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IS THE EUROPEAN BUILDING SECTOR ON THE WAY TO DECARBONISATION?

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ABSTRACT

This paper aims at showing energy demand for space heating and hot water and CO_2-emission savings potential until 2050 in the building sector in France, Italy, Norway and Poland. Two main drivers of energy savings are assessed, namely the renovation rate and renovation depth. The scenarios are modelled by using a bottom-up, techno-socio-economic approach in Invert/EE-Lab model.
Scenario results show an energy demand reduction of 18%, 44%, 27% and 28% in France, Italy, Norway and Poland in the business as usual (BAU) scenarios from 2012 until 2050. The reduction of the CO_2-emissions from 2012 and 2050 is 66%, 63%, 40% and 37% in France, Italy, Norway and Poland using current CO_2-emission factors. However, these results strongly depend on the CO_2-emission factors for electricity, which have been kept constant in this study.
In many countries fossil fuels for space heating, like oil and gas in Italy and particularly coal in Poland, are substituted with electricity, which generation mix is also dominated by fossil fuels and corresponding high CO_2-emission pollution according to the BAU scenario. This shows that decarbonisation of the electricity generation plays a central role in the low carbon economy, which is a crucial precondition for the decarbonisation of the European building sector.

Keywords: Energy efficiency, building sector, nZEB, energy modelling, energy demand scenarios

1. INTRODUCTION

European Union has set a roadmap for moving to a competitive low carbon economy in 2050, which provides a long term pathway to achieve an 80% cut in domestic emissions compared to 1990 by 2050 [1]. The European building sector (residential and services) can contribute to this goal by using two main instruments, energy efficiency measures and substitution of fossil fuels with renewable energy sources.
The achievements of the CO_2-emission reduction differ from one European country to another in terms of the differences in the existing building stock characteristics, ambitiousness of the energy efficiency requirements for new construction and building renovation as required in the national legislations. Moreover, the market shares of energy fuels for space heating and domestic hot water differ among the EU countries.

Thus, this paper aims to answer the following questions:

What CO_2-emission reduction and energy demand reduction can be achieved until 2050 in France, Italy, Norway and Poland´s building stock, which makes up 34% of the total European building floor area (EU 28 and Norway) while considering the following parameters:

- Existing building stock characteristics (building thermal conductivities, user profiles and installed energy supply systems of the different building categories);

- Policies to reduce energy demand (Implementation of the European legislation: Energy Performance of Buildings Directive (EPBD) and Energy Efficiency Directive EED)[1];
- Energy prices.

2. METHOD

2.1. Modelling energy savings and CO_2 – emissions by 2050

To calculate the final energy demand for space heating and hot water until 2050 and related CO_2 - emissions, a bottom-up techno-economic approach is used. For this purpose, the building stock simulation tool Invert-EE/Lab is applied. Invert/EE-Lab is a dynamic bottom-up techno-socio-economic simulation tool that evaluates the effects of different policies on the total energy demand, energy carrier mix and CO_2-emission reduction [2], [3], [4].
Fig. 1 shows the simplified flow chart of the model. The package "Database" describes input data used in the model. The building stock data (I) can be clustered to the following data categories: building types, vintages, building geometry, building envelope quality, heating supply systems, user profiles etc. These data were collected in an IEE project, ENTRANZE, for the investigated countries [5], [6], [7]. Data on the new building standards (II) and renovation standards (III) are based on the national definition (see section "Definition of the renovation rate and depth").
The package "Method" describes the methodology which covers three following steps. The first step is the energy demand calculation which is based on the monthly energy balance approach. In the second step, number of the new building construction, demolished buildings and renovated buildings are calculated. For this step, the Weibull-distribution approach is being used. Further, the type of renovation measure and the type of heating system are chosen based on the investment-decision module and the nested logit approach. The model assigns the highest market share to the most cost effective measures. Thus, not only the most cost-effective option of the measures is taken into account but also the market share of less attractive options, which are modelled with the nested logit approach. All these methodical steps are carried out for each single year starting with 2012 and finishing with 2050.

The model also uses the exogenous parameters which influence the decision process in the investment-decision module based on the abovementioned nested logit approach. These are inter alia the policy measures and energy fuel prices. Data on national policy measures were collected in the IEE projects ENTRANZE and ZEBRA2020 [8]. Renovation measures and their associated investment costs were collected in the frame of the abovementioned project ENTRANZE [9]. The CO_2-emission conversion factors for electricity and district heating are assumed to be constant from 2012 until 2050. This is to show the impact of the changes in the building sector, without assuming decarbonisation of the electricity sector.

[1] Although no EU member state, Norway is following a similar approach to European legislation (EPBD, EED).

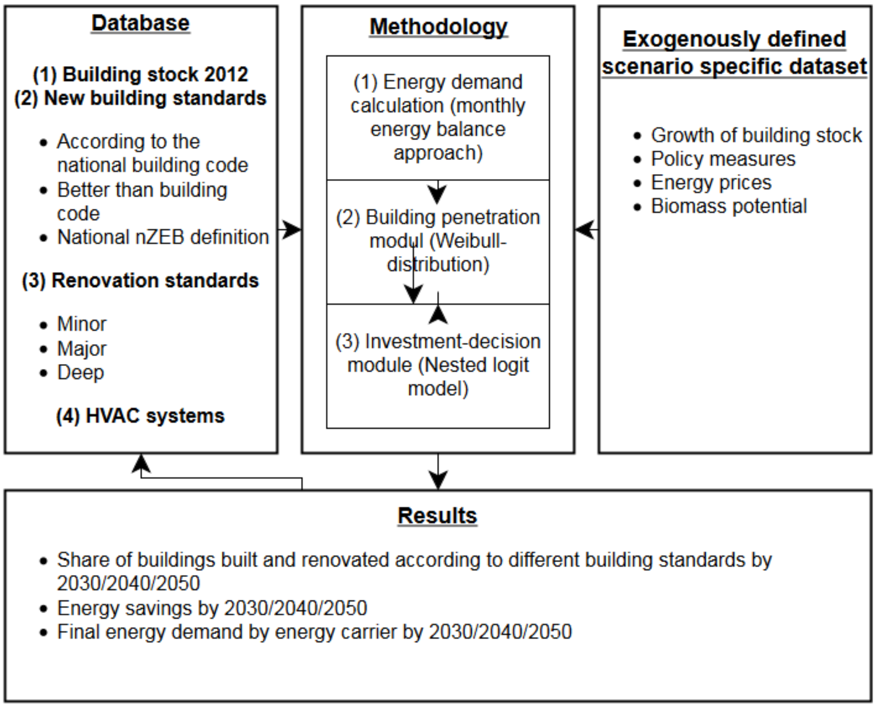

Fig. 1 Simplified flow chart of the model Invert-EE/Lab (own illustration based on [10])

2.2. Definition of the renovation rate and depth: renovation levels and nZEB definition

Energy savings and related CO_2-emissions were calculated in relation to the main drivers, building renovation rate and renovation depth. Renovation rate is the results of the model, which is calculated by using the following parameters of the buildings: building construction period and building elements life time. The whole building stock in one country is categorized into building classes, which are distinguished by the type of the building (single family houses, apartment buildings office buildings and other) and the construction period. The annual renovation of the building stock for each vintage is being calculated following a Weibull-distribution with the renovation rate $\lambda_{(t)}$ in year *t*

$$\lambda(t) = \frac{\beta}{T} * \left(\frac{t}{T}\right)^{\beta - 1}$$

in which β denotes the shape factor and T the characteristic life time.

By the renovation depth, it is meant different renovation technologies which are applied if the particular building is renovated. For each building undertaking a renovation activity, the final energy demand before renovation and after renovation by using different renovation technologies are calculated for each building. Further, the net present value of each renovation option is calculated. The selection of the technology follows cost-effectiveness of the investments and logit-approach. Four following renovation levels were defined:

- minor renovation,
- major renovation,
- deep renovation and
- maintenance (renovation without energy savings for aesthetical or security reasons).

“Major” renovation reflects the building standards which were used in 2012. “Minor renovation” is defined as renovation which increased building transmittance values by 30% compared to the building code “Major renovation”. Thus, the renovation package “minor renovation” should reflect lack of compliance with the current building codes. “Deep renovation” is an ambitious renovation which means that the U-values are reduced by 30% compared to the building code “major renovation”. Maintenance renovation measure is undertaken for aesthetic reasons and is not related to thermal energy savings. Apart of the last one, all these retrofit solutions lead to specific energy savings, corresponding cash flows and investments.

New building construction rate is the result of the exogenous input data on the growth of the building stock combined with the demolition of buildings, resulting also from the vintages of the building stock and lifetime Weibull distributions. For new buildings, different construction standards in terms of the energy performance were defined. The new building construction requirements reflect the national building standards and the implementation of the EPBD (European Building Directive 2010) which requires the member states to build new buildings as nZEB (nearly Zero Energy Buildings) after 2020.

The new building constructions are categorised as follows:

- buildings built according to the national building code
- buildings built better than building code and
- buildings built according to the national nZEB definition.

3. RESULTS

3.1. Drivers for energy savings

Two main drivers for energy savings were considered, renovation rate and renovation depth. Fig. 2 shows the cumulated building floor area, namely the non-renovated building stock and renovated building stock by different renovation levels (y-axis, left hand). Moreover, the figure indicates the yearly total renovation rate and the renovation rate excluding maintenance renovation (y-axis, right hand). Total yearly renovation rate includes all undertaken renovation activities in the country, while renovation rate without maintenance includes only thermal renovation activities meaning renovation actions which lead to energy savings. 2012 is the starting year of the calculation.

The total yearly renovation rate varies from 1.2% to 2.5% over time in France. However, the yearly renovation rate without maintenance ranges between 0.6% and 1.3%. By 2050 74% of the total building floor area could be renovated but the share of the thermal renovated building floor area by 2050 is 37% only. In Italy, the share of the renovated building floor area is 91% by 2050, the share of the thermal renovated floor area is 45%. 50% of these buildings undertake minor renovation levels, which is less ambitious than the current building energy performance requirements. In Norway, the share of the renovated building floor area is 80% of which 60% are renovation activities leading to the energy savings. Notably, the share of deep renovated buildings on the total renovated building stock (without maintenance) is 41%, which is much higher compared to the other investigated countries. This high share of the deep renovation is due to the several parameters inter alia the cold climate. In Poland, the total renovated building floor area is 77% by 2050. The share of buildings with thermal renovation is with only 10% remarkably lower compared to the other countries. This result was influenced by the given parameters of the BAU scenario such as low energy fuel prices and lack of financial public support.

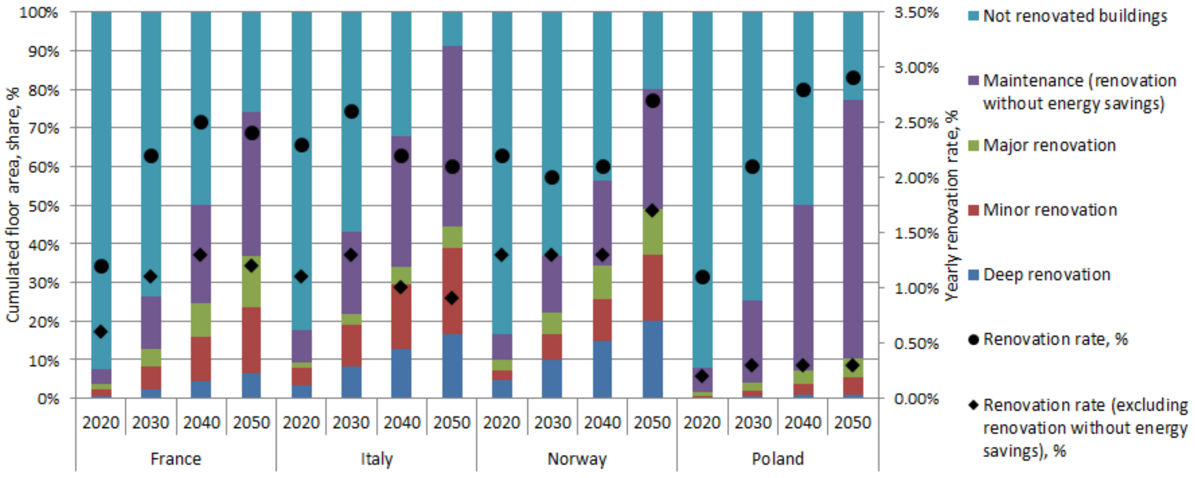

Fig. 2 Total cumulated building floor area by renovation levels, yearly total renovation rate and yearly thermal renovation rate in France, Italy, Norway and Poland in 2020, 2030, 2040 and 2050. Current policy scenario.

3.2. Energy demand and CO_2-savings scenarios

Fig. 3 shows the total final energy demand for space heating, hot water and CO_2-emissions caused by the building sector in France, Italy, Norway and Poland from 2012 until 2050. Final energy demand is expected to be reduced by 2050 in all investigated countries due to the building stock transition, namely the new building stock with very high energy efficiency (nearly zero-energy buildings), building renovation rates and depth (see previous section) and demolishment of the old (inefficient) building stock. The final energy reduction from 2012 to 2050 is 18%, 44%, 27%, 28% in France, Italy, Norway and Poland respectively. The main drivers of the energy reduction are the renovation rates, which is a result of the vintage of the building stock and the depth of renovation. In 2012 CO_2-emissions from the countries' building stock for space heating and hot water were 89 Mt, 78 Mt, 7 Mt and 56 Mt in France, Italy, Norway and Poland respectively. The reduction of the CO_2-emissions from 2012 to 2050 is as follows: 66%, 63%, 40% and 37% in France, Italy, Norway and Poland. The main drivers of the CO_2-emission reduction in the building sector are the heating system exchange rate and the substitution of the fossil-fuel-based heating systems with the renewable systems. The type of the heating system being installed depends on the energy fuel prices, technological learning effects and policy interaction. However, the results are strongly affected by assumed the CO_2-emission conversion factor of electricity, which varies strongly from one country to another due to the countries' generation mix. The BAU scenario assumes an unchanged electricity generation mix until 2050. A changing generation system, leading to altered CO_2 emissions, is subject of the alternative scenario, which is presented in forthcoming publications.

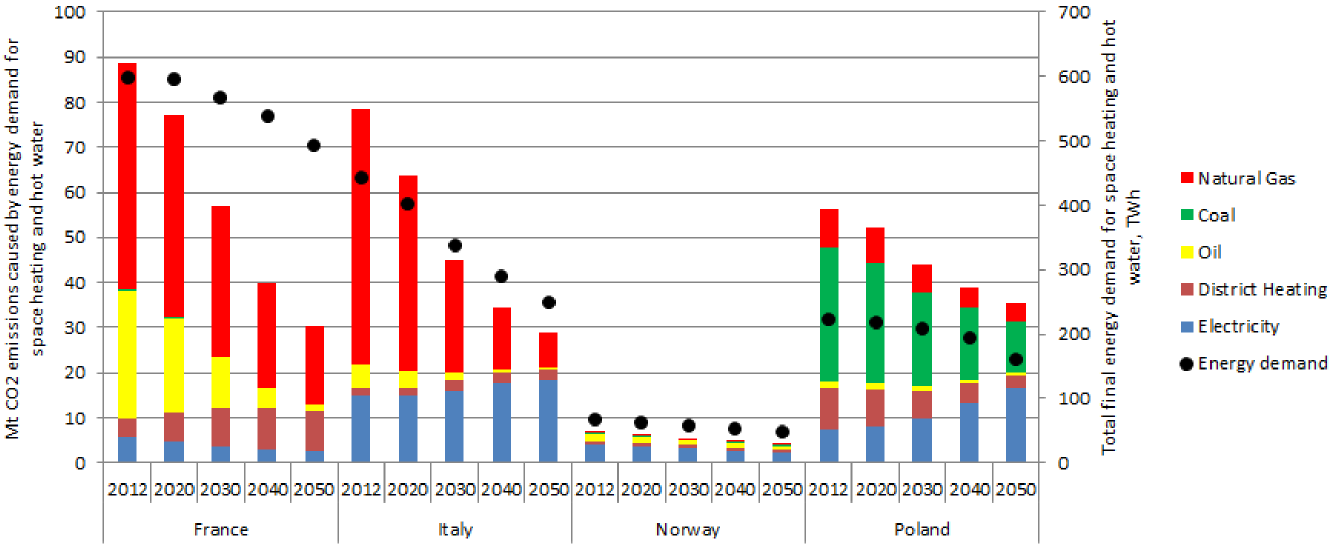

Fig. 3 CO_2-emissions by energy carrier caused by the building stock´s final energy demand for space heating and hot water (y-axis, left hand) and total final energy demand for space heating and hot water (y-axis, right hand) in France, Italy, Norway and Poland in 2012, 2020, 2030 2040 and 2050 in the BAU scenario. The CO_2-emission conversion factors for the energy carriers are assumed to be constant from 2012 until 2050.

4. DISCUSSION AND CONCLUSIONS

In this paper, the final energy demand for space heating and hot water and CO_2-emissions in the total building stock was calculated for France, Italy, Norway and Poland. Renovation rate and renovation depth - the main drivers for the energy savings and CO_2-savings - were assessed. The renovation rate and renovation depth by 2050 is the result of the techno-economic parameters such as thermal building characteristics, energy fuel prices, climate data, investment costs and others. CO_2-emissions by 2050 were calculated by using current, constant CO_2-factors. This allows to separate the impact of changes in the building sector from possible changes and decarbonisation in the electricity sector.

Scenarios have shown that the highest energy savings can be achieved in Italy and Norway, due to the high renovation rate and applied ambitious renovation measures, respectively. When it comes to the CO_2-emission reduction, the highest reduction was calculated for France. The main drivers of the CO_2-emission reduction in the building sector are the heating system exchange rate and the substitution of the fossil energy based heating systems with renewable systems such as biomass boilers.

In many countries the fossil fuels, like oil and gas in Italy and particularly coal in Poland, are substituted with the electricity, which generation mix is partly dominated by the fossil fuels and corresponding high CO_2-emissions according to the BAU scenario. This leads to an untapped potential of CO_2-emisson saving. In the European roadmap for moving to a competitive low carbon economy in 2050 it is stated that electricity will play a central role in the low carbon economy. This might be a crucial condition also for the decarbonisation of the European building sector.

Thus, these results call for a) an ambitious shift towards low-carbon electricity generation and b) in the light of climate change mitigation a binding United Nations CO_2-emission reduction agreement.

5. ACKNOWLEDGEMENTS

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