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Dynamic Heat Production Modeling for Life Cycle Assessment of Insulation in Danish Residential Buildings

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Abstract

Residential building insulation is regarded as an easy solution for environmentally friendly building design. This assumption is based on the perception that the amount of thermal energy used to create insulation in most cases is much smaller than the amount of thermal energy that is needed for space heating without insulation over the lifespan of a building. When the energy sources for insulation production are similar to the energy mix that supplies heat, this logic is valid to very high level of insulation. However, in Denmark, as well as many other countries this assumption is becoming increasingly incorrect. Given the generally long service life of buildings, the significance of future energy mixes, which are expected/intended to have a smaller environmental impact, can be great. In this paper, a reference house is used to assess the life cycle environmental impacts of mineral wool insulation in a Danish single-family detached home. This single-family house, is based on averages of current Danish construction practices with building heat losses estimated using Be10. To simulate a changing district heating grid mix, heat supply fuel sources are modeled according to Danish energy mix reports of fuel mix since 1972. Both the dynamic impact potentials saved by using insulation and the impacts induced from insulation's production are utilized to create an overall dynamic energy inventory for the life cycle assessment. Our study shows that the use of such a dynamic energy inventory is necessary for increasing the validity of optimization assessment, and our study further shows that it is likely that current Danish regulation will not promote optimum levels of insulation in the near future.

Peer-review under responsibility of the organizing committee of SBE16.

Keywords: Sustainability Assessment; Building Insulation; Energy Systems; Life Cycle Assessment

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Nomenclature

DE	Dynamic energy mix
SE	Static energy mix
IS2015	Insulation Scenario, designed to meet Danish BR10 Low Energy 2015 regulations for energy loss
IS2020	Insulation Scenario, designed to meet Danish BR10 Building Class 2020 regulations for energy loss
LCA	Life Cycle Assessment
BR10	Danish building regulations 2010, valid until 30 June, 2016 when they will be replaced by BR15

1. Introduction

Residential building insulation has long been a subject of interest when energy savings are being discussed. Of the massive amounts of energy that are used in the residential sector, a considerable fraction is spent on space heating. For example, in Denmark, the average household uses 71.2 GJ of energy per year, of which nearly 83% are used for space and water heating[1]. Issues such as energy consumption in households have led many researchers and innovators to look at the production of 'net-zero' or 'passive' buildings. Realizing that the environmental impacts, and cost, of insulation might be important when assessing an entire home, some have gone further to look at the energy balance[2] or life cycle cost optimization[3] of insulation, suggesting that balances and optimizations might be a better indicator of ideal insulation levels. Some have gone even further to creating a comparative life cycle assessment of various insulation levels used in buildings[5]. While these assessments thoroughly cover the potential energy/environmental and economic issues faced in optimizing a building's energy performance, they do not adequately address one of the most significant issues: energy system dynamics. When approaching the matter of projecting environmental impact into the future, already published assessments do not account for the dynamic nature of energy mixes used for heating of buildings and thus fail to account for the changing (over time) environmental impacts from energy provision to buildings.

In many places, such as Denmark, the makeup of the energy system has changed significantly over the last decades following a trend toward more efficient and environmentally friendly energy production, and it is likely that changes will continue to occur in the energy supply that provides heat to residential buildings going into the future[1]. This dynamic energy supply for buildings means that the environmental impacts of heating a house will change over time, while the impact of insulation, which is set at the time of construction, remains static. Looking at this relationship, with the environmental impact of insulation amortized over the life of a building, an environmental impact development curve can be established. This curve describes the development of the environmental impacts resulting from the heating of a building over time. When both dynamic and static energy scenario environmental impact curves are plotted, the disparity between the impacts of an assumed static energy mix and the reduction in environmental impacts due to improvements in the energy mix is easily seen (**Error! Reference source not found.** A). This approach for location of the energy break-even point can be further developed into a comparison of insulation levels where an insulation system optimized based on a static energy mix compared to a system that is optimized based on a dynamic energy mix (**Error! Reference source not found.** B).

In order to understand the break-even issue, a reference house representing an average Danish single family home using two insulation scenarios IS2015 and IS2020 is compared. These insulation scenarios are based on regulatory levels in the Danish Building code and are intended to be indicative of insulation levels found in a well-insulated standard single family home and a super-insulated near 'net-zero' single family home.