Environmental assessment of renovation projects

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1. INTRODUCTION

There is a growing demand for taking environmental impacts into consideration in renovation projects, both because the environmental impact from operation and renovation of buildings is considerable, and because the long service life of buildings implies that the existing building stock will dominate the total building stock for many years. Operation and management of existing buildings are therefore key issues for the efforts to reduce environmental impacts related to the building sector.

Most literature and guidelines on LCA describe assessment of new products. This is also the case for literature on the use of LCA for buildings, e.g. the SETAC report on the use of LCA within the building sector (Kotaji 2001). How to use life cycle assessments as decision support for refurbishment and retrofitting of buildings should be further discussed. Preliminary conclusions on the considerations needed are shortly referred here. Furthermore, results from preliminary environmental assessments of renovation projects are presented.

To facilitate environmental assessment of buildings and building elements LCA tools have been developed, e.g. the Danish BEAT tool (Petersen 2000), first of all focused on environmental assessment of new buildings. For the use of these LCA tools in renovation projects, System boundaries need to be clarified, and supplementary facilities are needed that represent renovation measures in the LCA tools.

The paper is based on a number of projects involving BEAT. A European project INVESTIMMO focuses on the inclusion of a number of criteria in a decision tool for owners of residential buildings. Another project focuses on the Danish procedure for subsidised renovation projects. Finally two projects have comprised environmental assessments of a number of energy saving measures and of traditional renovation measures as well as environmental assessment of renovation compared with a new building.

ENVIRONMENTAL IMPACT

In the Danish action plan for sustainable development in the Danish building and construction industries (Product Panel 2001), priority is given to energy consumption, consumption of materials, waste prevention, and consumption of hazardous and environmentally harmful substances. In addition impacts are also mentioned that concern water consumption, emissions to soil and water, noise and vibrations as well as indoor environmental conditions and conditions relating to health and safety at work.
Energy consumption for heating one square metre of residential building in Denmark is estimated to be 200 - 800 MJ/m² depending on the age and size of the building. The total energy consumption for a new building is approximately 2 - 4 GJ/m² and for maintenance and renovations within a service life of 100 years approximately 1.5 GJ/m². Therefore, the consumption of energy for operation, especially for heating (including energy source), ventilating and cooling are the most important factors to consider regarding the energy consumption of existing residential buildings.

The type and amount of materials in renovation works do have a strong influence on the total environmental impact connected with these works, though the total amount of materials used per year for maintenance and renovation of existing buildings is small compared with the total amount of materials used per year for new buildings. This is because the consumption of materials beside gravel, concrete and clay bricks are of the same magnitude for existing buildings as for new buildings (Olsen 1993). The amount of building waste produced in Denmark per year is approximately 3 million tonne, compared with the input of building materials of close to 9 million tonne. Approximately 75% of the building waste are related to renovation and demolition of buildings.

Until now recognised examples of harmful substances in building products, which have been used in Denmark, that can affect human health and environmental health are: sealants, paints, adhesives, impregnated wood, plastics and metals. Beside, many existing buildings do contain harmful substances, either because they were allowed, when the building was constructed (e.g. asbestos and PBC) or renovated on an earlier occasion, or because former use of the building has contaminated the building.

Environmental indicators
The plan is to use the same set of environmental indicators for the life cycle of renovation works as for the energy consumption for heating etc, so that the total environmental impact for alternative renovation scenarios can be presented.

The environmental effects used as indicators in the environmental module for INVESTIMMO should be effects that are generally accepted and often used, and effects for which reliable and complete environmental data are usually available. Therefore the use of the following environmental effects as indicators is proposed:
- Global warming potential (GWP)
- Ozone depletion potential (ODP)
- Acidification potential
- Nutrient enrichment potential
- Photochemical ozone formation potential (POCP)
- Resources (optionally divided into fuels and metals)
- Bulk waste
- Slag and ashes

It will be considered to include assessments of water consumption and household waste and maybe also impacts related to local and indoor environment.

The tool will also include aggregation of the environmental effects into one single environmental indicator. This aggregation will be based on the use of weighting factors chosen nationally or by the users of INVESTIMMO.
SYSTEM
The environmental impact related to the life cycle of buildings are related both to temporary interventions like construction, renovation and demolition and to continuous efforts regarding operation and maintenance before and after interventions like refurbishment and retrofitting. Therefore the environmental impact related to existing buildings first of all depends on:
- Operation and maintenance before and after renovation
- Production and waste management related to renovation works
- Service life for the building as a whole and for the individual building elements

For LCA tools to be used in renovation projects clarification is needed regarding system boundaries and service life. It will be argued that environmental assessment of renovation projects first of all have to focus on operation, the choice of new building elements (refurbishment and retrofit measures) and service life expectations.

System boundaries
One of the main ideas of life cycle assessments is to analyse the whole life cycle of all components of a product. But for comparative assessments, processes can be omitted that are included in all the alternatives. For renovation projects, distinctions can be made between:
- Existing building elements that are not (or to a very limited degree) affected by any of the considered renovation alternatives; foundations and load-bearing walls for example can often be omitted, because they are included in all alternatives.
- Existing building elements that are removed from the building in one or more alternatives normally does not have to be included, see comments below.
- New, supplementary or replacements of building elements like glazing of balconies, supplementary heat insulation and replacement of roof has to be included1.

Existing building elements, which are removed from the building, will normally have had such a long service life that it can be argued that the impacts related to the removal and waste management can be allocated to the service life so far and therefore will not differ between different alternatives. Looking at removed building elements, which can still be argued to be useful, and for which the service life so far has been short compared with the expected service life, it can be argued to allocate part of the impacts related as well to the production and construction as to removal and waste management to the removed element. This is not easy to do, because the existing building then has to be represented in BEAT.

Service life
The service life of buildings and building elements do have a strong influence on the environmental impact from the life cycle of the materials incorporated in the building. This is because this impact primarily is related to production and waste management, and because the impact will be calculated per year and added to the impact related to operation.

Moreover, further implications of the long service life for buildings and building elements need to be discussed. A difficult aspect is related to the definition of the alternative scenarios to be comparatively assessed. If the expected "renovation service life"2 for the compared alternatives is very different, then a comparative life cycle assessment should include the same period of time for all the alternatives being compared. For alternative scenarios that include no action now, but which anticipate substantial renovation works within a short time

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1 Incl. new elements anticipated to be included in the building within a shorter time horizon.
2 The time expected to go before the next comprehensive renovation is needed
horizon, these works, e.g. described in plan for maintenance and modernisation, has to be
defined and included in the environmental assessment.

The service life and the end of life of a building or building element is not a matter of
technical lifetime only, but it is also related to a number of other criteria such as functional,
technical, economic, aesthetic, ecological and contextual criteria. But it is also important to
state that for a number of building elements the technical criterion is crucial, and therefore
also the degree to which these elements are maintained.

**TOOL**

In two projects that included environmental aspects in the decision-making process for
renovation projects, efforts were made to facilitate the use of environmental assessment based
on the use of the LCA tool BEAT (Petersen 2000), which is based on the Danish EDIP
method (Wenzel 1998).

![Environmental effects](image)

Figure 2. Example of how environmental effects could be presented in the environmental
module in INVESTIMMO (screenshot from first prototype).

INVESTIMMO already includes modules for calculation of energy for operation (heating,
cooling and lighting) and a database of typical renovation works. These renovation works are
now being further specified and represented in BEAT for calculation of the environmental
indicators. These indicator values will then be exported to INVESTIMMO, including
indicator values for a number of energy sources for operation of the building. This means that
INVESTIMMO can be used without using BEAT, which only has to be used for updating
and for national adaptation. Facilities for weighting of indicators will also be included.

In the Danish project the intention is to represent typical renovation works in BEAT as
macro-elements related to a Danish scheme for subsidised renovation projects. This means
that the environmental assessment can be seen as a supplement to economic and other
assessments.
RESULTS
Two Danish projects have comprised environmental assessment of a number of energy saving measures and traditional renovation measures (Petersen 2001), and environmental assessment of renovation compared with a new building (Hansen 2001). Later assessments of a number of renovation works will be made in INVESTIMMO.

The environmental assessment of energy saving measures shows that the energy consumption for production of these measures are of minor importance compared with the energy savings obtained during operation. But for other environmental issues, the impact related to the consumption of materials is of greater importance than the energy consumption for operation. The environmental assessment of traditional renovation measures related to the addition of new kitchens and new bathrooms in older residential buildings shows significant differences with regard to environmental impacts. The assessment shows that metals are responsible for a large part of the environmental impacts related to the consumption of materials, but also gypsum boards and wood products contribute significantly.

The comparative environmental assessment of a typical Danish renovation project for an older residential building and a new building shows lower energy consumption and lower CO2 emissions than the renovation example, regardless of life cycle and heat source variations. The simple "pay-back" for CO2 emissions at demolition and new building, instead of renovation, is 25-30 years. The importance of significant changes to a number of selected preconditions and parameters were discussed. Based on the results, the most important parameters seem to be:
- Energy consumption and emissions related to building elements for new buildings
- Increase of thermal insulation for renovated buildings
- Energy consumption and emissions related to heat supply
- Expected service life is different for renovated and new buildings

Considerable changes will have to be made before the difference between new building and renovation of older residential buildings is equalised or favours renovation as long as only energy consumption and related emissions are in focus.

CONCLUSIONS
The consumption of energy during operation of the building is a key issue for the environmental impact of existing buildings, also regarding upgrading potentials. But also the consumption of materials for renovation and maintenance is of importance, because the materials used are often energy consuming and may include materials that may be scarce or include the use of harmful substances.

Renovation measures taken to reduce energy consumption during operation will reduce the environmental impact. Renovation measures that aim to provide greater comfort or new user facilities may heighten the environmental impact related to use, operation and maintenance. The rehabilitation and retrofitting of existing buildings can be so expensive and the obtainable reduction of energy consumption for operation so limited that demolition and building a new building can be the best choice, also from an environmental point of view.

The environmental assessment of renovation projects first of all to focus on operation, the choice of new building elements (refurbishment and retrofit measures) and service life, but normally does not focus on the existing building elements. Representation of refurbishment and retrofit works in LCA tools like BEAT can therefor facilitate the inclusion of
environmental aspects in decisions concerning management and renovation of existing buildings.

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6. REFERENCES


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