The 1st IAEE Online Conference takes place on 7th – 9th June 2021

IDENTIFYING RELEVANT PARAMETERS TO REPLICATE A STEP-BY-STEP RETROFFITING OPTIMISATION MODEL IN A BUILDING STOCK LEVEL

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Overview

Although the EU presented ambitious targets to achieve its building stock decarbonisation before mid of this century, several studies showed that in praxis, still many barriers needs to be overcome. To accelerate deep renovation activities and to diversify strategies how to achieve the decarbonisation goal, the EU introduced in Article 19a of the recast of the Energy Performance of Buildings Directive (EPBD) 2018/844/EU), the so called building renovation passports (BRP) (European Parliament, 2018) . BRPs should serve as an instrument to improve building's energy efficiency, by providing a long-term and step-by-step deep renovation roadmap for a specific building.

In fact, improving the energy efficiency of buildings is not necessarily restricted to single stage renovation, but can also be achieved by step-by-step renovation measures. In the literature however, there is no consensus wheter or not deep renovation can be achieved by a sequence of step-by-step renovation measures, where retrofitting measures are not performed at the same time. A profound answer to this question is crucial, since studies have showed that in the real-life most renovation of single family house are performed step-by-step (EuroPHIT project, 2016). A literature review showed that this research gap is partly fuelled by the fact, that optimisation models for deep renovation of existing building almost exclusively optimise single stage retrofitting.

This is, where this papers adds to existing literature. The main goal of the present paper is to; firstly, apply an individual building step-by-step optimisation model to different cases. Secondly, by characterizing the building stock in techno-socio-economic archetypes, we aim to identify relevant parameters that should be taken into account, when upscaling the step-by-step retrofitting optimisation model into a building stock level.

Methods

To carry out the analysis, a methodological approach of an optimisation model for individual buildings is applied. This optimisation approach considers the building owners' ability (and requirement) to invest in energy related measures (assuming owner-occupied buildings only). The main target is to calculate the optimum retrofitting time in a step-by-step deep renovation approach. For that, an optimisation model is formulated (Maia and Kranzl, 2019), which maximizes the net present value of (cumulated) asset available for energy related issues reduced by the energy related expenditures over a certain optimisation period. The energy related expenditures consist of investment costs (IC), energy costs (EC) and operation and mantanance costs (OMC).

$$max_{x,t} \sum_{t,t_{op} \in T} \sum_{i \in I} \frac{A_t - ICer_{i,t} - EC_t - OMC_t}{(1+r)^t} + \frac{L_{top}}{(1+r)^{top}}$$

Equation 1

where:
t time [a]; t_{op} optimisation period [a]; i is the available set of retrofitting measures *A,* cumulated allocated energy related asset [EUR]; ICer, energy related investment costs of retrofitting measure [EUR]; EC, energy costs [EUR/a]; OMC, annual running operation and maintenance costs [EUR/a]; L, residual value of the retrofitting measures in year top.

The cumulated allocated asset (At) destined to energy related issues in the year (t) is related to the household's income (INC), its share (s) which is allocated for energy related expenses (including running costs and investments) and previous assets (At-1) and energy related expenses:

$$A_t = (INC_t * s) - IC_{er,t} - EC_t - OMC_t + A_{t-1}$$

Equation 2

where:
A, cumulated allocated energy related asset [EUR]; *INC,* household income [EUR]; *s,* allocation factor of total annual income on energy related expenses [%]; *EC,* annual running energy costs [EUR/a]; *OMC*, annual running operation and maintenance costs [EUR/a].

These cumulated assets in year t (A_t) represent the budget restriction, which the household faces. In addition, the household may take up a certain loan. The amount of the loan which the bank is willing to provide is assumed to be proportional to the cumulated asset and is represented by the variable l (share of the cumulated asset which can be gathered by a loan). Thus, the overall budget restriction in year t (B_t) may be written as:

$$B_t \geq \; IC_{er,t} + \; EC_t + \; OMC_t \qquad \textit{Equation 3}$$

with

$$B_t = \; A_{t-1} * (1 + l)$$

where:
B; budget restriction [B]; $IC_{er},$ energy related investment cost of retrofitting measures [EUR]; *EC,* annual running energy costs [EUR/a]; *OMC*, annual running operation and maintenance costs [EUR/a]; l, loan [EUR].

With the second aim of upscaling this approach into a building stock level, in the second step of this analysis the building stock is characterized in techno-socio-economic archetypes. This characterization goes beyond the commoly used techno building typologies (based on construction vintage, U-values, g-values, heating/cooling systems, energy carriers etc.). The techno-socio-economic archetypes take also into account parameters such as ownership structure and income distribution of owners. In the scope of this analysis are primarily reference buildings for the German single-family houses building stock.

Results

The step-by-step retrofitting approach, when compared to the one-step retrofitting approach, enables faster adaptation to energy efficiency standards, since the building elements can be improved at different time steps. However, in real life, performing a deep renovation depends on other relevant aspects, as for example invidual's budget restriction. The results from the step-by-step optimisation model for individual buildings should give first insights of how the time aspect would affect the EU-targets for building stock decarbonisation until 2050. By identifying techno-socio-economic archetypes, we expect to identify influencing parameters as for example choice of heating systems, and respect share of different technologies, minimum energy demand targets for the retrofitting plan and respectively investment costs related to that.

Conclusions

The present study considers relevant aspects of real-life retrofitting, not only by analysing the step-by-step retrofitting approach under the consideration of building owner's ability to pay. Also, by trying to understand the impact of individual step-by-step deep renovation on a aggregated level. To guarantee accuracy on the analyses, in a next phase of the present study, sensitivity analyses will be included as well as important parameters as income projection, energy price scenarios and related policies. Finally, with this kind of analysis we prepare the ground for providing policy and incentives designs to increase building stock decarbonisation rates.

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