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Submission:

Energy Transition in the Building Sector:
Comparison of German and Norwegian Policies & Technologies Regarding Residential Buildings

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Notification for the readers:
This paper is a policy review. It is a draft and supposed to be published later, so please do not site or publish anywhere.

1 Introduction: Buildings and Climate Change

Buildings are responsible for about 30% of the global greenhouse gas emissions mainly due to their need for heating and cooling energy. This corresponds to about 30 to 40% of the global final energy consumption. (GBPN, 2013; Lucon et al., 2014; UNEP SBCI, 2009) According to the latest IPCC report, published in 2014, three quarters of this energy use fall upon residential buildings considering the global average (Lucon et al., 2014, p. 678). Therefore, it is inevitable that the building sector has to be integrated in the strategies of the energy system's transformation to mitigate climate change.

Within the building sector lies a huge potential for emissions reduction through the increase of energy efficiency and the decarbonization of the energy mix. The main areas of intervention in the building sector are the renovation and energy supply of the existing building stock, climate-friendly building codes for new constructions, change of the consumers' behavior and a higher performance in energy efficiency of the appliances (see e.g. Amecke et al., 2013). Studies state that about 30% of todays' emissions related to the building sector can be reduced in many countries, although the sector is even estimated to grow in the next decades. (GBPN, 2013, p. 2; UNEP SBCI, 2009, p. 5) In the IPCC-Report different regional studies concerning the stock-aggregated levels of buildings are being compared and in many cases the potential is calculated to be even higher, between 30% and 60%. (Lucon et al., 2014, p. 702) Nevertheless, the state of the art of the building sector's emissions shows that still a lot of efforts have to be invested in order to exhaust this potential or overcome the so-called *energy efficiency gap* or *emission gap* and contribute to the 1.5-2.0°C target. (GBPN, 2013, p. 2; Lee & Yik, 2004, p. 488; UNFCCC, 2015)

However, as there are several different pathways to a decarbonized energy system, there is always the question which political and technological solutions are most efficient, effective and feasible. There has not been done enough research yet that assesses the (cost-)-effectiveness of the several political and technological solutions, as has been stated e.g. by the Climate Policy Initiative[1] in 2013 (Amecke et al., 2013, p. 2).

To start filling this research gap this paper aims to analyze building efficiency policy measures and instruments as well as different technological solutions in two frontrunner-countries of the energy transition with different structural conditions: Germany and Norway. We, hence, apply an interdisciplinary approach, which allows us to assess the existing policies and their incentives including the trade-offs between policies, different technological solutions and structural realities. The paper answers two research questions: (1) which policy instruments and measures prevail in Germany and Norway to foster the deployment of energy efficient and decarbonized solutions for residential buildings? (2) Which trade-offs arise from climate change policies regarding residential buildings and the related implemented technologies in the context of the structural realities in Germany and Norway?

Considering the specific challenges within the two applied case studies, we do not focus on new building and showcases. Those are specifically interesting when demonstrating the technological possibilities, but not eligible when it comes to the dominating socio-structural conditions in Germany and Norway. In the center of our analysis we rather put political and technological measures concerning the existing

[1] The Climate Policy Initiative is a research network that has been founded in 2009. The institute conducts studies to evaluate and compare climate policies around the world with a focus on energy and land use policies. See: http://climatepolicyinitiative.org/

building stock in residential use, which include the retrofit, the appliances and the consumer's behavior. In this context we examine if the different instruments can overcome the country-specific main barriers to fulfill the energy transition in the building sector. For the policy measures we look both at voluntary and regulatory solutions, whereas for the technological part we consider both active and passive measures.

In section 2 and 3, hence, we introduce the main barriers to the energy transition in the building sector and define the differences between the technological solutions called active and passive measures. Section 4 provides some topic related background information on the case countries Germany and Norway linking them to the country specific barriers in the context of the energy transition regarding residential buildings. In the following sections 5 and 6 the research questions are being answered by comparing, firstly, the different German and Norwegian policies on carbon and energy efficiency in the building sector and, secondly, discussing soma major trade-offs related to (cost-)efficiency, behavior and positive spillovers. The concluding chapter summarizes the analysis and discusses some recommendations as well as suggestions for future research.

2 Barriers to the Energy Transition in the Building Sector

To reduce emissions caused by buildings there are mainly **four areas of intervention**: (1) standards for new building construction, (2) the retrofit of the existing building stock, (3) the replacement or improvement in efficiency of the buildings equipment and the appliances, and (4) behavioral change of the consumers (based on Amecke et al., 2013). A number of barriers hinder the diffusion of buildings energy efficiency measures also in cases where the investment in such measures is beneficiary. Many scholars discuss barriers to the different mitigation options and some of them try to weigh them according to their importance for the policy options in the building sector. These can be summarized as follows (author's categorisation based on the following literature: Amecke et al., 2013, p. 5; Brown, Chandler, Lapsa, & Sovacool, 2008, pp. 101–103; Lee & Yik, 2004, p. 488; Lucon et al., 2014, p. 709; Managan, Layke, Araya, & Nesler, 2012, p. 34 ff.):

- **Institutional barriers:** The building sector is characterized by a manifold actors constellation with heterogeneous interests. This is often described in the literature as being a "fragmented market" that is difficult to coordinate. Additionally, in some jurisdictions there is also a lack of institutional capacity for the design, implementation and enforcement of energy efficiency policies.
- **Misplaced Incentives**: In countries with a mixed ownership structure the question of who is benefitting from investments in efficiency measures is stressed. Further, systems prevail, where the provider is paid for the amount of energy delivered rather than for the level of energy saved.
- **Lack of awareness and information:** Imperfect and asymmetric information (about the cost-effectiveness of measures) do not lead only to principal-agent problems, but also to the perception of the buildings becoming more expensive.
- **Market-related barriers:** They include risk aversion as well as situations of imperfect competition. These occur due to externalities in the calculation of mitigation options that are not reflected in fossil fuel prices.

- **Financial barriers:** Limited capital or even a lack of finance is confronted with high transaction and investment costs, high hurdle rates and often also the lack of affordable technology.
- Other barriers regard **unfavorable policies and laws,** e.g. statutes or fiscal policies, the **lack of know-how and technology** as well as the **long duration of the building stock and path dependencies.**

To tackle these barriers different policy measures are being developed or have already been implemented. They consist of both regulatory and voluntary instruments. Research has proved that the mix of voluntary and regulatory policies appears to be most effective to promote climate-friendly solutions for buildings (Lee & Yik, 2004). Nevertheless, every country or regional jurisdiction has to design the most effective policy package suiting its specific conditions and structural as well as economic realities (Amecke et al., 2013, p. 2; Managan et al., 2012, p. 36). In section 5 the different policy options are exposed in more detail in the context of the two case countries Germany and Norway.

3 Technological Solutions: Passive versus active measures

To increase energy efficiency of a building we normally divide into two distinct types of measures – active and passive. ***Passive measures*** aim at reducing the total energy consumption of the building by reducing energy loss, especially related to heating (e.g. insulation, LED's). ***Active measures***, instead, target at reducing the need of external energy use by actively controlling energy consumption and efficiency (e.g. demand side management, smart thermostats, heat pumps) or by on-site renewable energy production (e.g. solar cells, solar thermal, woodstoves) (Marchais, 2011; Ramesh, Prakash, & Shukla, 2010). In table 1 the most common technological solutions for reducing the buildings energy demand are presented with an indication of relative complexity and investment cost.

Table 1: A selection of the most common technologies for upgrading buildings according to building energy efficiency standards

Technology	Type of measure	Complexity[2]	Investment cost
Extra insulation	Passive	Medium - High	High
Low U-Window	Passive	Medium	Medium
Heat recycling (HVAC, grey water)	Passive	Medium – High	High
Energy saving appliances (LED's ..)	Passive	Low	Low
Heat pump	Active	Low (air-air) – High (water/ground)	Low - High
Smart devices (thermostats, demand side management, ...)	Active	Low	Low
Solar thermal	Active	Medium	High
Photovoltaic	Active	Low	High
Woodstove (bio)	Active	Low - High	Medium

[2] The term “Complexity” is used here to describe the degree of change in the existing building structure to install the different technologies.

The degree of incorporation of the given technologies determines the buildings energy standard (see European Parliament & Council of the European Union, 2010). A buildings energy standard is set along a scale (A-G/H) according to the degree of passive and active measures for increasing energy efficiency and is used in legislation and technical standards for new buildings in respective countries ("Energimerking" in Norway [3], "Energiausweis" in Germany[4]).

4 Context data for the case study countries Germany and Norway

In this section, the relevant context information regarding the two case study countries, Norway and Germany, is presented. Since this paper focuses on policies related to residential buildings, the descriptions of measures related to other aspects that are relevant to building energy efficiency, e.g. for commercial or public buildings, are excluded from this review.

The public policies are closely related to the context in which they are created and implemented. In our case, the energy efficiency in buildings policies are linked to various contextual factors, such as the characteristics of the building stock, the institutional framework in the given country as well as the population and GDP trends, housing ownership, availability of energy sources, cultural or behavioral factors etc. Table 2 presents some comparative data of both case countries, Germany and Norway, relevant to the energy efficiency policies in the building sector. In the following, these data will be discussed in the context of the specific barriers to an energy efficient built environment in Germany and Norway.

Table 2: Relevant context data in both case countries, Germany and Norway

	GERMANY	NORWAY
Population (2015)	81.4 mill (Statistisches Bundesamt, 2015)	5.1 mill (Statistics Norway, 2015b)
Population Growth Rate	-1.65% (Statistisches Bundesamt, 2015)	1% (Author's calculations based on Statistics Norway, 2015b)
Annual GDP growth (2011-2014) (The World Bank, 2016c)	1.50%	1.65%
GDP per capita in $ (2014) (The World Bank, 2016b)	45,802	64,856
Number of residential buildings	18.5 mill (Statista, 2016)	1.47 mill (Statistics Norway, 2016)
Private home owners rate (2014) (Eurostat, 2015b)	52.5%	84.4%
Average housing size in m^2 per capita (2011)	42.7 (Statistisches Bundesamt, 2016)	54 (Enerdata, 2016)
Electricity price for households in EUR/KWh (2014) (Eurostat, 2015a)	0.297	0.166
Energy use per capita in kg of oil equivalent (2013) (The World Bank, 2014)	3,874	6,487
CO_2 emission in tons per capita (2011) (The World Bank, 2016a)	8.9	9.2

[3] For more information on the Norwegian standards for energy efficiency, which are also used for energy labeling, see: http://www.energimerking.no/no/Energimerking-Bygg/Energimerking-av-bolig/Om-energiattesten/Karakterene-i-energiattesten/

[4] For more information on the German standards for energy efficiency, which is also used for energy labeling, see: https://www.energieausweis-vorschau.de/

Structural and economic conditions in Germany and Norway

As can be seen from the table above we are looking at two growing economies. Nonetheless, their growing annual GDP with 1.5% and 1.65% lies in the case of Germany only slightly under and in the case of Norway slightly above the country-specific inflation rate. (The World Bank, 2016c, 2016d) Significant is the difference if we consider the GDP per capita in current international dollars, with approx. 65,000 in Norway compared to about 46,000 in Germany. (The World Bank, 2016b) A similar picture can be drawn for the housing size per capita (54 to 42.7 m^2). (Enerdata, 2016; Statistisches Bundesamt, 2016) When it comes to the ownership of the residential buildings it is more likely that Norwegians live in their own homes (referred to nearly 85% of the population), but approximately half of the Germans are tenants. (Eurostat, 2015b; Statistisches Bundesamt, 2013)[5]

Whereas in Germany we witness a population decrease of about 1.65% the Norwegian population is still growing by an annual average of 1% (in the period of 2000 to 2013). Considering the total population of 5.1 million people in 2015 in Norway it equals only a sixteenth part of the German population, i.e. 81.4 million. This huge difference is also reflected by the number of residential buildings in the case countries: where Germany has to deal with about 18.5 million dwellings, recent statistics in Norway calculate with about 1.47 residential buildings.

Energy consumption, emissions and trends in Germany and Norway

Energy consumption in Norway per capita has been growing in the past years and it can be found at least among the top 15 countries of energy consumers per capita in the world. The picture in Germany is different: with about 3,900 kg oil equivalent per capita the consumption is considerably lower than the Norwegian average of about 6,500 kg. (The World Bank, 2014) Nevertheless this variation between the two case countries vanishes when it comes to the CO_2 emissions per capita: The German average emitted 8.9 tons CO_2 compared to the Norwegian average of 9.2 tons in 2011. (The World Bank, 2016a)

These observations can be explained by the energy mix and trends in consumption in the case countries. In Norway the main energy source provided for residential buildings is electricity with 81% in 2013. The bio energy sources, mainly woods, make 13%, followed by oil 3%. (Enerdata, 2016)[6]

In Germany the electricity share of the total energy consumption in households in 2013 is 19.2%. 37.8 % is covered by natural gas, 22.8% by mineral oil and 1.1% by lignite and hard coal. The remaining share is based on other energy sources (including also renewables) with 11.9% and on district heating with 7.2%. The ladder mainly originates from fossil fuels themselves. (AGEB, 2015b) 70% of the total energy consumption in private households is used for heating in Germany (Gynther et al., 2015), which consists of 52% gas, 26% oil, 12% district heating, 3.4% electricity and 4% heat pumps (others 3%). (Frondel et al., 2015)

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[5] The European and national statistical data are contradicting in that case: To guarantee the comparability of the case countries we decided to refer to the Eurostat numbers that include references to both Norway and Germany. The German statistics, e.g., state that even more than half of the Germans rent their houses with 57% of tenants and only 43% of owners in 2013 (Statistisches Bundesamt, 2013).

[6] The sited data have been extracted from the database of the ODYSSEE-MURE project. This European Project`s goal was to monitor both the energy efficiency trends and related policies. 28 EU Member States plus Norway has been involved. The project was co-funded by the *Intelligent Energy Europe Programme*.

If we have a closer look at the electricity production in both countries, the Norwegian performance in terms of the renewable's share is impressive. Electricity as the main energy source for households derives mainly from hydro power with 96.1% and a small part from thermal power (2.5%) as well as from an increasing amount of wind power (1.4%) in 2013. (Statistics Norway, 2015a) German electricity production in contrast reached a share of 23.9% of renewables in 2013 and the main energy sources remain lignite and hard coal with accumulated more than 45%, followed by nuclear energy (15.2%) and natural gas (10.6%). (AGEB, 2015a)
Considering the energy efficiency trends in both countries, according to the ODYSSEE energy efficiency index (ODEX) (Enerdata, 2016) for households there has been an annual improvement of 1,9% in Norway, while in Germany 1,7% in the period between 2000-2013. The share of total energy consumption by the household sector in 2013 in Germany was 28%, while in Norway 20%. Comparing the trends in the period 2000-2013, the share of the household sector of the total energy consumption decreased by 2% in Germany and by 1% in Norway. (Enerdata, 2016)

Country-specific barriers for energy efficiency policies in Germany and Norway

Talking about a fragmented market and a manifold actors constellation the size of the building sector in Germany with about 18.5 million dwellings and its multi-level governance systems highlights the need to address the above described institutional barriers within the system. Germany has to deal with not only an aging society, but also with an aging building stock, where renovation is becoming more and more important due to the population decrease and less new constructions. Compared to Norway also the available financial resources per capita are lower, which means that the German average household has less money at disposition to invest. Additionally, the split owner-structure with approximately half of the Germans renting their homes puts emphasis on the challenge to make investments for energy efficiency attractive, if it is not clear who is going to benefit from less energy consumption in the case of more energy efficient buildings. At the same time the electricity price for private households in Germany is comparatively high in the European context. (Dieckhöner, 2013)[7] Both of these challenges need therefore measures that address the barriers of "misplaced incentives". This is also the case for Norway, but in an almost opposite situation: With a very low price for electricity produced through hydropower, which is the main energy source for Norwegian households and also very climate-friendly, the need for the overall reduction of the energy consumption is not a matter of course in the perspective of the consumers. Nevertheless, Norway has still very high per capita energy consumption and since most of the Norwegian own their homes, they would directly benefit from investments in energy efficiency measures for their private households. Therefore, information related barriers concerning the homeowners and construction services play an important role in the Norwegian case.

5 Reality Check: Comparison of the German and Norwegian Policy Approach

The transformation of the energy system of Germany, known as the *Energiewende*, which gained increased intensity since 2011, includes particularly ambitious targets. The energy efficiency targets aim at reducing energy consumption by 20% until 2020

[7] The comparatively high electricity prices, both in total and relatively to the household´s income, in Germany result from the increasing costs related to taxes and contributions in the context of the energy transition ("EEG-Umlage"). A similar development can be seen in Denmark. (Dieckhöner, 2013)

and by 50% by 2050 using 2008 as a baseline year. Germany has set rather ambitious targets also for the building sector: 80% reduction of the primary energy use in buildings by 2050; reduction by 20% in the heating demand by 2020; all new buildings must be climate neutral by 2020; increasing the annual thermal retrofit rate to 2%. (BMU, BMWi, 2010)

On the other side, Norway aims to become carbon neutral by 2050. Targets for energy efficiency in residential buildings aim at 67,5% renewable energy in the primary energy consumption by 2020[8] and saving up to 15 TWh by 2020.[9] The energy standards in buildings outlined in the legislation from 2010 are strengthened to passive house level in 2015 and are foreseen to turn to zero energy level by 2020.

Both the case countries have developed different policy options to reach their targets. In this chapter the specific policy instruments in Germany and Norway are being presented and an overview of the main policy options for the improvement of building energy and carbon efficiency is provided. The aim is to analyze, which policy instruments and measures prevail in Germany and Norway to foster the deployment of energy efficient and decarbonized solutions for residential buildings.

Policy Instruments in Germany and Norway

The energy buildings efficiency measures in Germany are outlined in three main currently active instruments:

- 3rd National Energy Efficiency Action Plan [NEEAP] - submitted in June 2014 by the German Ministry of Economic Affairs and Energy (Federal Office of Economics and Export Control (BAFA) & Federal Agency for Energy Efficiency (BfEE), (BMWi, 2014a);
- National Action Plan on Energy Efficiency – [NAPE], submitted in December 2014 by the Germany Ministry of Economic Affairs and Energy (BMWi, 2014b);
- Climate Action Program 2020, outlined by the German Federal Ministry of Environment, Nature Conservation, Buildings and Nuclear Safety in December 2014 (BMUB, 2014).

Other than regulatory energy efficiency measures, these instruments include reviewed versions of previous measures regarding economic incentives, information distribution and advice. They also highlight the need of a long-term strategy for mobilizing the investments in the renovation of the national buildings stock. The National Energy Efficiency Action Plans are an obligation deriving from the EU Energy Efficiency Directive [EED] (2012/27/EU) (European Parliament & Council of the European Union, 2012). This directive is not implemented in Norway, therefore Norway does not have a National Energy Efficiency Action Plan. However, even though Norway is not part of the EU, Norway has been implementing some of the EU directives on energy efficiency. For example, the Building Regulation TEK10 (Reference) is a result of the Energy Performance of Buildings Directive [EPBD] (2010/31/EU). The current TEK10 includes specific numbers on insulation thickness, average heat transfer (u-value) and so on, and is gradually updated to stricter values eventually reaching near passive house standard in 2015 and with a goal of net zero

[8] Ministry of Foreign Affairs, 2011a. Samtykke til deltakelse i en beslutning i EØS-komiteen om innlemmelse i EØS-avtalen av direktiv 2009/28/EF om å fremmebruken av energi fra fornybare kilder (fornybardirektivet). In: Affairs, M.o.F.(Ed.), Oslo.

[9] Endringer i statsbudsjettet 2012 under Olje- og Energidepartementet, Prop. 33 S (2012–2013) pp. 7-10, https://www.regjeringen.no/no/dokumenter/prop-33-s-20122013/id708448/

energy buildings by 2020 [REF[10]]. However, existing residential buildings do only have regulation concerning total renovation, and not individual upgrades of the building envelope. The energy efficiency policies and instruments in Norway are managed by ENOVA SF, a Government owned public enterprise, administered under the Ministry of Petroleum and Energy.

Table 3 presents a comparison of all energy efficiency measures in Germany and Norway, which regard the private household sector. In the literature we can find different categorizations of policy options for the mitigation of climate change in the building sector (see e.g. Lucon et al., 2014, pp. 715–718, Amecke et al., 2013; Lee & Yik, 2004; Levine et al., 2012). To avoid overlaps in the categorizations of the policy instruments and to ensure the operationalization of the scheme to the German an Norwegian cases we will base our analysis on a tripartite classification, similar to Amecke et al., 2013: all the policies to promote energy efficiency in Norwegian and German households will therefore be matched to (1) **regulatory measures** including building codes and standards; (2) **economic incentive-based measures**, such as taxes, loans, subsidies and other market interventions; (3) **information-based measures** that raise awareness and build capacity, implying e.g. advice, campaigns and leadership programs as well as voluntary and mandatory labeling and certification schemes.

The two right columns of the table present the number of measures, completed and on going, which can be located in the household's energy efficiency policy instruments of both countries. A more detailed table referring to the concrete policies belonging to each category can be found in Appendix 1.

Both countries consider the residential sector to have a high potential for lowering CO_2 emissions by improvement of energy efficiency and they aim at climate-neutral building stock by 2050. In both Germany and Norway the policy-measures address variety of actors on the demand and the supply side.

The focus on energy efficiency policies in the residential sector in Norway is to lower energy loss, to diversify energy sources and to increase the share of renewables (other than hydropower) in the energy mix as well as to reduce the dependency on electricity for heating. In Germany the focus of the energy efficiency measures in the residential buildings is in increasing the energy efficiency in the heating systems in order to decrease the energy demand for heating while electricity savings measures have been rather low.

Table 3 shows both similarities and differences in policy categories between the two case countries. When it comes to matching policies, both Germany and Norway have introduced strong regulation on energy performance, thermal insulation and standards for electrical appliances. Both countries introduce variety of incentive-based economic measures for investment in energy efficiency. However, differences can be observed as well. Germany has given emphasis on low interest rate loans and eco tax measures. On the other side, Norway has introduced more policies on education and information, particularly regarding raising awareness among consumers. When it comes to the decrease in energy demand for heating, Norway has introduced economic incentive-based measures, while in Germany more regulatory measures prevailed. Phasing out of oil in the heating systems is mandatory in Norway, therefore many incentive-based measures regard investments

[10] https://www.regjeringen.no/globalassets/upload/krd/vedlegg/boby/rapporter/energieffektivisering_av_bygg_rapport_2010.pdf

in new energy efficiency heating technologies. While measures in Norway offer economic incentives for replacement of old heating systems to more efficient ones (heat pumps) the according measures in Germany focus on provision of heating checks (Heizungscheck), regulation and labeling of old boilers and on-site consultancy.

Table 3: Energy Transition Policies in the Building Sector in Germany and Norway

Policy Measures (Enerdata, 2016):	GERMANY	NORWAY
Regulatory measures		
○ Energy Performance Standards	5	4
○ Minimum Thermal Insulation Standards	3	3
○ Minimum efficiency standards for boilers	3	1
○ Mandatory periodic inspection of boilers	3	0
○ Mandatory periodic inspection of heating/ventilation/AC	2	0
○ Minimum efficiency standards for electrical appliances	2	1
Economic incentive-based measures		
○ For investments in energy efficient building renovation	3	3
○ For the purchase of more efficient heating equipment	0	1
○ For other energy efficient investments	2	4
○ For investments in renewables	1	1
○ For energy audits	2	1
○ Reduced interest rate loans	5	1
○ Eco-tax on electricity/energy consumption or CO_2 emissions	1	1
○ Eco-tax with income recycled to energy efficiency / renewables	1	0
○ Eco-tax with income recycled to direct labour cost	1	0
○ Eco-tax with reduced rates for the industrial sector	1	0
Information-based measures		
○ Mandatory energy labeling of electrical appliances	2	1
○ Mandatory energy efficiency certificates for existing buildings	3	1
○ Mandatory labeling of heating equipment	1	0
○ Mandatory audits in large residential buildings	1	0
○ Mandatory audits in small residential buildings	1	0
○ Voluntary labeling of buildings/components (existent & new)	1	2
○ Information campaigns (energy agencies, energy suppliers)	3	5
○ Detailed energy/electrical bill aiming at energy efficiency improvement	0	1
○ Individual billing (multi-family houses)	1	0
○ Regional and local information centers on energy efficiency	1	2

Country specific implementation of measures

Given the degree of implementation of different policy measures, in what kind of technologies do the consumers invest? There is strong evidence in the literature, on how socioeconomic and structural realities have a large impact on the rate of energy efficiency investment (Ameli & Brandt, 2015). How is this reflected in the implementation of measures in Norway and Germany?

In Norway, there has been a large increase in use of heat pumps the last decades – from 0.5% in 1995 to 28% in 2012. Simultaneously oil for heating has been replaced and decreased from 13% in 1995 to 5% in 2012. By the end of 2015, only about 1

MW capacity of rooftop PV was installed on private houses in Norway, totaling to around 500 installations or less than 0.02% of the total building mass (Holm, 2016). However, 700kW of these were installed in 2015 alone due to a new subsidy scheme from ENOVA and Multiconsult expect a major increase in the coming years. A questionnaire of Norwegian households in 2012 revealed that 36% had invested in energy efficiency. 24% had some kind of thermal retrofit, 42% of the windows have been changed (although not necessarily to more energy efficient solutions) and 16% use automatic temperature controllers (smart thermostats). In contrast, manual measures not demanding any investment such as switching off light and reduce temperature in room have high rates of usage of 93% and 80% respectively (Bøeng, 2014). These numbers are average over a buildings stock ranging over more than a century and the implementation rate will vary a lot between type of househoulds and building age.

In Germany, the implementation of some active measures has grown considerably the last decade. Between 2006 and 2014, the number of households that had implemented solar thermal rose from 5.9% to 11%, heat pumps from 2.7% to 3.7% and PV from 2.1% to 6.8%. Also the use of wood furnaces have increased significantly from only a few percent of households in 2006 to around 30% in 2014 (Frondel et al., 2015). The annual rate of thermal retrofits of the existing building stock in Germany is around 0.8%, much less than the goal of 2% (Diefenbach, Cischinsky, Rodenfels, & Clausnitzer, 2010).

6 Trade-Offs in the Existing Policies and the Implemented Technologies

This chapter discusses which trade-offs arise from climate change policies regarding residential buildings and the related implemented technologies in the context of the structural realities in Germany and Norway. In the center of interest lie cost-efficiency and social challenges as well as behavioral matters and positive spillovers.

Trade-offs related to cost-efficiency

Cost-efficiency is considered by far the most important criteria for investing in energy efficiency measures (Lee & Yik, 2004, p. 486). Cost-efficiency can be seen from two perspectives: that of the policymaker (what measures are most cost-efficient to abate CO_2 emission in the society as a whole?) or of the consumer (what investment should I make to reduce my future energy consumption?). Since energy efficient and climate-friendly technologies typically are many times more expensive than the “standard” solution, to be economically viable the extra investment should yield an acceptable return on investment compared to other investment opportunities. The evaluation of investment in energy efficiency measures is in principle a simple weighing of the extra cost related to investment versus the potential future energy savings. Financial instruments can affect this balance by either reducing the investment through subsidies, or by increasing the cost of energy through taxation (Allcott & Greenstone, 2012). Calculations of the cost-effectiveness of different energy saving technologies, in terms of the environmental impact, generally show that passive measures are better than active ones (Ma, Cooper, Daly, & Ledo, 2012). Still, looking at the data from Norway and Germany, active measures have a higher implementation rate than passive ones. According to Sallee (2014), a consumer is more likely to be ***imperfectly informed*** (not make the rational economical choice), if the energy cost relation with future consumption is low compared to the total investment. Clearly, high price and complexity would demand a much higher rate of return on investment from a consumer perspective. Passive measures are often expensive and tend to involve much more complex intervention with the existing building than active measures making them more prone to ***investment inefficiencies***, i.e. not investing in something that will pay off in the long term. This was also found in a Norwegian study of homeowners. With high rates of building ownership and yearly investments in refurbishment, the key factor resulting in investment in passive measures is the necessity of renovation due to natural degradation (Risholt & Berker, 2013). However most homeowners find passive measures inconvenient and with high uncertainty of real cost savings, resulting in large investment inefficiencies. In addition, it was found that the craftsmen consulting the homeowners had limited knowledge on the cost-efficiency of potential energy efficiency measures, thereby resulting in the craftsman giving bad advice, further increasing investment inefficiencies (Risholt & Berker, 2013). In contrast, due to the high amount of renewable electricity in the Norwegian energy mix, the subsidy for heat pumps have dominated energy efficiency implementation in private households resulting in a very high share of air to air heat pumps. They are relatively cheap and easy to install without any changes in the existing building envelope. Passive measures are historically more popular during abnormal low temperature periods. 2010 and 2011 were especially cold winters driving electricity prices up in Norway, thus making the investment appeared to be more cost-efficient to the consumer, which lead to an increasing implementation rate (Bøeng, 2014).

In addition to the question of cost-efficiency comes the question of ***energy/fuel poverty*** [REF], as many homeowners do not have access to capital to make the investment in the first place. For this group, financial measures are much more important to realize the energy efficiency potential.

Also the ownership structure is of importance, especially in Germany with a high ratio of renters over homeowners. Rising rents due to investment in energy efficiency can be a high burden to pay for the renters if the increase in rent is not outweighed by the reduction in the monthly energy bill. If there are real investment inefficiencies, the total rent including energy should become lower. However, there is a risk that investments in the end are not cost-efficient due to a divergence between building owner estimations and users real consumption.

Trade-offs related to behavior

As written above, the investment inefficiencies are the largest trade-offs for passive measures, like e.g. the thermal retrofit. But do these investment inefficiencies actually exist? Allcott and Greenstone (2012) argue that in many cases, the stated investment inefficiencies are based on engineering analysis and not on objective observations of the full impact. In fact, several studies have shown that policies and measures to increase energy efficiency both in Germany and Norway are much less effective than anticipated or even lead to a negative impact. The ***rebound effect*** is often encountered when analyzing these imbalances (Druckman, Chitnis, Sorrell, & Jackson, 2011; Hens, Parijs, & Deurinck, 2010). It describes the situation where the saved energy (or money used on energy) is compensated by an increase in energy consumption by e.g. increasing indoor temperatures. More recently, the ***prebound effect*** was also introduced (Sunikka-Blank & Galvin, 2012). The prebound effect describes how the actual energy consumption before implementation of energy efficiency measures often is lower than theoretical models say. A recent example is the Office of the Auditor General of Norway's investigation of the authorities' (ENOVA) work on energy efficiency in buildings (Office of the Auditor General of Norway, 2016). In the period 2005-2014, approximately 2.2 billion NOK in subsidies have been handed out to building refurbishment in the private sector. While ENOVA themselves, based on engineering analyses, predicted energy savings of 3.3 TWh/year from these investment (about 9.3% relative saving), the Auditor General has verified actual savings, based on energy consumption data, to the amount of not more than 0.67 TWh/year, which is equal to 1.8% reduction in energy consumption. Furthermore, the same report concludes that ENOVA's focus on residences has very little effect as an instrument of influencing energy use in homes. Only 113 of 2.3 million households have received support for refurbishment since 2013, mainly due to the fact that they only support full refurbishment into low-energy or passive house standards. In addition, they conclude that more information on the support opportunities and energy labeling is needed, primarily to address investment inefficiencies. Also in the German case scholars assessed the performance on the implementation rate in thermal retrofits. Galvin et al. (Galvin & Sunikka-Blank, 2013; Galvin, 2014) argue that the missed targets are not connected to investment inefficiencies, but to the fact that actual energy savings are much less than calculated in the beginning. Policy makers do not take into account the large heterogeneity of the buildings as well as their residents and their vastly different behavior. A more effective approach would be to focus on a smaller scale and consider the single buildings, the individual consumer and its personality as well as socio economical status. That means, as a consequence, to leave more room for flexibility and tailor-made solutions on a policy planning level.

Positive spillovers

A co-benefit of subsidies, apart from promoting energy efficiency, is its role in promoting industrial and technological switch. The future benefits of such effects are very hard to determine. If it had not been for the heavily support of PV in Germany throughout the last decade there is a question whether PV technology would have reached such record level reduction in cost in the same period. This has had clear benefits for the rest of the world, however partly paid for by German electricity consumers and not directly by governmental subsidies (Weiss, 2014). The same is also the case for the early subsidies of heat pumps in Norway. This shows that the technologies that are being subsidized through the policies result in a high innovation rate that leads to cost and complexity reduction. Therefore, these policies become rather successful in terms of the implementation rate of the specific technology.
Another interesting positive spillover of local renewable energy production is that of ownership. When a consumer enters the market as a producer, effectively becoming a "prosumer" (REF), the energy is now more valuable which can lead to higher awareness and thus investment in energy efficient technologies as well as generally behavioural choices.

7 Discussion and Conclusions

The building sector with currently a third of global emissions is highly relevant to mitigate climate change. In this paper we addressed the question, which policy instruments and measures prevail in Germany and Norway to foster the deployment of energy efficient and decarbonized solutions for residential buildings.

Both Germany and Norway have designed a policy mix to reach their ambitious targets to realize the energy transition in the building sector. Due to the low electricity prices and the green energy mix Norwegian consumers might not feel the urgency to reduce their energy consumption. At the same time most of the Norwegians own their houses and they would directly benefit from energy savings. This explains a focus on information-based approaches in Norway to tackle information asymmetries as well as reach their energy policy goals by addressing the area of consumer's behavior. Due to a situation of misplaced incentives as well as huge necessary investments related to a big and old building stock in Germany, German policy measures focus on regulatory and information based instruments to firstly force stakeholders to provide information on energy efficiency (e.g. mandatory labeling schemes) and secondly make investments in energetic renovation more attractive and easier to achieve.

Both countries introduced a variety of incentive-based economic measures to promote the energy transition in the building sector, e.g. in the case of heating in Norway where the installation of heat pumps has been strongly supported. In contrast German policies put emphasis on economic incentives to foster the renovation of residential buildings.[11] This approach has been pointed out as a good practice example in providing incentives for implementation of single as well as combined measures (Energy Efficiency Watch, 2013).

Translating the policies into technological practice, the combination of active and passive measures is needed to release maximum energy efficiency potential for the household. With a steady increase in awareness and availability of energy efficient technologies, in combination with falling prices and complexity, the actual investment inefficiencies will become more clearly and therefore easier to see from a consumer's perspective. Of course, the choice of the technology and its complexity matters a lot when looking at the barriers of implementation.

In the last part we therefore discussed the second question of this research on the trade-offs that arise from climate change policies regarding residential buildings and the related implemented technologies in the context of the structural realities in Germany and Norway.

The calculated benefits of cost effective energy efficiency measures do often not match their actual savings. Or in other words: theoretically calculated savings are far from the achievements in real contexts. Some scholars come to the conclusion that the standards and instruments put in place to mitigate climate change in the building sector lack in integrating the diversity of the settings. Standards are often too general. (Reference) For future corrections more flexibility is needed in the applied instruments to be able to develop and implement more tailor-made solutions to reduce the emissions caused by the building sector.

Therefore, to reach the potential of cost effective reduction measures, it is indispensable to overcome the information-related barriers. With the existing policy measures and the development of different technological solutions both in Norway and Germany, it appears that the need to inform all the relevant stakeholders has

[11] The investment programs by the state-owned KfW bank support the buildings' retrofits that follow fixed, often relatively intensive, renovation standards. More information on the KfW loan program can be found here: https://www.kfw.de/inlandsfoerderung/Privatpersonen/Bestandsimmobilie/Energieeffizient-Sanieren/F%C3%B6rderratgeber

been neglected. The significance of awareness raising and trainings has to be highlighted, e.g. also pointing at both the people that assign and execute the renovation of houses. Information is key to address investment inefficiencies, and more diverse policies and measures covering a more heterogeneous group of consumers needs to be implemented to avoid energy poverty and misplaced incentives. In addition, more research and monitoring of actual energy savings of implemented measures is needed to identify all potential prebound and rebound effects.

Furthermore, it is to say that most of the research has been focused on the cost effectiveness of measures to somehow testify that investments in energy efficiency in buildings is also economically worthwhile. We state that the argumentation should also include other relevant notions in order to get the full picture, such as the often overlooked externalities in the case of “business-as-usual” and as well as the side-effects linked to the technological and societal development. The investment in solar energy in Germany e.g., has also brought an additional income to farmers and consolidated Germany’s role as a technology hub for renewable energy technologies. (Reference) That might also explain, why Germany has put a remarkably effort in the promotion of solar energy, whereas passive measures for the building sector would have been much more effective. A similar case can be witnessed concerning the deployment of heat pumps in Norway.

Finally, if we also want to overcome the barriers that are linked to social and societal challenges, we have to focus on the win-win situations that go hand in hand with the measures that point at the reduction of CO_2 emissions in the building sector. Here policy makers have to connect energy efficiency measures also to individual wellbeing and innovation. We have to move from a very general and centralized approach to a more individualized one that understands the specific target groups and their needs, because there is not one strategy for all the homeowners or all the tenants.

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Table XX. Comparison of energy efficiency measures in households (old buildings) in Germany and Norway
source: ODYSEE- MURE database[1]

	Energy Efficiency Measures:	**GERMANY**	**NORWAY**
Regulatory measures	Energy Performance Standards	○ EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Energy Savings Ordinance (Energieeinsparverordnung - EnEV) ○ EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Länder activities in the building sector ○ EU-related: Energy Performance of Buildings EPBD Recast (Directive 2010/31/EU) - Energy Savings Ordinance (Energieeinsparverordnung-EnEV) - revision 2013-2014 ○ Further development of Energy savings ordinance 2014	○ Building regulations 1987 (Byggeforeskrift 1987) ○ Building regulations 1997 (Byggeforeskrift 1997) ○ Building regulations 2010 (Byggeforeskrift 2010)
	Minimum Thermal Insulation Standards	○ Thermal Insulation Ordinance (Wärmeschutzverordnung) of 1977 ○ Thermal Insulation Ordinance (Wärmeschutzverordnung) of 1982 ○ Thermal Insulation Ordinance (Wärmeschutzverordnung) of 1994	○ Building regulations 1987 (Byggeforeskrift 1987) ○ Building regulations 1997 (Byggeforeskrift 1997) ○ Building regulations 2007 (Byggeforeskrift 2007)
	Minimum efficiency standards for Heating Systems and Hot Water Systems	○ National efficiency label for old heating systems	○ EU-related: Performance of Heat Generators for Space Heating/Hot Water (Directive 92/42/EEC) - Performance of Heat Generators for Space Heating and the Production of Hot Water (92/42/EEC) - Minimum energy efficiency standards for boilers
	Mandatory periodic inspection of boilers	○ EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Energy Savings Ordinance (Energieeinsparverordnung - EnEV) ○ EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Länder activities in the building sector	
	Mandatory periodic inspection of heating/ventilation/AC	○ EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Energy Savings Ordinance (Energieeinsparverordnung - EnEV) ○ EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Länder activities in the building sector	
	Minimum efficiency standards for electrical appliances	○ Energy Consumption Labeling Ordinance (Energieverbrauchskennzeichnungsverordnung)	○ EU-related: Energy Labeling of Household Appliances (Directive 92/75/EC) - (Energimerking av hvitevarer) - Law 1981.12.18 No.0090, Reg. 1996.01.10 No.0016, Directive 92/75/EC ○ EU-related: Ecodesign Directive for Energy-using Products (Directive 2005/32/EC) - Ecodesign Directive for Energy-using products and Energy Labelling of Household Appliances (Økodesigndirektivet og Energimerkedirektivet) - Law 1976.06.11 No.0079 and 1999.06.25 No.0053, Reg. 1999.08.20 No.0956, Directive 96/57/EC
Economic incentive-based measures	For investments in energy efficient building renovation	○ Replenishment of the KfW programs for energy-efficient construction and renovation (Aufstockung KfW-Gebäudeprogramme) ○ Quality assurance and the optimization of existing energy consultation ○ Upgrading the CO_2 Building Renovation Programme	○ Local energy efficiency fund in Oslo (Enøkfondet i Oslo) ○ Energy efficient low energy houses (Energibruk i boliger) ○ Grants for energy savings in the built environment (Bygg, bolig og anlegg) ○ Block by Block approach (Blok voor Blok)
	For the purchase of more efficient boilers		○ Energy efficient low energy houses (Energibruk i boliger)
	For other energy efficient investments	○ Energy-Related Urban Renewal – Grants for Integrated District Concepts and Renovation Managers (Energetische Stadtsanierung – Zuschüsse für integrierte Quartierskonzepte und Sanierungsmanager) ○ Heating Check (Heizungscheck)	○ Grants to electricity savings in households (Elsparetiltak i husholdningene) ○ Grants for electricity savings in households (Tilskuddsordningen i husholdningene) ○ Grants for energy savings in the built environment (Bygg, bolig og anlegg) ○ Energy measures for households (Enova) ○ Block by Block approach (Blok voor Blok)
	For investments in renewables	○ Market Incentive Program for Renewable Energies in Heat Market (Marktanreizprogramm für erneuerbare Energien im Wärmemarkt– MAP)	○ Energy measures for households (Enova) ○ Block by Block approach (Blok voor Blok)

[1] http://www.measures-odyssee-mure.eu/fastsearch_mr.asp?cerca=OK

	For energy audits	○ BAFA Onsite Consultancy (BAFA Vor-Ort-Beratung) ○ Energy efficiency checks (Caritas) (Stromspar-Checks für einkommensschwache Haushalte)	○ Local energy efficiency fund in Oslo (Enøkfondet i Oslo)
	Reduced interest rate loans	○ KfW Program "Energy-efficient refurbishment" (former CO2 Building Rehabilitation Programme)	○ Energy saving loans (Husbanken)
	Eco-tax on electricity/energy consumption or CO_2 emissions	○ Ecological Tax Reform (Energy and Electricity Tax) (Ökologische Steuerreform – Energie und Stromsteuer)	○ Energy and environmental taxes - Law 1933.05.19 No.0011, Reg. 1979.11.26 No.0003, 1999.12.14 No.1298, Reg. 2010.11.25 No. 1535
	Eco-tax with income recycled to energy efficiency/ renewables	○ Ecological Tax Reform (Energy and Electricity Tax) (Ökologische Steuerreform – Energie und Stromsteuer)	
	Eco-tax with income recycled to directs labor cost	○ Ecological Tax Reform (Energy and Electricity Tax) (Ökologische Steuerreform – Energie und Stromsteuer)	
	Eco-tax with reduced rates for the industrial sector	○ Ecological Tax Reform (Energy and Electricity Tax) (Ökologische Steuerreform – Energie und Stromsteuer)	
Information-based measures	Mandatory energy labeling of electrical appliances	○ EU-related: Revised Directive for Labeling of Energy-related Products (Directive 2010/30/EU) - Energy Consumption Labeling Ordinance – revised version (EnVKV - revised) Further development of EU Ecodesign and Labeling 2015	○ EU-related: Energy Labelling of Household Appliances (Directive 92/75/EC) - (Energimerking av hvitevarer) - Law 1981.12.18 No.0090, Reg. 1996.01.10 No.0016, Directive 92/75/EC EU-related: Ecodesign Directive for Energy-using Products (Directive 2005/32/EC) - Ecodesign Directive for Energy-using products and Energy Labeling of Household Appliances (Økodesigndirektivet og Energimerkedirektivet) - Law 1976.06.11 No.0079 and 1999.06.25 No.0053, Reg. 1999.08.20 No.0956, Directive 96/57/EC
	Mandatory energy efficiency certificates for existing buildings	○ EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Energy Savings Ordinance (Energieeinsparverordnung - EnEV) ○ EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Länder activities in the building sector EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Energy certificates for buildings (Energieausweise für Gebäude)	○ EU-related: Energy Performance of Buildings (Directive 2002/91/EC) - Bygningsenergidirektivet
	Mandatory labeling of heating equipment	EU-related: Revised Directive for Labeling of Energy-related Products (Directive 2010/30/EU) - Energy Consumption Labeling Ordinance – revised version (EnVKV - revised)	
	Mandatory audits in small and large residential buildings	Smart Metering	
	Voluntary labeling of buildings/components (existent and new)	Environmental Label "Blue Angel" (Umweltzeichen "Blauer Engel")	National standard: Passive and low energy residential buildings Norwegian standard: Criteria for passive houses and low energy buildings – Residential buildings (NS 3700:2013)
	Information campaigns (by energy agencies, energy suppliers etc.)	○ Top Runner Strategy ○ Energy Efficiency Campaign (Initiative EnergieEffizienz) ○ Information Campaign on Climate Protection	○ Simple Energy Audit (Enøk-sjekken) ○ Information activities (media campaigns, magazine, exhibition material) ○ Educational awareness program for children about energy use and environmental impacts (Regnmakerne) ○ Energy information helpline (Enovas svartjeneste) ○ Energy guidance label "Enova Recommends" (Enova anbefaler)
	Detailed energy/electrical bill for EE improvement		○ Energy Act on informative billing (Energiloven)
	Regional and local information Centers on energy efficiency	○ Energy Consultancy and Energy Checks of the Federation of German Consumer Organisations (Energieberatung und Energie-Checks der Verbraucherzentralen Bundesverband (vzbv))	○ Mandatory Energy Efficiency Activities through Regional Energy Efficiency Centres (Lovpålagt enøk - Regionale enøksentra)