Of course, when it does not cost anything who will be that much active to save energy. people do not turn off the light, heater, or other energy-intensive appliances when they do not need or left their homes". FKR5 and FKR2

"I think, climate change is not a very easy thing to solve, as most important in the political arena around 20% of politicians do not believe in climate change or it is occurring by the anthropogenic activities, which is very scary to convince masses about these issues, however, the number of member in green party is increasing day by day, this is the positive change among politicians but the change is very slow". FKR5

Bounded rationality, Norwegian people are very watchful about the investment to upgrade EE level in their houses, due to the high investment cost or longer payback time. Concurrently, they spent millions of Kroner to upgrade the kitchen and toilet every year and follow the trend rigorously without thinking the actual benefits of this investment,

"I think, most of the renovation has been performed related to the comfort or interior aesthetic aspects, renovation to improve the EE is very low since it is cost-intensive along with the longer pay-back time. Another fact we have registered many large buildings from the 70s or 80s for the renovation is very difficult to inspire them for the renovation since they are staying in those

houses only for 5-10 years, then they move to new houses. Therefore, they do not want to invest here which needs a longer pay-back period, at the same time even though if they invest, they do for the aesthetic perspective.

The Norwegian tech market is the trend-based market which refers to getting popularity of certain products of a certain period and purchaser's decisions are also influenced by that trend. For instance, currently, technologies for solar energy are the most popular energy-efficient technology in the Norwegian energy-efficient technology market, while people do not know much about this technology, whether it is energy efficient or cost-effective but people are purchasing to the greater number. However, solar energy is not much cost-effective for Norway to some extent". FKR3

5.1.5 Building efficiency assessment barriers

This Figure 5.4 below word cloud frequency results leads to unearthing the key themes of building efficiency assessment barriers, those are discussed below,

Figure 5.4 Functional Key Respondents word frequency query results for building efficiency assessment barriers

The informational difficulty, the flow of information is tremendously crucial to make masses aware of the importance of EE in the old building stock,

"I think that most people go to the entrepreneurs about the guideline before the planning for the up-gradation of EE, most of the entrepreneurs present the cheapest options to the house owners, and the entrepreneurs often do not know much about the benefits of improving EE so they cannot do guide properly. Moreover, they invest lumpsum amount every year to increase the indoor comfort level, if they would be informed at the right time, they will go for the renovation to improve the EE. And in some cases, they do not know who provides economic assistance or how to get that. So, it is evident that there is a big informational gap". FKR1

"At the same time house owners do not have the proper guideline about the renovation or retrofitting of their houses and they do not know about the long term economic benefits of the renovation as they can reduce the average expenditure by cutting down the consumption along with the contribution to reducing the CO2 emission. However, mass house owners do not have enough information about the long-term benefit of EE". FKR4 and FKR2

"As house owners in most cases do not know much about the building envelop as well as energy measurements of buildings. Most of the house owners of old buildings are aged, they do not know about the life span of existing technologies, and when it will cross the timespan. Moreover, they even do not know the benefits of EE properly. Naturally, old people do not like to go any cumbersome work like building renovation, as they need to relocate during the renovation. And generally, if old people be used to with a type of technology, they do not likely to change to new technologies with the existing technologies as they are adapted with the old technologies". FKR6

There is a political party, Green party, who is very vocal about those issues, but their voice is constrained just in the surrounding of the cities, not far from city,

"I think people are not conscious that much about these issues that building is a unit that has a contribution to increase or decrease global warming. House owners to a large extent do not have information about the EE or producing of CO2 and they can reduce the emission through changing their attitude or changing building envelop. GHG emission or EE issues are mostly known to the people who live in a big city like Oslo, Trondheim, Stavanger, or Bergan and political parties who have pictured those issues in their election agenda, they are also centric to big cities". FKR2 and FKR5

Institutional practice, there are many rules and regulations to identify the barriers along with the comprehensive solutions. Those regulations must be implemented properly to address all the constraints, whereas house owners might find the institutional procedures cumbersome to some degree, which discourages them to go for any service,

"Norwegian government has determined a goal 10 TWh\year through EE up-gradation, while the implementation phase does not seem much comprehensive to fulfil this goal due to the very slow institutional process and fewer incentives, even though Enova is providing the grants for the renovation but it is insufficient relative to the demand to reach the goal 10 TWh\year through the renovation". FKR1

"I think, if private owners try to get the support from Enova, they have to follow some institutional procedures and practices, which might seem not user-friendly to the Norwegians. This is also a barrier, which needs to make very simple for mass people as they can get the financial amenities with simple means. But I do not think so, that govt can make this process simple within a short period, but if govt wants to improve the rate of renovation to grow the level of efficiency, the financing process must formulate in a simple". FKR3, FKR4, and FKR5

Lack of qualitative framework to achieve the goal, Norwegian govt has determined a goal to save 10 TWh/years through the up-gradation of EE in the buildings, however, it seems that government does not have any long-term or concrete plan to achieve the goal,

"I think, the goal of the Norwegian government is to reduce the energy consumption 10 TWh/year by the improvement of EE level, which is the only solid goal of the Norwegian government to improve the level of EE in the buildings. This is the cheapest way to reduce the CO2 as well as reduce energy consumption. They have only designed the quantitative goal, rather than designing the qualitative framework to achieve the 10 TWh/year of energy saving. So, the government should emphasize more to the old building stock to reach the goal of EE and the reduction of emission, as old buildings present greater opportunity to improve the EE level through the renovation or replacing the outdated technologies; and old buildings are featured with poor insulation, use of energy-intensive appliances, and out-dated technology which must be renovated partially or holistically". FKR4, FKR2, and FKR1

A time-consuming process, practically the renovation process of old houses is very time consuming due to carrying some pre-assessments about existing technologies, overall building envelops, and preparation of aggregate cost of the total process. And no institutions in Norway who provide the One-Stop-Shop service, that means people will get all types of services under the one company. The more time consuming for the renovation, the investment will increase more. This long-time process creates numerous difficulties for the residents as well,

"I think the renovation process for the old houses is usually time-consuming, as it needs comprehensive assessment to figure out the proper model, business case, selection of technologies, working-feasibility of the existing technologies, and total cost of renovation". FKR2 and FKR3

Disturbance in the usual routine, Norwegian people culturally tend to lead a hassle-free life. The renovation process requires to accomplish many procedures which might disturb their routine life. For instance, managing the government incentives, relocation of all the appliance and residents and so on,

"And the renovation of old buildings is a long-time process as it needs phase by phase renovation and never-ending since all the appliances have a different life span. for instance, in terms of roof renovation, it takes from a couple of weeks to a year Due to demanding longer period, it demands more money and discourages house owners to go for the renovation. During the renovation, it interrupts the regular lifestyle of the residents". FKR3 and FKR5

Lack of metering, it is very common all over Europe, that majority of old houses do not have a proper metering system to monitor the monthly or daily energy consumption and it is tough to determine how much energy efficient that building. And Norwegian government does not have any such process to collect the information about the particular house such as when that house has been built, which energy measurements are being used or what time a house should be renovated or retrofitted to improve the overall energy performance or comfort level of a house,

"Government does not have data about the house such as the construction year, existing technologies, energy standards, and what measurements have been done since the construction of the house, although it is very difficult to collect. Due to the lack of substantial amounts of

data about the old building stock, it is impossible to some extent send the house owners a notice that it is time to renovate your house or to change the existing technologies. Although the government has some data, which is full of loopholes which is not enough to fix the timing for the renovation. therefore, the government should increase the institutional capability to gather data about old houses". FKR5

"In terms of energy consumption, there is hardly any metering system in the old buildings, unless residents are extra careful about the environment. So, residents do not know how much energy is being consumed per month, although lyse is publishing on their website nowadays. I mentioned earlier that, most of the old houses are owned by the old people, they are not much known to the technology or webpages to some extent, which results in remain incognizance of their consumption. I believe, the metering system will help residents to control their consumption". FKR6

5.1.6 The strategies to overcome the barriers

The over-mentioned sections have discussed the barriers from the outlook of 7 interviewees. These barriers must be identified and mitigated to improve the EE level in the old residential building stock in Norway. To overcome those barriers, requiring government interventions, standard policies, to inspire people to be more cautious and behavioural change. Several points enlist below regarding the development of EE in the Norwegian old residential building. Figure 5.5 below mentioned word cloud frequency results leads to extrapolate the key themes about the strategies to overcome the barriers, which are discussed below,

Figure 5.5 Functional Key Respondents word frequency query results for overcoming the barriers.

Phase by phase renovation, it is quite difficult to renovate the whole building stock with a certain time or process. Since it is a noticeably extensive area and lifespan of used technologies varies. Consequently, the government should carry on the renovation project phase by phase as holistic renovation approach very demanding task,

"Energy use in the Norwegian building mass follows the flat line or bit lower trend line over the last year. Since the ban of oil for the heating source, heat pump or electricity based heating system have to be installed in old and new buildings phase by phase, renovation (with steady pace) of old houses to attach the better degree of insulation and later development in lighting system has contributing to raise the level of efficiency and to lower the CO2 emissions. So, the government should push people to renovate their homes phase by phase as it is challenging to renovate holistically". FKR4

The relationship between energy behaviour and billing system, it has mentioned earlier that Norwegians are quite unaware of their energy consumption for several reasons. One of the key reasons for being unwatchful for their consumption is non-cognizance or inadvertent to their monthly energy consumption. Most of the Norwegian does not know how much they consume per month. Therefore, if is it possible to make a connection between energy behaviour and billing system which might lead to making people more cautious,

"I think again if you can make link behavioural side with the EE measurements, and the billing system that must be paid every month, I think Norwegians responds very quickly". FKR2 and FKR5

Ensure sufficient financial flow, which is the most stated fact by the interviewees to ensure the up-gradation of the EE level in the old building. The Norwegian government has already provided several schemes of financial assistance for the up-gradation of EE in the old residential buildings, which is quite insignificant relative to the practical needs. Moreover, financial flow is the most key aspect to improve the EE level.

"Lack of financial flow is one of the key barriers. Although there are some financial models or schemes for the renovation of the old buildings, they are not enough. I think the government should upgrade the financial models based on the demand of the situation. And I believe if the government wants to make the residential sector carbon-neutral, govt needs to prepare more comprehensive incentives or proper financial flow to renovate the old buildings stock step by step". FKR2, FKR3, FKR6, and FKR7

Informational availability is a significant parameter in the renovation of the old houses in Norway, as all key respondents state the importance of sufficient informational flow. Due to the lack of information, homeowners renovate their homes in the wrong way which might be dangerous for the whole building envelop. Moreover, sufficient flow of information and maintain the proper timing to provide the information will change the scenario,

"I have seen many people just renovate inside but they do not pay the attention for the roof or building envelope which so dangerous for their building as it can damage anytime. Therefore, the availability of information is so crucial to make people more aware about the renovation project". FKR1

"I believe, proper information can steer the people's mentality and perceptions, since Norwegians always follow the government rules and regulation to the latter. So, the

government should spread the information extensively to change this situation". FKR3 and FKR2

"I think govt should place the information at the right time when its requisite rather than spreading randomly such as energy labeling in the home appliances or arrange a campaign to spread the information. It is also key to disseminate the information in an understandable way that people can perceive the meaning of the attached information. If you are already in refurbishment or planning to refurbish the roof, in that case, it is very smart to add extra insulation. House owners would do so if they would be provided the information in proper time. And it is too costly to add insulation alone in the roof if they do not have the plan to go for the holistic refurbishment". FKR4, FKR5, and FKR7

Designing the proper policy, Norwegian people follow the state policy rigorously, which is a key point to drive the mass people with proper policy instruments. Furthermore, the up-gradation of policy with the time is inseparable part to address such issues such as the old buildings' renovation. Since this is a very diverse and extensive area, which is needed to focus meticulously,

"I think the main goal of the Norwegian government is to reduce energy consumption through the improvement of EE which is the cheapest way to reduce energy consumption and CO2 emission. The government must ensure the proper policy cycle to provide financial assistance and encourage more people to do the renovation for improving EE in the building". FKR5 and FKR7

"I think Norwegian govt always try to implement EU's policy, currently they are looking forward to implementing the new EU policy which is called Green Deal along with the country-wide renovation project to improve the efficiency in the buildings which is followed by the whole Europe to improve the EE level in their existing building stock". FKR5 and FKR7

"We Norwegian follow the govt very carefully, so I believe that if the government makes the rules stricter to implement the designed policies regarding the up-gradation of EE, masses will follow cautiously". FKR6

Imposing extra tariffs, unawareness in the energy consumption has been discussed in the previous section, some of the respondents have suggested for imposing the extra tariffs on the energy consumption which might control the unwanted consumption form the end-users viewpoint,

"It is not possible to change overnight but I think energy price should be coupled to make people more responsible, but recently we are observing some interesting things, that NVE and Statnes are talking about the power tariffs for the commercial and residential building as well, it might result in to provide some incentives for the building owners to be more aware of the EE facts in their renovation project. I think again if you can link the behavioural side of the EE measurements, and the billing system that must be paid every month, I think Norwegian responds very quickly". FKR5 and FKR7

"Another key cause is that cheap electricity, people are paying almost nothing for the electricity. And they have the perception that our electricity is from hydropower, so it is emission-free. These two reasons drive them to be more unconscious for facts such as EE, CO2 emissions, and saving energy costs in the long run through the improvement of the EE level. I believe the imposition of new tariffs on the energy consumption will change the user perspective about their energy consumption, simultaneously states and Kommune should come up with the different schemes to reach the information to the house owners about the long term benefits of EE". FKR6

Political concentration, Norwegian people are very focused on those issues which are most discussed in the political arena. Although, the factor of climate change or other related issues is being discussed with consistent length.

"It is very difficult, but we are trying to communicate to contact the mass to inspire them. although it is a matter which should come from their side as well. But higher political attention about this matter will attract more masses attention and at the same time EE is not the primary focus when it comes to the reduction of CO2". FKR2 and FKR4

"I think It is not a very easy thing to solve, as most important in the political arena around 20% of politicians do not believe in climate change or it is occurring by the anthropogenic activities, which is very scary, however, the number of member in green party is increasing day by day, this is the positive change among politicians but the change is very slow". FKR5

The new research project, the old building stock is very significant, and the process of up-gradation is very challenging and cost-intensive. Consequently, if the process of up-gradation needs to make smooth, cost-effective and renovate or refurbish a greater number of houses, the research projects must be coupled,

"Currently we are doing a project with Enova which is called "New energy services" that are emerging in the business nowadays, it can be interesting for residential buildings, for instance, PropTek (property and technology) business they are providing a lot of services for the commercial buildings. I believe this type of same project or business idea can be implemented in the residential sector as well. And OPPTREK is another pilot project, where old wooden houses are tested to improve equivalent to nZEB (nearly zero energy building)". FKR5 and FKR1

6 Discussion of results

The starting point for this discussion part is, what slacken, that means which parameters slower the EE in the old residential buildings in Norway. This thesis has discussed in the theory part about the EE gap which leads to creating the barriers that slacken the speed of EE in Norway.

Norway promised to emission reduction, align with the EU, of 40% in sectors subject to emission credits by 2030 (Enova, 2019a). In February 2020, the government announced that these goals would be reinforced by the extra increment of the level of ambition, to 50-55% emission cuts leading up to 2030 (Enova, 2019a). Apart from this, the Norwegian govt's goal to build a low carbon society that is connected to the improvement of EE level in all energy-related sectors. The thesis has shown the importance of improving the EE regarding the buildings, in the introduction section, to construct the low carbon society or to achieve the gain of 50-55% emission cuts by 2030.

Around 90% of houses are old houses built on since the 1950s and those houses might exist another 50 or 100 years. Generally, the older portion of the Norwegian housing stock is featured by poor insulation despite the harsh climate and decentralized electric resistance heaters, an adverse condition occurred by an amplitude of cheap electricity produce by the hydropower at the time houses were built (Klöckner & Nayum, 2016). So, it is presumed that this massive number of houses poses a big possibility for the Norway regarding the achieving EE. Moreover, the Norwegian government has the plan to make the building sector carbon neutral by 2030. The interviewees also stated about this possibility of achieving massive energy savings and reducing the emission from the building sector in Norway. And the also stated that the EE growth rate from the buildings is not much significant. There are ways to increase the EE in the building sector, such as renovation fully, renovation or replacement of the existing technologies partially, and reduction of energy consumption by the behavioural change. Among these three parameters, according to the functional key respondent, the holistic renovation rate is quite low, and the partial renovation or replacement of the existing technologies does not reflect significant growth but growing day by day. Besides that, the EE of a house can be upgraded significantly by improving the insulation standard, thus lowering the energy loss to the environment (Klöckner & Nayum, 2016).

Moreover, in the case of behavioural aspects or attitudes, Norwegians are quite unconscious about their personal or daily consumption.

This thesis has discussed the definition of the EE , EE policy, and EE gap in the Norwegian perspective in theoretical and background sections to more detail, EE refers to the consumption of energy efficiently in respect to saving the energy along with the reduction of emissions. And the Norwegian EE policy (ENØK) is quite controversial as it is emphasizing more on the economic perspective to achieve the EE targets, rather than other instruments of achieving EE in the buildings. Apart from this, this policy has quite an obscurity regarding put that into practice by stakeholders. However, since the 1970s Norwegian government has implemented several polices to improve the EE, while outcomes do not fulfill the expectations. For instance, one of the interviewees has resonated with this perception that Norwegian govt has determined the quantitative goal to save 10 TWh/y through improving the EE level in the existing residential buildings, while the measures to achieve this goal is not much qualitative to achieve that goal. And the growth of the EE level in the existing building sector seems very slow (Enova, 2019a), despite the implantation of numerous measures to scale EE up. Therefore, it is evident that there is an EE gap in the Norwegian building sectors which makes the EE up-gradation process slower to be précised. So, the so-called EE gap leads to create the number of constraints in case of the development of EE, which hints to the objective of first sub-question.

The first sub-question points to the barriers of EE in the old building sector in Norway, it has precisely presented the answer to the key research question. In the theoretical chapter, a generic discussion has been presented about barriers of EE of the building under the four commanding points which are the economic perspective, the government or procurement perspective, knowing or raising awareness barriers, and building efficiency barriers. This thesis has carried a comprehensive interview and have used the NVivo data analysis software to identify the most stated theme by the respondents. Based on the NVivo analysis, this thesis will discuss the key barriers concerning the Norwegian existing residential buildings.

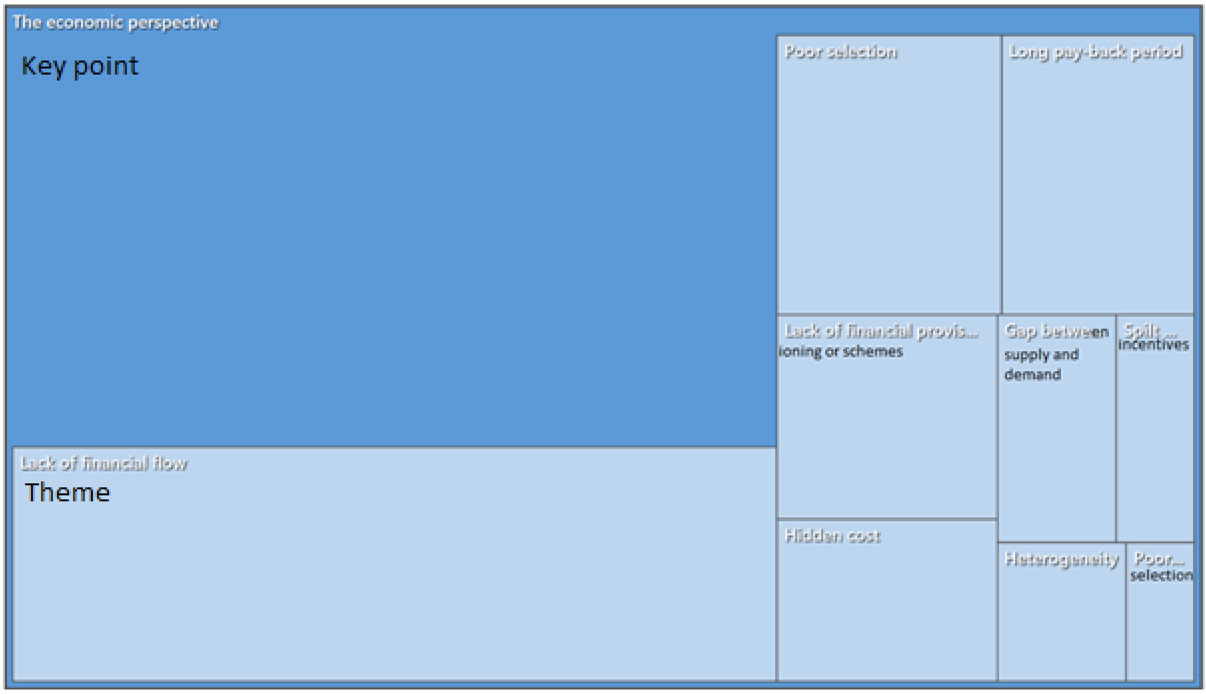

Figure 6.1 Compared by number of coding references of the economic perspective (prepared by NVivo)[58]

The economic perspective is one of the biggest parts of the fact of EE in the buildings, which is proved by the Figure 6.1 above/mentioned graph, among all the economic barriers, lack of financial flow is the most crucial constraint in the economic perspective.

Almost all the respondents have stated that the existing building portion is a very massive area, so it needs a massive amount of public investment to enhance the EE level in the old buildings. Although, Enova is providing a significant amount of grants or other economic assistance, which is not enough compared to the demand to reach the target of 2030 or more further goal for 2050 to build the carbon-neutral or low carbon society. Enova has increased the economic assistance significantly in 2019 for the up-gradation of EE in the existing buildings, which has mentioned more details in the background section. According to Klockner and Nayum (2016), if the Norwegian government wants to reach the goal of scaling down of energy intensity of the building sector, voluntary investment should be coupled (Klöckner & Nayum, 2016). In Norway, 6.3% of the households are renovated or refurbished every year regarding the aesthetics perspective, while only half of these projects are performed for the sake of EE (Klöckner & Nayum, 2016).

[58] ***The more specious themes in the graph are the more referred by the functional key respondents and the deep blue portion in the figures is key point and the light blue presents the themes in the graph.***

The long payback period is the second key parameter to discourage house owners to go for the investment of EE improvement, all the measurements related to the EE in existing buildings are cost-intensive as well as profit usually takes 20-30 years according to the functional key respondent. This long payback period obliges house owners to select the cheaper option, although that is not suitable or standard.

The poor selection of technologies is another drawback in the EE progress, in the theory section, it has discussed in detail how it occurs generally. According to the respondent's (FKR1 and FKR2) opinion, the building market is very diverse and there are variegated energy-efficient technologies are available, but due to the informational deficiency leads people to purchase the wrong appliances. Moreover, energy technologies seem often to be selected based on how strongly they symbolize EE, not from calculations to identify optimal solutions of energy consumption (Moe, 2006). For instance, heat pumps were occasionally selected as part of the energy supply system as of their iconic status because environmentally friendly, even when another technology would have given greater EE in the building (Ryghaug & Sørensen, 2009). Simultaneously, lot of small companies (construction or maintenance companies) are involved with the building industry, they work as intermediaries between house owners and markets, they consider the EE as a secondary issue as well as a continuous change of product information make buyers skeptical (O'Malley et al., 2003). Lack of financial schemes or structures which is another key economic barriers as one of the respondents (FKR5) opines that Enova has the responsibility to provide the economic grants to the house owners regarding the EE issues, however, Enova's financial structure are not quite standard for the residential building compared to the commercial or public buildings.

Hidden cost occurs due to the absence of proper pre-assessment or research, as it has mentioned earlier in this these, the old building stock is a massive area which requires proper planning and assessment instruments to present the cost-effective solution for the homeowners. Concurrently Moe (2006), shows that there are no established standards for measuring the EE level or for the assessment of energy measurements of buildings, let alone the extent of environmental soundness in the Norwegian building industry (Moe, 2006). Certainly, the energy consumption of buildings can be measured, and there are some consultant systems available, such as 'Økolrofil' (Eco Profile) (Ryghaug & Sørensen, 2009). However, none of these assessment methods has achieved any official status in the Norwegian building industry (Ryghaug & Sørensen, 2009). Contractors who want to build sustainably way may choose what criteria for environmentally soundness they want to employ (Ryghaug & Sørensen, 2009).

Consequently, sustainability, including EE, is formed by local interpretations, priorities, and interests, even while a high energy standard is materialized into an important design criterion (Ryghaug & Sørensen, 2009). This leads to the less efficient implementation of sustainability, as local builders frequently prioritize in an idiosyncratic manner, using an incidental feature of environmental friendliness of buildings (Moe, 2006) (Ryghaug & Sørensen, 2009).

Among the other four barriers in the graph (the gap between supply-demand, poor arbitrage, heterogeneity, and spilt incentives), the gap between supply demand and split incentives are important regarding the Norwegian building industry. Technology for the EE is available in the Norwegian market, and amount of technologies outweighs the number of buyers, as Norwegian people are less attractive to the energy-efficient appliances and due to the trend-based culture of Norwegian people, particular technology has got popularity in a particular time, such as currently appliances related to the solar energy are so popular in Norwegian market (according to the respondents FKR3 and FKR4). In Norway, there are numerous rented houses, house owners do not willing to invest for the EE up-gradation as the returns of EE investment will go to the tenants' pocket, This problem is most relevant to the so-called tenant-owner dilemma (Lovell, 2005).

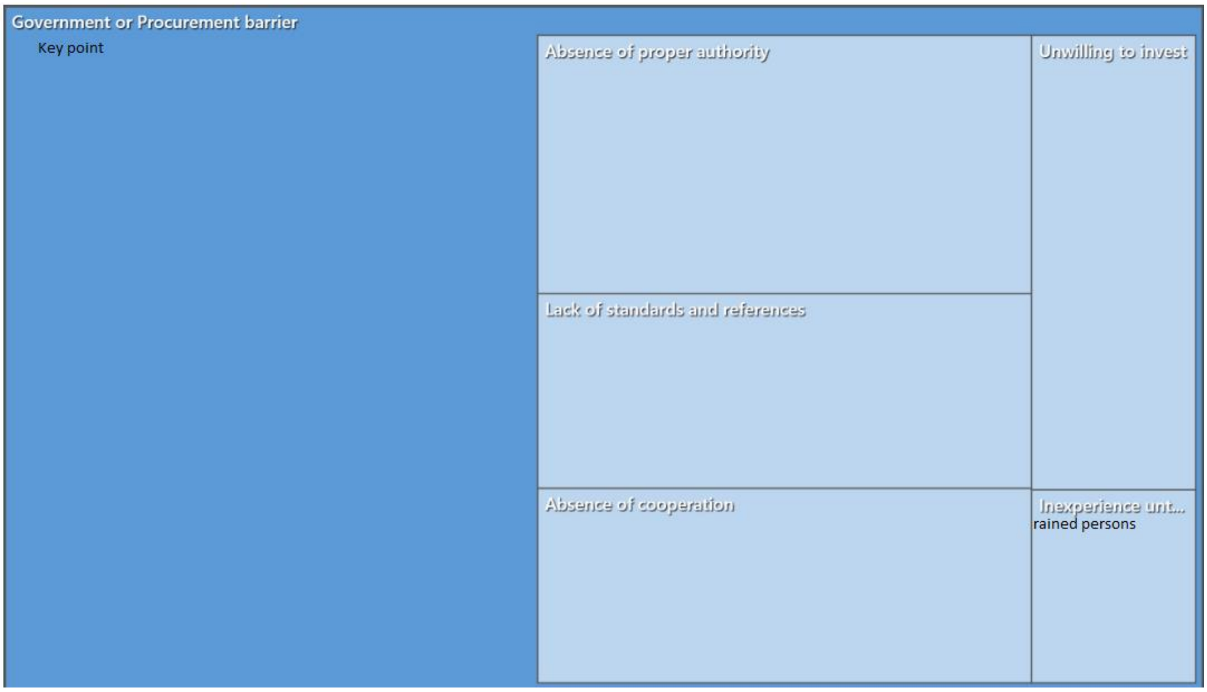

Figure 6.2 Compared by number of coding references of the government and procurement perspective (prepared by NVivo)

From the common perception, the government is the key actor to ensure all the amenities, policy instruments to address such massive issue as the escalation of EE in the existing building stock, and many entities are incorporated with this issue. This thesis has discussed in the background and earlier of the discussion sections, that the Norwegian government has implemented different types of strategies to enhance the EE level, to reduce the energy consumption along with the reduction of GHGs emissions. Yet, the outcome of the government's efforts does not match with the delivered measures to some extent. however, there are several key limitations regarding government perspective Figure 6.2 above in the respect of improving the EE level in the Norwegian existing residential building stock.

The absence of proper authority is stated by most of the functional key respondents, they emphasize that the improvement of EE in the existing building stock follows the flat line for a couple of years. So, they have pointed out the reasons for this sluggish upward trend are lack of policy interventions. And they also have addressed the issue of the EPC project, which is also has implemented very steadily because of less administrative capacity of Norwegian municipalities. This thesis has already discussed the energy efficiency policy in Norway in the background section, where it shows that the Norwegian energy efficiency policy (ENØK) has formulated with the ambiguities in interpretation among the associated actors, which is one of the key reasons to fail the improvement of EE level in the existing buildings in Norway, which is referred by the (Ryghaug & Sørensen, 2009) in this article.

Lack of standards and references to implement the EE strategy through the renovation of the existing buildings, interviewees have argued that Norwegian govt has decided the target to achieve 10 TWh\y through the EE measurements, but the references and standards to achieve this goal are not quite promising, concurrently Moe (2006) has resonated the same statement as there are no established measures in Norway, to evaluate the EE condition or to implement the EE strategies substantially (Moe, 2006; Ryghaug & Sørensen, 2009).

Another constraint that is widely discussed by the respondents is the absence of cooperation among the private, public, business institutions and landlords as well. And Ryghaug & Sørensen (2009) also have stated that, Over more than three decades, the Norwegian government has implemented variegated policies or strategies to improve the EE in the building design, while the achievements may be pointed as modest at best (Ryghaug & Sørensen, 2009). Why that so? The fact of EE of buildings needs to be perceived as connected to a complex socio-technical system where different actors work at the centre point of industry, market structures, institutions of governance, innovation systems, evaluation practices, supplier-users chains, designer and engineering practices, etc (Ryghaug & Sørensen, 2009). Therefore there are several possible points of failure, and the challenges in presenting a comprehensive analysis solution are formidable (Ryghaug & Sørensen, 2009). Apart from this, the communication among the actors in building projects. The Norwegian building project is diverse of actors and professions that take part and may influence the energy standard of the resulting building (Ryghaug & Sørensen, 2009). Probably, there are many conflicting interests in the building industry due to the diversity of professional traditions, epistemic paradigms, and competences (Ryghaug & Sørensen, 2009). Moreover, communication is complicated by linguistic diversity among the professions and differences in the way make representations of buildings (Ryghaug & Sørensen, 2009).

Unwilling of the house owners to invest in EE is very common in Norway, as it is considered that EE up-gradation has a very high upfront cost and longer payback periods discourage the house owners to go for that investment. As many scholars have opined that it is very difficult to inspire private house owners to decide on the investment for the increasing the EE of their homes (Friege & Chappin, 2014; Klöckner & Nayum, 2016; Wilson, Crane, & Chryssochoidis, 2014). Despite having said that Norwegians are unwilling to invest in the renovation of their buildings, whereas renovation rate is very high in Norway yearly, however, the renovation related to the energy measurements is below of the half of total renovation (Klöckner & Nayum, 2016). Therefore, it is evident that people invest but due to the lack of guidelines house owners do not invest in EE.

Inexperienced and untrained professionals involved in the renovation or demolition project of the existing building stock in Norway. Respondents have argued that professionals must have competence about the used technologies in the old houses, a lot of technologies have been dumped despite having expiry, which is a waste of money and impact environment adversely in the long run. Apart from this, the tech industry is dynamic, it is key to ensure the adaptation of professionals with this dynamic nature of tech markets. According to the Zen report (2020), a significant amount of building's products, those are usable, has been thrown away, burned or destroyed, this occurs due to the improper management in this sector (Bremvåg et al., 2020). with a view to reduction of cost of building renovation as well as to lower the negative impact of climate and environment, it is key to ensure the proper utilization of the products (Bremvåg et al., 2020).

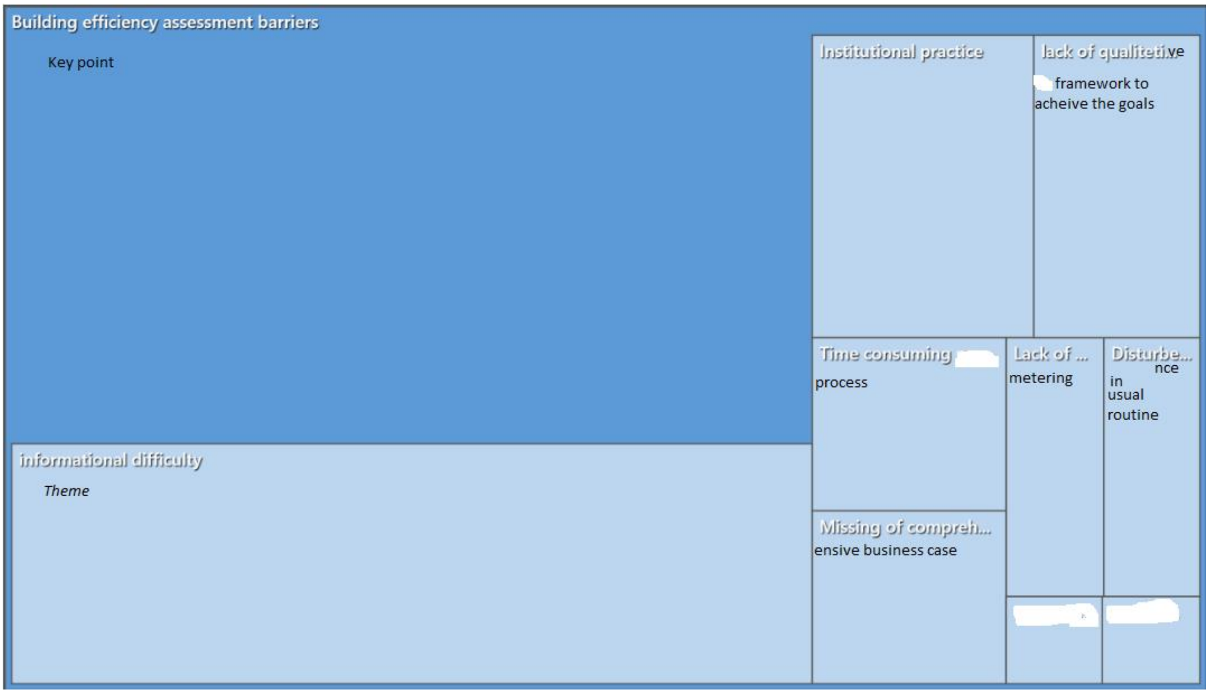

Figure 6.3 Compared by number of coding references for building efficiency assessment barriers (created by NVivo)

Building efficiency assessment limitations are consist of several co-themes which is shown in Figure 6.3 above-mentioned graph, the more spacious theme in the graph is emphasized mostly by the respondents. Subsequently, the informational difficulty is the most crucial fact in the section of building efficiency assessment barriers.

Information difficulty is contributing a lot to slacken the pace of the EE process in the Norwegian existing buildings. As it is mentioned earlier that Norwegian people invest a huge amount for the renovation of their homes to increase the aesthetic features, but they do not invest for the EE as they deep-rooted idea of cost intensity in EE up-gradation and longer time to get the profit back. Although there are many cost-effective measures existed, due to the proper informational dissemination, house owners cannot grasp those opportunities. According to the Amoruso et al, (2018), the informational deficiency is quite prevalent among service companies and mass people in Norway, which interrupt very significantly the escalation of EE (Amoruso et al., 2018). And another problem that occurs because of the information inefficiency is the rebound effect (K. C. a. K. Palmer, 2020), which is quite significant in Norwegian households, for instance, replacement of the washing machine convinces residents to use more as it is energy efficient. And another key aspect of informational difficulty is that the dissemination of information is constrained to the city, while the people from the country side does not receive as much information as they need, that interrupts the country wide EE implementation process (FKR2&FKR5).

Institutional practice and lack of a qualitative framework to achieve goals make the process of EE steady. As respondents have pointed that, institutional activities in terms of EE in Norway are featured as steady and full of procedures, as house owners argue that we must go through many procedures to receiving of the Enova's grants. As this thesis has discussed earlier in this chapter, the government has a more promising quantitative goal of EE improvement compared to the qualitative goals to get success. Another part of the institutional practice is the time demanding procedures, respondents say that it is a never-ending process or longer process which discourages the building owners to go for the EE related renovation. This time consumption nature of EE improvement leads to create difficulties in the resident's usual routine which results in avoiding the issue of EE, although it has long time benefits.

Lack of metering system another fact in the Norwegian existing building stock, although it is quite difficult to collect all the data about a building envelop. The Norwegian government has introduced energy performance certificates (EPCs) to provide detailed information about a building. However, These certificates generally are less comprehensive than those implemented by the professionals and the cost of the certification process for these buildings is normally at least NOK 1000 (Olaussen et al., 2019).

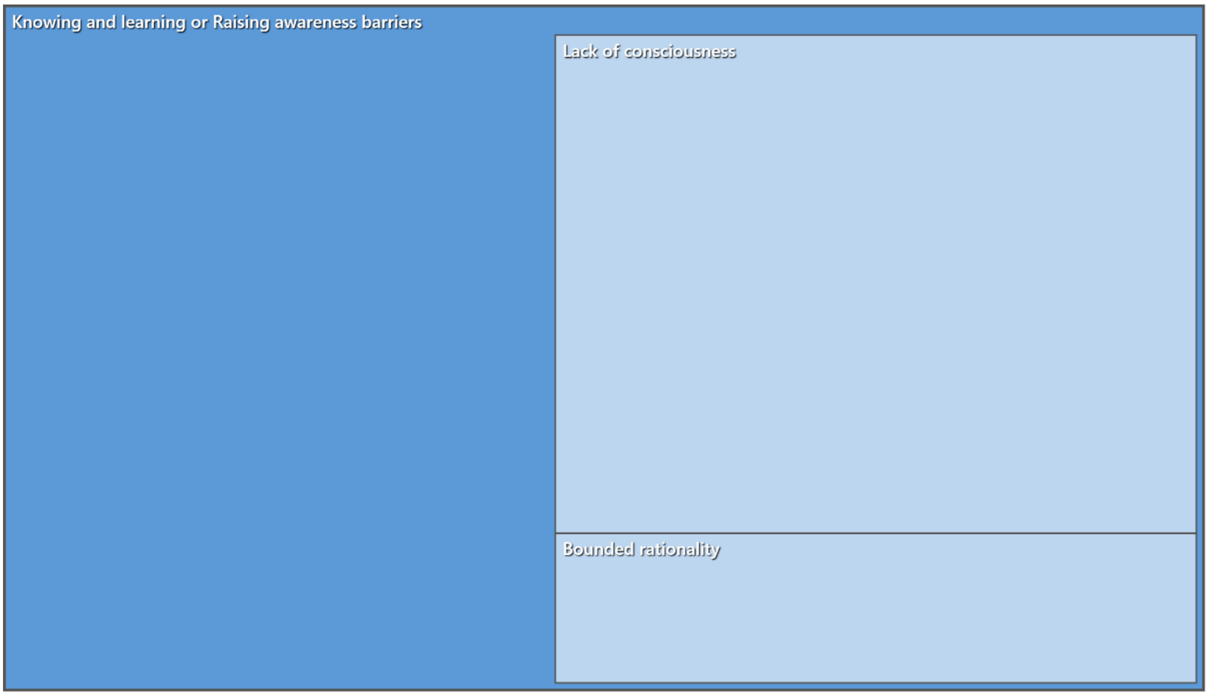

Figure 6.4 Compared by number of coding references for knowing and learning or raising awareness barriers (created by NVivo)

Lack of consciousness among quite significant among Norwegian mass people which shows Figure 6.4 above mentioned graph. Cheap electricity is one of the key reasons to make people more unaware of the EE up-gradation in the existing buildings. Norwegian people pay nothing for their electricity consumption. And most of the Norwegian people do not know how much they consume per month, because of this people are unconscious to their consumption. lack of knowledge, wrong advice from the craftsman, or priority to work which they can perform by themselves stopped other homeowners to go for the renovation for the EE up-gradation (Risholt & Berker, 2013). Moreover, around 20% of the politician in Norway does not believe in climate change which also inspires masses to be wary about the EE up-gradation in their buildings or be chary about their consumption. the below-mentioned figure shows that the significant percentage (around 7% of Norwegian people according to the graph) of people does not believe in climate change, Norway is the 4th climate deniers country among other countries, this perception also trammels the EE up-gradation in the existing building sector in Norway.

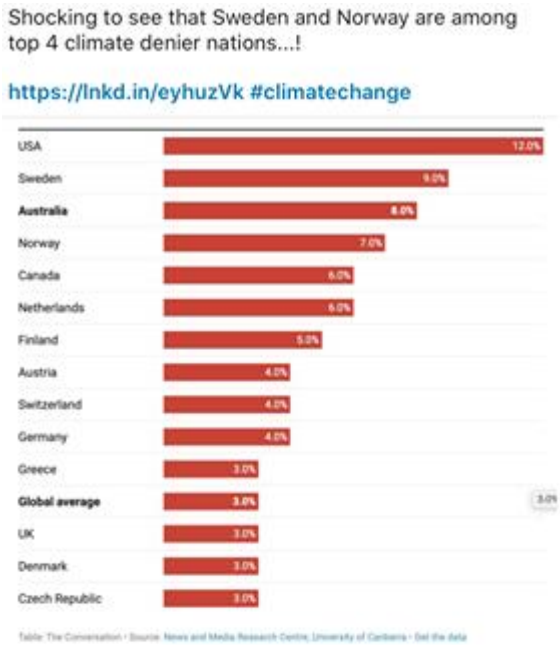

Figure 6.5 Percentage of climate deniers in Norway
(this graph formulated based on a conversation in the University of Canberra, I have taken it from the LinkedIn)

This prevalent perception of cheap energy and general unconsciousness about energy consumption leads to create the bounded rationality regarding deciding EE development among the masses. Form the administrative point of view, it is mentioned several times that Norwegian authority has implemented many strategies to upgrade the EE in the existing buildings, whereas the results seem pessimistic. Therefore, it is proven that the administrative decision-making process is very slow which influence negatively to increase the EE project. Accordingly, the trend-based culture of Norway does not let people think rationally while they purchase any appliances or during the renovation as well. Moreover, energy technologies seem often to be selected based on how strongly they symbolize EE, not from calculations to identify optimal solutions of energy consumption (Moe, 2006). For instance, heat pumps were occasionally selected as part of the energy supply system as of their iconic status because environmentally friendly, even when another technology would have given greater EE in the building (Ryghaug & Sørensen, 2009).

The 2nd sub-research question focuses on the possible solution of the barriers to improving the EE in the context of Norwegian existing residential building stock. In this section, some possible solutions will be presented based on the informant's statement, and themes for the possible solutions have been created by the NVivo data analysis software. The result is being shown in Figure 6.6 below.

Figure 6.6 Compared by number of coding references of strategies to overcome the barriers

Ensuring the financial flow is one of the most key parameters to push more people for the renovation of EE improvement. All the interviewees have put the importance on the sufficient funding for the EE project. Along with this, the standard financial model must be implemented to provide financial assistance based on the priority. This thesis has already mentioned the Enova's financial contribution for 2019, the amount of financial flow has increased in 2019 compared to the previous years. However, proper incentives, grants, and authentic information can solve all the barriers related to economic barriers. Homeowners will renovate their homes to improve the EE level if financial incentives have been provided (Barenergy, 2011; Risholt & Berker, 2013).

Another key parameter to improve the EE is informational availability, which is also very significant regarding Norway. There is a lot of information available in the Norwegian institutions, the dissemination of that information is very insignificant. As it is mentioned, Norwegians are the first position to renovate their homes as the modernization of their homes every year is part of their culture, if they are being provided the information while they are on-process to renovate they will invest for the EE up-gradation. As Enova (2012) rightly said that, homeowners will likely do the investment for the EE, if they receive the information when they are renovating their home for other purposes (Enova, 2012c; Risholt & Berker, 2013). Moreover, proper knowledge about the long term benefits of the up-gradation of EE in the old buildings, the availability of attractive appliances and services along with the smooth access to reliable advices on the standard renovation solutions have a greater possibility to imbue more homeowners to make energy-efficient selections in the process of renovation; and mostly who has the prior experiences who can perceive the real benefits of EE in their homes (Risholt & Berker, 2013).

EE strategies have been implemented for the last couple of decades, for that purpose lot of different tools, methods, standards, and business models have been developed. Proper implementation of those strategies is very crucial to upgrade the EE level (Søraa et al., 2019). This thesis has discussed the Norwegian energy efficiency policy (ENØK), due to having some obscurity, the implementation of this policy is quite struggling for the associated actors. According to the Risholt & Berker (2013), coordination of more policy strategies along with the specific information and incentives can push more people towards the renovation of their houses to improve the EE (Risholt & Berker, 2013; Søraa et al., 2019). Still, policymakers encounter many challenges to upgrade the existing buildings (Vlasova & Gram-Hanssen, 2014)(Søraa et al., 2019). Renovation of the existing buildings presents a big challenge for the policymakers since it is nor matter to regulation in the same way as new construction. In Norway, as many as 90% of dwellings are owned by the dwellers themselves. A major portion of the houses are detached or semidetached (Søraa et al., 2019). There are around 2.2 million houses that go with these categories (Enova, 2012a; Søraa et al., 2019), and the renovation is frequently implemented by the homeowners themselves or by small contractors and builders

(Søraa et al., 2019). Taken as a whole, these houses consist of a complex mass of buildings and actors which is critical for the government to reach (Søraa et al., 2019).

Several institutional features seem to create conservatism and a lack of importance given to sustainability and EE in buildings in Norway, therefore blocking the translation of EE policies into attractive areas of action (Ryghaug & Sørensen 2009). First, the short-term cost efficiency and the high pace in the design process lead to an extensive re-use solution. Second, the situations for transfer on new knowledge from research institutions are poor (Ryghaug & Sørensen 2009). The building and construction industry in Norway are large and complex and controlled by small and medium-sized enterprises (apart from a few large actors) that cooperate on the design and construction of buildings (Ryghaug & Sørensen 2009).

Political concentration is important from the Norwegian perspective, as Norwegian people are very watchful about political issues or agendas. According to the informants, member of the green party is increasing day by day, which is the sign of getting these issues more popularity that leads to extensive dispersion of the information of the climate-related issues. hence people will be more careful about their consumption. According to the EU directives increased political attention towards the built environment and its relationship to climate change has led to regulatory strategies in the form stricter building codes and mandatory energy labeling of dwelling (Directives 2002/91/EU and 2010/31/EU) (Søraa et al., 2019). And Recently, govt has been measured to involve actors who are already incorporated in home renovation, such as contractors, builders, and craftspeople, by easing a more active role for these professionals as energy consultants (Søraa et al., 2019). According to the Risholt and Berker (2013), craftspeople have been a barrier to EE, while professionals pose a great possibility (Risholt & Berker, 2013)(Søraa et al., 2019).

Imposing extra tariff is another instrument to make people more aware about their consumption. Current energy prices are understood as being too low to make EE investments attractive to homeowners (Risholt & Berker, 2013). Therefore, several EE measures can only be cost-effective if they are implemented while the renovation is going to be finished (Risholt & Berker, 2013). Emphasizing the new research is the key window to make the EE process is more dynamic, as it is mentioned earlier that numerous strategies have been implemented while the results cannot meet the expectations. According to Hubak (1998), Almost no Norwegian companies in the building industry have units liable for R&D or innovation (Hubak, 1998). Therefore, there is a lack of people that are involved in and have the skill needed for successful knowledge transfer. Consequently, the contact with relevant research institution is weak (Ryghaug & Sørensen 2009). Moreover, the building and construction industry in Norway has a low level of investment in R&D and innovation. Thus, it seems obvious to ask whether the industry's innovation falls outside the scope of the official's statistics or if the industry is not very aware about innovation (Ryghaug & Sørensen 2009).

Relationship between energy behaviour and billing system, some of the respondents (FKR2 and FKR5) has stated, there is a misconception among mass people that Norwegian electricity is emission-free along with the cheap electricity lead them to be unaware about the preservation of energy. Therefore, if it is possible to make a connection between the billing system and energy behaviour, it would be possible to create the perception of awareness among people about the saving of energy.

Norwegian existing building stock consists of around 90% of the total building stock, at the same time, no company plays the role of One-Stop-Shop (it means a single company provides all kind of services form up to bottom to renovate the old house). And the renovation process is time-consuming, therefore, some interviewees have presented that it will be easier for the Norwegian government to implement phase by phase renovation process.

7 Conclusion

The aim and purpose of this thesis are to find out the barriers which slower the EE process in the Norwegian existing residential building as well as present some possible solutions from the perspective of Norwegian existing building stock.

The point of the departure of the thesis was a discussion on the introduction of study a precursor for the problem statement of the thesis. The introduction part involved a pragmatic approach to the present discourse on climate change and its possible impact. Subsequently, the urgent wake-up call of international key institutions for all the nations to work for limiting the emissions from all the possible sources. Among all the possible sources, the building sector is one of the key players, which consumes around more than one-third of total energy consumption and produce a significant amount of CO2.

Since the focus of the thesis is Norwegian existing buildings so it discussed more Norwegian building sector is liable to consume around 40% of global energy consumption (UNEP, 2015), and Norway's energy consumption in the building sector closely maps onto this average, accounting for around 40% of national energy use. At the same time, one-quarter of the GHGs are produced by the Norwegian existing building sector. The Norwegian building sector is quite a big area which consists of around 80% of total houses in Norway. The main objective of the introduction pate is to prove the EE gap in the Norwegian building sector, which have shown by many scholars. This massive amount of old buildings consumes a significant amount of energy, at the same time it presents a big opportunity to save a tremendous amount of energy and to lower the emissions through the up-gradation of EE. Based on such sentences, the problem statement of the thesis has been prepared; and have constructed three one key research question and two sub-research questions.

Based on the research questions, the thesis has presented detailed background sections to show the comprehensive scenario about Norwegian existing residential building stock. In the background section, there are many key points has been discussed related to the energy consumption scenario, a scenario of how to turn a building more energy-efficient, how to renovate the existing buildings and which technologies need to be used, Norwegian policy for the EE and the predicted scenario of the EE in the Norwegian existing residential buildings, to be précised.

Therefore, the thesis addressed the research questions by examining theoretically the whole framework of EE in the existing building sector in Norway. As the point of departure, the thesis defined the fact of energy efficiency and the so-called energy efficiency gap. The thesis presented the generic barriers of EE implementation in the old building stock under the four key points of EE improvement. And the potential options to overcome those barriers.

The thesis contributed to the theory development by thematically interpreting the barriers of EE. Moreover, the theoretical framework of EE in the Norwegian existing building sector, the thesis abductively employed the analysis of the barriers of EE which present many themes followed by the encompassing of five key points: financial barriers, government or procurement barriers, building efficiency assessment barriers, knowing and learning or raising awareness barriers and strategies to overcome those barriers.

A single-case study is premised on the optimum test of a significant theory (Yin, 2014, Brotherton, 2008). Therefore, based on the epistemological and ontological philosophical assumption, the qualitative research approach was used as a main methodological framework for addressing the research questions. The strategy of data collection for the thesis was through a semi-structured and unstructured video interview process. The thesis intended sample selection and population resonated with the barriers of EE up-gradation in the Norwegian existing building sector and strategies to overcome those barriers of functional key respondents in the unit of analysis.

The thesis data analysis and reduction has been carried using NVivo qualitative data analysis software. The gathered data through the interview transcript has been exported to NVivo qualitative data software. Thereafter, nodes on the barriers of EE and strategies to overcome the barriers have been constructed to identify the key themes from the transcribed interview in NVivo. The nodes on financial barriers, government, or procurement barriers, building efficiency assessment barriers, knowing, and learning or raising awareness barriers and strategies to overcome those barriers were formulated.

The thesis data analysis has based on the thematic analysis and the analyzed data on each node created using NVivo qualitative data analysis software. The point of departure for the analysis involved identifying the themes in NVivo using word clouds frequency results query. This helped to find out the key concepts from the functional key respondents.

7.1 Managerial Implications

The thesis presented the results relied on the theoretical framework of EE barriers in the Norwegian existing residential building sector and data presentation in tandem to addressing the research questions. The results discussion pointed out the research questions by addressing the barrier of EE and possible solutions. The results of the key research question, how the process of EE get slower, there are many barriers exists in the Norwegian existing residential buildings, among them some are very alarming for the improvement of EE, such as lack of proper financial assistance and financial methods, lack of information, lack of consciousness lack of proper policy and so on. These key points are very crucial for the policymakers to address to speed up the EE in the Norwegian existing residential buildings.

The thesis managerial implications for practice should focus on the importance of the up-gradation of EE in the old residential buildings. This thesis has shown the positive outcomes of the improvement of EE in the old buildings, as it is possible to save about 10 TWh/y through the improvement of EE. And the EE gap in the Norwegian old building stock has been proven in this thesis, which leads to creating many barriers to scale up the EE in the buildings. The financial insufficiency, informational difficulty, absence of cooperation among the key actors to implement the strategies properly, and the unawareness of the mass people for their energy consumption are the key constraints in the process of EE up-gradation in the Norwegian old building stock.

The managerial implication, to overcome the above-mentioned key barriers, is to provide enough financial assistance with the proper guidelines in the right time, to offer the cost-effective solutions for the renovation of the houses. Moreover, the government must improve cooperation among all the stakeholders relevant to this industry to materialize the proposed strategies competently. And the Norwegian government should introduce the One-Stop-Shop business model to reduce the time consumption of the renovation process and to simplify the process of renovation for the house owners.

Another managerial implication involves the implementation of the concept of 'deep renovation' has introduced by the EE directive 2012/27/EU, which points to the holistic renovation of a house. The majority of the renovation projects are the partial renovation, which is cost-intensive in many cases and not fully sustainable as all the existing appliances of an old building need to be replaced with time. Therefore, this thesis suggests implementing the 'deep renovation' scheme to improve the standard as equivalent as passive house along with the reduction of renovation cost as well.

7.2 Limitation

The thesis limitation is varied in the research process. One of the limitations was concerning data collection from the houseowners' perspective. The insight was to get an outlook on end-user energy consumption, only a few house owners have participated in the data collection phase. Therefore, the dearth of participation of house owners has impacted the thesis research analysis phase to capture the end-user's perspective on the up-gradation of EE in the buildings.

Another limitation of the thesis is germane to the generality of the study owing to a limited sample size of only seven respondents were chosen as part of data collection techniques. This is a massive area with thousands of researchers, scholars, and employers across the globe, and the study, therefore, does not generalize the findings on all the related people. However, the purpose of the thesis has been attained to unearth some key constraints and to present several solutions to improve the EE level in the Norwegian existing residential building stock.

The limitations pertinent to tools for the qualitative analysis presented a huge challenge for the thesis. This was due to a lack of comprehensive training in the know-how on the options of interpreting data qualitatively. Moreover, the sources for placing the proper framework for qualitative analysis was not simple to situate in the stratum of academic data analysis literature.

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Annexures 1: Interview Protocol Guide

Professional questions about an interviewee

1. What is your job position?

2. How long have been working with this company?

3. Have you been directly connected to the project that dealt with the issues of energy efficiency in residential buildings, technical renovation of old buildings and installation or replacement of energy related appliances to reduce the energy consumption?

Précised question about topic

1. What are the key objectives to improve the level of efficiency in the building's energy consumption?
2. Can you notice changes through the project of renovation work to improve the level energy efficiency since it initiated? Or do you think that level of EE is up to the mark?
3. Have the CO_2 emissions gone down since the renovation project of old houses has been started?
4. What are the barriers (Economic, Social, environmental, or mental) can be seen to carry the renovation work in old houses?
5. What are the opinions of the owner of the houses in terms of renovating their houses and installing the new technologies to improve the quality of life as well as to reduce the energy demand and CO_2 emission?
6. Are there any alternative plans (other than Renovation method) that state is considering or is being considered to raise the EE level in the existing building?
7. Do you think that private or public investment is available for the house-owners to the renovation?

8. Do you think the renovation rate is up to the mark align with the climate policy of the government? If it does not follow what are causes to not follow the climate policy properly?
9. Do you think people are enough aware regarding climate change or about their contribution to reduce the global warming? How Consciousness can be increased?
10. Why people are considering more about the aesthetic aspects rather than the improving energy efficiency level, while they are renovating houses?
11. Do you think that people are quite aware about their monthly usage of all types of energy?
12. Do you think information is available concerning the EE, renovation/retrofitting of the house, energy savings, reduction of CO_2 and the long-term benefit of EE upgradation?
13. Some people believe that renovation costs are too high, while finance institutions opine that pay-back period is too long for the renovation investment, what do you think about that?
14. What are your suggestions to overcome all the sorts of barriers to improve the level of efficiency and reduce the CO_2 emission?