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# Method for a component-based economic optimisation in design of whole building renovation versus demolishing and rebuilding

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## HIGHLIGHTS

- Development of a method for evaluation of renovation projects.
- Determination of an economic optimal combination of various energy saving measures.
- The method compared the renovation cost to those for demolishing and building new.
- Decision was highly influence by the investment cost and buildings market value.
- The results indicate that buildings should be renovated and not demolished.

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## ABSTRACT

*Aim:* This paper presents a two-fold evaluation method determining whether to renovate an existing building or to demolish it and thereafter erect a new building.
*Scope:* The method determines a combination of energy saving measures that have been optimised in regards to the future cost for energy. Subsequently, the method evaluates the cost of undertaking the retrofit measures as compared to the cost of demolishing the existing building and thereafter erecting a new one. Several economically beneficial combinations of energy saving measures can be determined. All of them are a trade-off between investing in retrofit measures and buying renewable energy. The overall cost of the renovation considers the market value of the property, the investment in the renovation, the operational and maintenance costs. A multi-family building is used as an example to clearly illustrate the application of the method from macroeconomic and private financial perspectives.
*Conclusion:* The example shows that the investment cost and future market value of the building are the dominant factors in deciding whether to renovate an existing building or to demolish it and thereafter erect a new building. Additionally, it is concluded in the example that multi-family buildings erected in the period 1850–1930 should be renovated.



## 1. Introduction

In the European Union (EU) the energy efficiency of the building sector has been regulated through the Energy Performance of Building Directive (EPBD) introduced in 2002 (EU, 2002). A revised EPBD was implemented in 2010 (EU, 2010) fostering the increased utilisation of renewable energy sources for energy use in buildings. Thereby, EU endeavours to liberate itself from the use of fossil fuels and, in turn, increases its energy security. Improving the energy efficiency of the building stock is expected to play a key role in meeting the EU commitment to the Kyoto Protocol with respect to reducing $CO_2$ emissions. The energy use of the EU's building stock accounts for about 40% of the overall energy use including 25% to the households (EC, 2010). Thus improvements regarding energy usage in households account for a significant energy saving potential. Existing buildings represent about 99% of the building stock, where the replacement rate is less than 1%. This indicates that the energy savings must be realised through renovation of the existing building stock (EC, 2010; Hartless, 2003).

The Danish government has adopted a long-term policy regarding energy usage implying that Denmark should become independent of fossil fuels by the year 2050. One milestone in achieving this aim is the conversion from fossil fuels to renewable energy sources for heating buildings by 2035 (Danish Government, 2011). The conversion may be reached by investments in renewable energy supply technologies e.g., low temperature district heating plants,

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especially in district heating areas. The investments must be executed by ensuring a balance between energy supply and energy renovation of the existing building stock. This both counteracts oversized heating plants and ensures that energy renovation is not too extreme. Ideally, a balance must be found between the costs for improving energy efficiency in the existing building stock and the costs of buying energy from heating and power plants based on renewable energy sources. Another important aspect is the cost balance between retrofitting existing buildings or demolition of the building followed by the erection of a new building. The EU delegated regulation No. 244/2012 (EU, 2012), a supplementing directive to the EPBD, presents a framework for a comparative methodology for calculating cost-optimal levels of minimum energy performance requirements for new and existing buildings and building elements. The framework prescribes calculation of macroeconomic (society) and financial (private) viewpoints including sensitivity analyses regarding energy price, interest rate and other non-energy related costs.

This paper presents a component-based optimisation method to determine the combination of various energy saving measures in the design of whole building renovation. The design proposal balances the cost for renovation to the cost of buying energy from heating plants solely based on renewable energy. Furthermore, the method considers whether to retrofit the building or demolish it and thereafter erect a new building.

## 2. Existing methods for whole building retrofit

Building renovations undertaken to obtain energy savings are largely propelled by the potential economic benefits of the project. Often, the intent is to ensure the profitably of the retrofit project, regardless if a single energy saving measure is considered or a combination of several energy saving measures. However, several other parameters can be motivating factors for an energy renovation; for example, improved indoor environment, lower energy consumption, and better layout of the building. Jakob (2006) included these factors in a study for the Swiss residential sector even though these factors are difficult to quantify in economic terms. These kinds of improvements to buildings are generally achieved for new buildings but should also be considered in the renovation of buildings. This implies that a new building should be considered as an alternative to energy renovation if the overall costs of the new building and the energy renovation are of the same magnitude.

### 2.1. Simple payback time and net present value

The optimisation of building renovation proposals can be investigated by applying various economic evaluation techniques. Remer and Nieto (1995a, 1995b) identified 25 different techniques for project investment evaluation. The most commonly used techniques are simple payback time and net present value. Both techniques, as well as their limitations, are described by Martinaitis et al. (2004). Contrary to the method of simple payback time, the net present value (NPV) method includes consideration of both the service life of the renovation measures and the cost of borrowing money to complete the renovation. However, the dependency of an estimated future energy price is a disadvantage of both techniques. In renovation projects, the NPV method has been used for optimising retrofit measures (Gustafsson, 2000; Verbeeck and Hens, 2005) and for assessing energy-saving measures (Tommerup and Svendsen, 2006).

### 2.2. Cost of conserved energy

A more readily comprehensible method derived from the NPV method is the cost of conserved energy (CCE) (Meier, 1983), which gives the cost to save 1 kWh of energy. The CCE is directly comparable with the cost of supplied energy. Thus the CCE is a way to underscore the least expensive alternative; CCE helps determine whether to invest in energy saving measures or to purchase energy. This makes the CCE technique more transparent and practicable for understanding the cost-effectiveness of the measures as compared to the monetary result obtained using e.g., the NPV method. However, the method of CCE uses the estimated future energy price as the evaluation criterion.

Martinaitis et al. (2004) suggested a “two-fold benefit” method using CCE and a “project marginal cost” as described by Jakob (2006). In this method a coefficient of building rehabilitation is introduced for which the value of the coefficient captures renovation investments in respect to the cost of rehabilitation and those related to energy savings. By dividing the investment costs in this manner, it became apparent that more retrofit measures became profitable. Thereafter, Martinaitis et al. (2007) presented the “two-factor” method for appraising building renovation and energy efficiency improvement projects. Use of this method has permitted determining an investment ceiling for a project based on the difference between the market value of the existing building and market value of a new building. If the investment for energy renovation exceeded the investment ceiling, it was concluded that financing the construction of a new building would be a better choice. In this approach, the CCE method was used on the energy saving retrofit measures and the NPV method was used in respect to maintenance and operational costs. Neither the “two-fold benefit” method nor the “two-factor” method includes an optimisation of energy saving measures. Consequently, the selected retrofit measures are not necessarily the most economically beneficial to the investor.

The CCE method was also used in optimising the design of new buildings using a component-based optimisation approach (Petersen and Svendsen, 2012). This approach used the energy performance framework (i.e., buildings total energy consumption) as a constraint in the optimisation process. Thus the dependency of the estimated future energy price in the evaluation criterion was eliminated. The optimal combination of measures was obtained where the marginal values for the CCE were identical for the respective measures. However, the results from the study showed that for the different building components, identical marginal values of the CCE resulted in the selection of insulation having excessive thicknesses. This indicates that fulfilling the requirements set out in an energy performance framework might bring about measures that result in too much energy renovation of the building as compared to the cost of buying energy.

### 2.3. Other optimisation methods

Other methods, such as multi-objective optimisation methods (Asadi et al., 2012; Diakaki et al., 2008) can also be applied in renovation projects. The selection process in the use of these methods can become extremely lengthy if no predefined or pre-evaluated measures are chosen. Similar issues are evident using the NPV method due to the calculation of a NPV for each combination of energy saving measure.

Note that according to Verbeeck and Hens (2005), the economic optimum is assumed to be achieved if the total NPV is minimal. However, the economic optimum for energy saving measures in buildings is not one single combination of measures, but can be realised through a range of combinations of measures.