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Energy and investment intensity of integrated renovation and 2030 cost optimal savings

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ABSTRACT

Energy and investment intensity of integrated renovation variants were studied to determine cost optimal energy savings by 2030 as a part of new Estonian energy roadmap preparation. For major residential and non-residential building types, 3–4 renovation variants with different ambition were defined, all including the installation of adequate ventilation system in order not to compromise indoor climate. Cost optimal energy performance level of renovation corresponded in most cases to minimum energy performance requirements of new buildings. In most of building types cost optimal renovation cost was slightly below or higher of 200 €/m^2 which could be seen as major barrier in residential buildings needing support schemes in order to realize the potential. Cost optimal energy savings were remarkable in heating energy, which was reduced by factor of 3 to 4, but electricity use tended to increase in most of building types while retail and industrial buildings showed strong electricity reduction potential. The reduction in electricity use by 2030 was without and with new construction 7 and −8%, respectively. By 2030 cost optimal renovation saved 16% of final energy, but with the inclusion of new construction the reductions in final energy and non-renewable primary energy were 8% and 0% respectively.

1. Introduction

National energy roadmaps and action plans need solid evidence based technical input about energy savings, indoor climate improvements and cost effectiveness of energy performance improvement measures. Such technical and economic data can then be used in scenarios with different ambition to predict energy use development trends in the building stock, required investments, direct and indirect economic effects in order to find most suitable measures for the implementation. This study contributes to the preparation of new Estonian energy roadmap ENMAK 2030+[1], which uses the reference level of 2010 and constructs three building stock improvement scenarios by 2030.

ENAMK 2030+ is an actual example of a national roadmap; it is partly implementing EU 2020 targets and goes up to 2030, which is the time frame for next detailed EU targets currently under discussion as described in Green Paper [2]. Green Paper reflects a need on a new 2030 framework for climate and energy policies and refers to roadmaps for 2050. Energy Roadmap 2050 [3] states that the prime focus should remain on energy efficiency, where buildings play a major role. It is stated that an analysis of more ambitious energy efficiency measures and cost-optimal policy is required which is one core activity in ENMAK 2030+. The roadmap concludes that electricity will have to play a much greater role than now (almost doubling its share in final energy demand to 36–39% in 2050), that shows an importance of electricity use also in buildings. Therefore, energy saving potential assessment in buildings cannot be limited on heating energy, as often done [4], but electricity use should be a consistent part of analyses as affecting both energy use and cost effectiveness. Roadmap 2050 [5] sets out a cost-efficient pathway to reach the target of reducing domestic emissions by 80% by 2050. To get there, Europe's emissions should be 40% below 1990 levels by 2030, and the sector specific target for residential and service sectors CO_2 reduction is 37 to 53%, which include efficiency improvements together with increase of the share of low carbon technologies in electricity mix up to 75–80% in 2030 [5].

In energy efficiency targets, the building stock and its energy performance improvements play a major role, because energy use in buildings has steadily increased and has exceeded the other major sectors: industrial and transportation [6] while the replacement rate of the existing stock is only 1–2% per year. Compared to 1994, energy use in buildings increased in 2004 by factor of 1.17, but stayed in about of 37% of total EU final energy consumption during this period [6]. In the last years, energy use in buildings has shown some decrease, but grew again substantially reaching the highest level of the last 20 years with the share of 39.9% in 2010 [7].

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Nomenclature

Final	energy is the energy finally consumed in the transport, industrial, commercial, agricultural, public and household sectors. It excludes deliveries to the energy transformation sector and to the energy industries themselves.
Primary	energy is the extraction of energy from a natural source.
Renewable	energy includes hydroelectricity, biomass, wind, solar, tidal and geothermal energies.

Acronyms

NPV	Net present value
EP	Energy performance value
EPC	Energy performance certificate
nZEB	Nearly zero energy building
HRV	Heat recovery ventilation
AHU	Air handling unit

Symbols

f_{tot}	Total primary energy factor
f_{nren}	Non-renewable primary energy factor

Energy use in buildings varies in members states while European average annual heating energy use has been estimated 173 kWh/m^2 in apartment buildings [8] and in residential buildings between 150 and 230 kWh/m^2 [9]. Estonian data is in the range and is discussed in the results. Cost effective energy saving potential in 10 countries was calculated in [4] concluding that cost-effective saving of 10% of heating energy can be achieved by 2020 and 20% by 2030. Reported minimum and maximum costs of renovations show remarkable variation between countries, min values ranging from 3 to 70 €/m^2 and max values from 5 to 200 €/m^2 allowing to conclude that cost optimal renovation variants depend much on local conditions.

Regarding cost effective renovation measures, Nemry et al. [10] modeled building stock for the EU-25 and reported that additional roof and façade insulation as well as sealing of leakages were cost effective in houses while sealing of leakages appeared to be the only cost effective measure in multi-family and high-rise buildings. Verbeeck and Hens [11] reported economically feasible hierarchy of energy-saving measures, based on five reference building describing Belgian residential buildings, as follows: insulation of the roof; insulation of the floor, if easily accessible; new windows; more energy efficient heating system and renewable energy systems. These measures are generally in line with ones used in this study with the exception of heat recovery ventilation that is indispensable in a colder climate.

EPBD directive, launched 2007 and 2010 [12] has generated in Estonia a deep renovation of 520 apartment buildings with KredEx support scheme [13], which experience and technical solutions are utilized in this study. This study focuses on energy performance measures intended for integrated (deep) renovation of residential and non-residential buildings. By integrated renovation it is meant that both adequate indoor climate (especially improved ventilation) and improved energy performance are to be achieved.

The aim of this study was to develop a useful minimum number of alternative integrated renovation variants for minimum number of reference buildings representing building types in order to be able to predict energy use in Estonian building stock as well as required investment needs for integrated renovation. Energy use and renovation of Estonian apartment buildings has been previously comprehensively studied in [14] allowing to use representative reference buildings and renovation package variants from these studies. For other building types, reference buildings and alternative integrated renovation variants were defined in this study. For each renovation variant studied, investment cost and net present value of 20 years with corresponding energy and cost data was calculated. As an application of defined renovation variants and reference buildings, technical and cost optimal energy saving potentials of Estonian building stock were determined. Achievable energy savings by 2030 were calculated in final and primary energy with assumptions of three scenarios which included incentives and cost optimal renovation variants. The study was limited to energy and investment intensity analyses of building type specific integrated renovation variants and building stock energy analyses. These results will be used as input to national economy analyses which will be conducted in ENAMK 2030+for buildings and other sectors to show direct and indirect effects, benefits and public finance effects allowing one to identify most suitable measures for the implementation.

2. Methods

The methodology used in this study was oriented on detailed description of renovation alternatives which will most probably used in majority of renovated buildings in future. This was somehow different approach compared to building stock energy modeling, where enough detailed distributions of age and building types play an important role and for example 300 categories have been used in the modeling of Swedish building stock [15]. In this study, the accuracy of the energy modeling in the building stock was intentionally compromised, so that very limited number of reference buildings was used, to be able to cover about 80% of the building stock, which was considered enough for the estimation of the technical energy saving potential. Major effort was put to detailed energy and cost simulations of such integrated renovation variants which would be directly applicable in practice. For every reference building, 3–4 renovation variants with different ambition were studied so that even the variant with the lowest cost included the installation of adequate ventilation system, in order to strictly avoid energy savings at the cost of indoor climate that was a specific target of ENMAK 2030+and is also stated in EPBD recast [12]. The renovation variants with higher ambition were intended to be used together with relevant incentives.

The building types used, to describe the building stock with given limitations, were selected according to floor area distribution of the building stock as shown in Table 1. Major categories of residential and non-residential buildings were described with reference buildings for which detailed energy and cost simulations were conducted. For industrial buildings (without process) and retail an available sample of buildings with implemented energy performance improvement measures was used.

Table 1
The size of Estonian conditioned (heated and ventilated) building stock and the number of reference building used in the study.

Building type	Floor area (m^2)	Floor area (%)	No of ref. buildings
Multifamily	34,281,629	31	4
Single family	26,447,774	24	2
Other residential	5,962,745	5	-
Industrial (w/o process)	16,658,128	15	1
Office buildings	8,269,072	8	2
Retail	6,487,440	6	1
Educational	4,133,084	4	2
Hotels	1,741,856	2	–
Hospitals, clinics	1,840,182	2	–
Other	4,419,816	4	–
Total	**110,241,726**	**100**	