Investigating cost-optimal refurbishment strategies for the medieval district of Visby in Sweden

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Highlights
- LCC optimization and building categorization are combined to study the cost-optimal energy efficiency potential (CEEP) of different cluster of buildings
- LCC reveals that CEEP is cluster specific.
- The order of implementing cost-optimal EEM packages on clusters depends on which perspective are considered most important e.g. reduce CO₂ emissions or reduce primary energy use
- The district heating price should be reduced by 23% in order it is beneficial for all the buildings.

Abstract
This paper presents a methodology, using Life Cycle Cost (LCC) optimization and building categorization, to achieve a systematic study of the cost-optimal energy efficiency potential (CEEP) for 920 listed buildings in the medieval district of Visby in Sweden. The aim is to study the CEEP and CO₂ emission reductions for this city that is included in the World Heritage List by UNESCO. The total CEEP is found to be 31% (20.6 GWh) resulting in a CO₂ reduction of 57% (33.3 kton). The categorization method showed that the buildings could be divided in four clusters depending on building material, geometry and layout. The LCC analysis revealed that the energy efficiency measure packages were cluster specific. It is shown that multi-story wood buildings (Cluster II) have lowest specific LCC, and would arguably be the starting point for a renovation process. Presently most of the studied buildings are connected to the district heating (DH). The results show that heat pump (HP) and wood boiler (WB) is cost-optimal heating system for multi-story stone and wood buildings, respectively. In order for the DH to compete with HP and WB, the DH price needs to be reduced by 23% and 16%.

1. Introduction

The building sector accounts for around 40% of energy demand in the European Union (EU) as well as in Sweden [1 – 2]. More than 40% of the residential buildings in Europe were built before the 1960s when the regulations related to the energy performance of buildings were less strict [1]. In addition to this, the built environment in Sweden has a large share of listed buildings compared to most other countries in the EU, as 15% of all multi-family buildings and 27% of all single-family houses are built before 1945 [3]. According to the
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