INTEGRATED STRATEGIES FOR RETROFITTING BUILDINGS TO REDUCE PRIMARY ENERGY USE, GHG EMISSIONS AND COSTS

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Summary

The increasing number of retrofitted buildings reaching requirements of advanced building standards is an indicator for the availability and feasibility of energy-efficient technologies. The paper assesses the economic effectiveness and viability of such retrofits and reveals the impact of factors such as scope, time horizon, interest rate as well as energy price expectations and preferences. Retrofit strategies to reach ambitious targets of primary energy reduction and CO_2 mitigations at low life cycle costs are identified for different building typologies. This is done both in a generic way referring to the building stock of the countries involved in the research, Denmark, Finland, Romania, Sweden and Switzerland, and for a selection of case studies. Some recommendations for retrofit strategies are given as conclusions. The paper presents selected outcomes of the project *Integrated strategies and policy instruments for retrofitting buildings to reduce primary energy use and GHG emissions (INSPIRE)*, in the frame of the Eracobuild programme.

Keywords: retrofit strategies, primary energy reduction, CO_2 mitigation, cost-effectiveness

1 The building retrofit sector

The building sector accounts for 40 % to 50 % of the final energy consumption in the countries participating in this project. While in the European Union energy-related requirements for new buildings are constantly increasing (e.g. EPBD, nearly zero energy buildings up to 2020), the improvement of energy performance of the existing building stock constitutes a major challenge. The mastering of this challenge requires the identification of cost optimal retrofit strategies to achieve maximal reduction of energy consumption and carbon emissions through and within building renovation.

The increasing number of building retrofits reaching the requirements of advanced building standards is an indicator for the availability and feasibility of energy-efficient technologies. Buildings efficiency potentials and cost-curves of building envelope measures and renewable energies are also quite well-known, at least for standard applications and new buildings [1]. In the case of building renovation, there are often object-specific additional costs for integrating energy-related retrofit measures into existing buildings, which give rise to an extended cost range and to uncertainties regarding resulting costs of building retrofit [1].

2 Objective and scope

The research focused on residential building typologies in Denmark, Finland, Romania, Sweden and Switzerland. The objective of the research was to provide an overview and systematic assessment of retrofit strategies and policy portfolios, through the evaluation of generic strategies and comparative case study analysis. This knowledge is critical in designing, developing, implementing and evaluating policy instruments supporting retrofit strategies. Currently available technologies and retrofit practices were evaluated with respect to technical performance, primary energy needs, ranges of application, costs and CO_2 emission reduction potential. Evaluation was done for commonly available and for best practice technologies. Prefabricated multi-family residential blocks represent a particular retrofitting challenge in Eastern Europe and, special focus was directed towards this typology.

3 Methodological approach

The evaluation methodology was structured into the following steps:

- Characterization of the building stock, selection and definition of generic buildings;
- Definition of basic parameters: interest rates and energy prices; time period of the evaluation; electricity mix, subsidies;
- Definition of the reference situation and of potential measures (retrofit or other) to reduce primary energy use or greenhouse gas (GHG) emissions;
- Gathering of techno-economic data on primary energy and GHG mitigation measures
- Calculation of energy related impacts of measures and of cost-effectiveness;
- Comparison of different options and conclusions concerning cost efficient and sustainable mixes of measures on the building envelope; the heating system and energy related building equipment.

Strategies and policy instruments for retrofitting buildings were evaluated using a methodology which takes into account the following indicators:

- Greenhouse gas emissions: direct and upstream GHG emissions (in CO_2eq);
- Costs: investments costs, operational and maintenance costs, energy costs. Costs refer to yearly life cycle costs;
- Primary energy (PE) use: direct and upstream primary energy use of energy carriers consumed as well as embodied energy use for retrofit measures. Both total PE and non-renewable PE were considered.

The method to calculate indicators for the above mentioned dimensions includes the following steps (see **Fig. 1**):

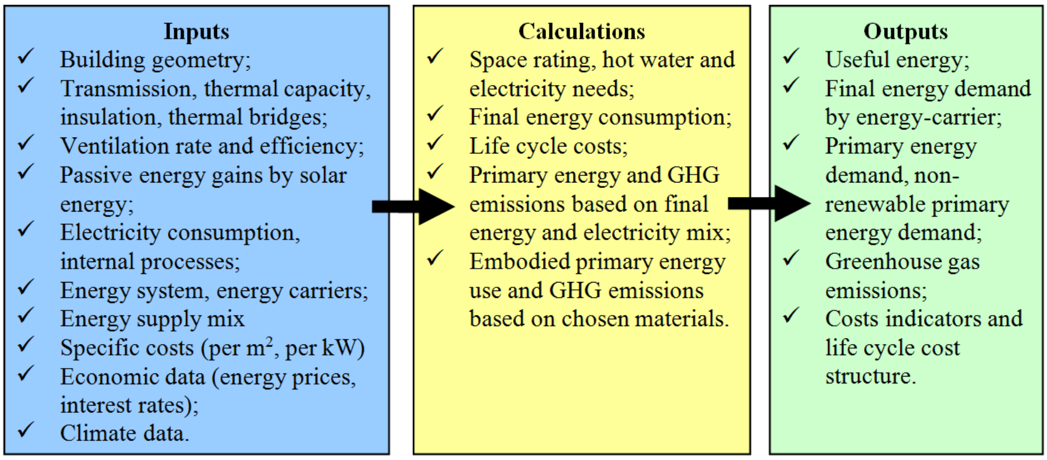

***Fig. 1** Simplified model of used methodology*

In order to assess potential measures and develop strategies for retrofitting buildings:

- Reference cases and a list of measures were defined and the energetic and economic impacts of these measures were assessed compared to the reference cases;
- For each building type a set of potential measures to improve the energy performance of the building was identified that fits best the targets of reducing primary energy demand and greenhouse gas emissions.

3.1 Strategic elements: renovation packages, choice of energy-mix

Nine different strategic elements (SE), i.e. options for increasing efficiency of primary energy use and reducing GHG emissions of existing buildings, were identified and classified by three dimensions (see **Tab. 1**):

***Tab. 1** Strategic elements and their classification*

SE	Description	Classification		
		Demand/PE/ GHG reduction	Investment/ Operational type	Construction/ Technology type
SE 1	Improvement of the thermal protection (insulation)	Demand/PE/GHG	Investment	Construction
SE 2	Choice of energy carrier/ Change in the heating system	Demand/GHG	Investment/ Operational	Technology
SE 3	Implementation of ventilation system with heat recovery	Demand/PE	Investment/ Operational	Technology
SE 4	More efficient electricity use (lighting, cooling, appliances)	Demand/PE	Investment	Technology
SE 5	Choice of electricity mix	PE/GHG	Operational	Other
SE 6	Construction and materials	PE/GHG	Investment	Construction
SE 7	Control and regulation of building systems	Demand/PE	Operational	Technology
SE 8	Implementation of solar thermal panels and PV	PE/GHG	Investment	Technology
SE 9	Improvement of the sun and the overheating protection	Demand (cooling)		Technology

4 Discussion of analysis outcomes and recommendations

For each typology of residential buildings, reference buildings were defined in at least two countries serving as basis for calculations. Single-family residential building was selected for Denmark and Sweden, multi-family residential building for Romania and Finland, and both typologies were used for Switzerland. The selected typologies were chosen according to their relevance for the building stock of the countries, and to exemplify the constraints faced by professionals when renovating buildings designed with different priorities and requirements than the ones used today. For reference buildings in Denmark, Finland, Romania, Sweden, and Switzerland, it could be shown that many renovation measures to improve the energy performance of a building are cost effective, when:

- Costs are taken as life cycle costs over the entire lifetime of each building element, including investment costs, maintenance costs, and energy costs. Since in retrofit reality parts of the building elements may be replaced before they arrived at the end of their technical life span, this cost assessment tend to underestimate real costs;
- For energy prices, future price increases during the (typically long) life span of retrofit measures are taken into account;
- The cost effectiveness of renovation packages depends on the reference situation. If in the reference situation refurbishment is required anyway, simultaneous energetic improvement of the wall is more cost effective.

Energy efficiency measures on the building envelope reduce particularly primary energy use. Resulting reduction of carbon emissions is depending on the energy system and the energy carrier covering residual heat or electricity demand. It is difficult to achieve low levels of GHG emissions with efficiency measures alone. Such a retrofit approach would not be the most cost effective. Also, the life cycle cost curve of building envelope measures does not depend significantly on the choice of the heating system, as resulted from the investigated examples. The replacement of the heating system offers good opportunities when combined with measures on the building envelope. As the energy need of the building is reduced, peak capacity of the heating system can be reduced as well, which is a key driver for making many renovation measures of the building envelope cost effective also when renewable energies are used as the main source for heating. If this opportunity is missed, and the dimensions of the renewable energy based heating system are set without taking into account renovations on the building envelope, subsequent energetic renovation of the building envelope will be less cost effective.

Acknowledgement

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References

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