Life cycle assessment: A design element for ventilation system selection

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ABSTRACT

A Danish office building designed with a hybrid ventilation system has been compared to a full mechanical ventilation system in the same building. The comparisons include a life cycle analysis (LCA) focussing on CO_2 equivalents (CO_2equiv.) and life cycle cost (LCC) of the two ventilation solutions. The LCA includes embodied carbon form the ventilation components and operational energy due to heating and electricity. A potential reduction of 32% in the total global warming potential (GWP) was found when using a hybrid ventilation solution instead of a mechanical ventilation solution. This includes a 46% reduction in the embodied carbon and a 26 % reduction in the operational energy. The hybrid ventilation solution was 7 % cheaper to acquire, and the life cycle cost was found to be 16 % cheaper than a mechanical ventilation solution.

KEYWORDS

Embodied carbon, operational carbon, hybrid ventilation, life cycle analysis (LCA), life cycle cost (LCC).

1 INTRODUCTION

Traditionally there has been a focus on lowering energy consumption in the building sector by reducing heat loss in the buildings through increased insulation, or development of more energy efficient ventilation systems design. These parameters are still important as this has an impact on the operational energy consumption of the building, hence the environmental impact.

Life cycle assessment (LCA) focusing on CO_2equiv.) in the design of buildings has been a well-known and used methodology for measuring adverse environmental impacts for several years. However, it is only recently that there has there been a significant emphasis on the environmental impact of construction activities and its impact on our planet's climate. The focus is also led by a push from legal requirements and certification scheme tightening the requirements mainly regarding the global warming potential (GWP) using kg. of carbon dioxide equivalents (CO_2-equiv.) as an indicator.

LCA for buildings is a comprehensive approach used to evaluate the environmental impact of a building throughout its entire life cycle. This assessment considers various stages, from raw material extraction and construction to operation, maintenance, and eventual demolition or recycling. LCA involves a systematic analysis of the building's environmental performance, considering factors such as energy consumption, resource usage, emissions, waste generation, and overall ecological footprint. The goal is to provide a holistic understanding of the building's sustainability, enabling informed decisions to minimize its environmental impact.

Only a limited number of published studies have employed LCA as a primary design consideration to determine the optimal ventilation system for a specific building.

2 METHODOLOGY

An 1230m^2 office building has been used as reference to compare different ventilation solutions. The office building is located in Denmark and incorporates a hybrid ventilation system which has been compared to a full mechanical ventilation system. The hybrid ventilation system consists of an automated natural ventilation solution through façade and roof windows to handle the cooling period and a downscaled mechanical ventilation system with heat recovery to fulfil the ventilation requirements during the heating period. This is compared against if the building was to be using a mechanical ventilation system, only. Both systems are sized to fulfil the same requirements regarding thermal comfort and indoor air quality.

An LCA comparison between the two systems has been establish based on embodied carbon and operational energy (heating and electricity) from the usage and products of the systems. The LCA includes eight of the total seventeen phases of the LCA. The once included in the current study are marked in blue in Figure 1.

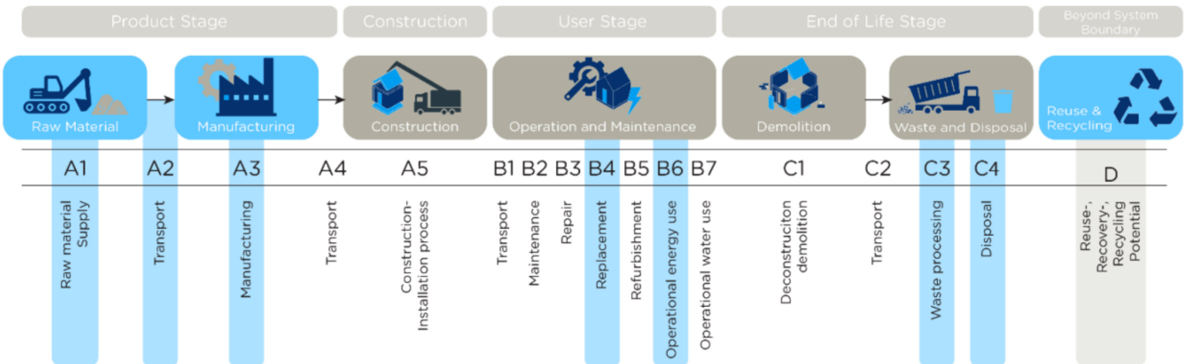

Figure 1: Included phases of the LCA.

Phase D is included in calculations, but is declared separately from the total environmental impact, as it is deemed outside the scope according to the Danish building regulation. Module D accounts potential benefits when reusing, recycling, or recovering the material after its end of life. The calculation is done in a Danish LCA tool named LCAByg using a reference period of 50 years.

The embodied environmental impact of the ventilation systems is calculated on component level for each system. The air handling units in the mechanical and hybrid ventilation systems, are simplified using generic data from the Ökobau-database that reflects the typical build-up of an air handling unit. This generic air handling unit is multiplied to the accurate weight for each scenario. The individual ventilation components used in the mechanical and hybrid ventilation systems (ducts, air handling unit, silencers, air diffusers, façade grills, air flow dampener and regulators, end cap and control valves) are modelled into their respective raw materials. This is by using the building product declarations for the individual component build-ups. For the natural ventilation components (actuators and controllers, latter enables intelligent control of the actuators) EPD-data has been used.

A Life Cycle Cost (LCC) has been used to give an insight into the overall economic costs of the given ventilation system over its life cycle. In LCC, all costs from design, construction, maintenance, and replacements during the assessment period are included.

The ventilation systems are evaluated for the economic life cycle cost associated with design, construction, maintenance, replacements, and operational costs for electricity/heating.

2.1 Key results

Figure 2 shows the LCA results focusing on GWP with CO_2-equiv. as an indicator for the two assessed ventilation systems.

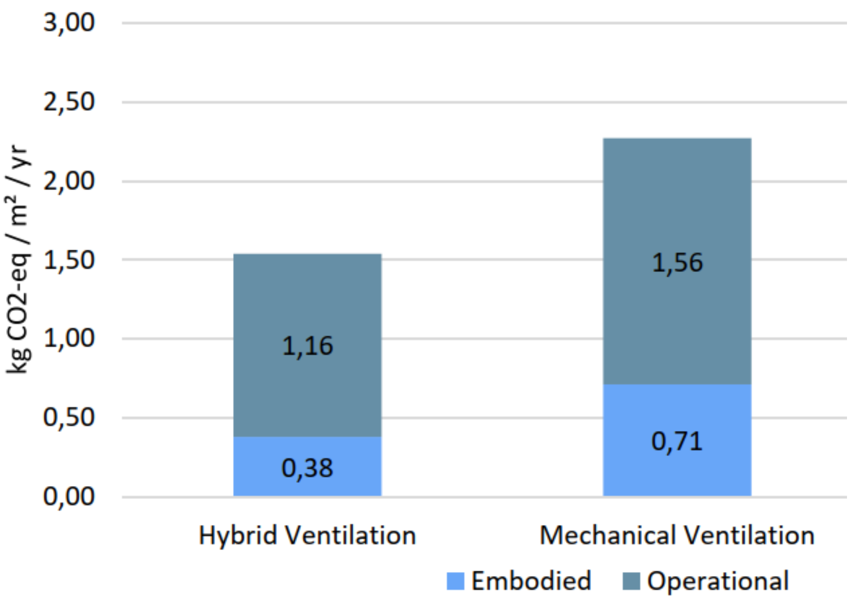

Figure 2: GWP results for the ventilation systems

Compared to the mechanical ventilation the hybrid ventilation system solution enables a:
- 46% reduction in the embodied carbon
- 26 % reduction in the operational energy
- 32% reduction in total (GWP, CO_2-equiv.)

The embodied carbon for the intelligent natural ventilation system is 0.033 kg CO_2-eq./m^2/year out of the 0.38 kg CO_2-eq./m^2/year in the hybrid ventilation solution.

Figure 3 shows the cumulative embodied and operation total GWP over the 50-year reference study period. The difference between hybrid ventilation and mechanical ventilation is due to the higher energy use from the mechanical system, along with a noticeably higher jump at year 2045, where most of the ventilation components are replaced.

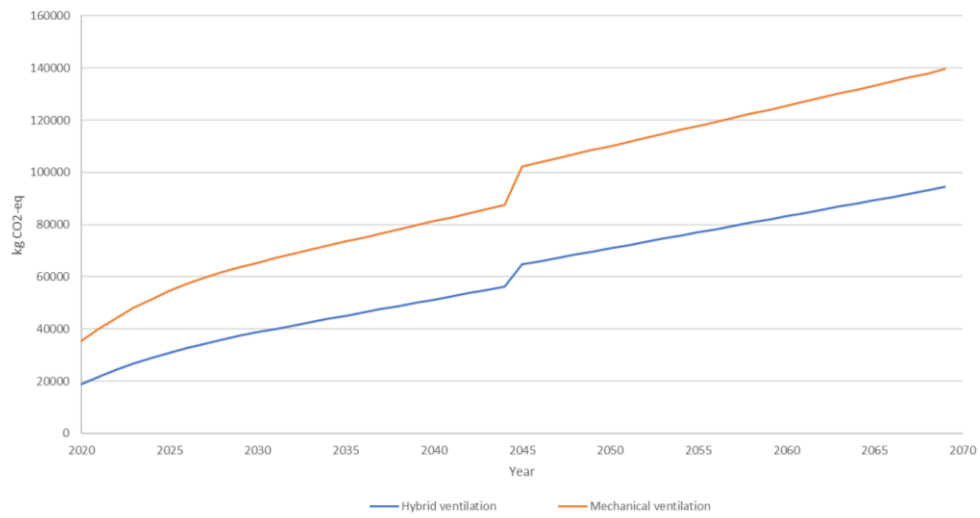

Figure 3: Total cumulative GWP, CO_2-equiv.

Figure 4 show the LCC for the hybrid and mechanical ventilation system.

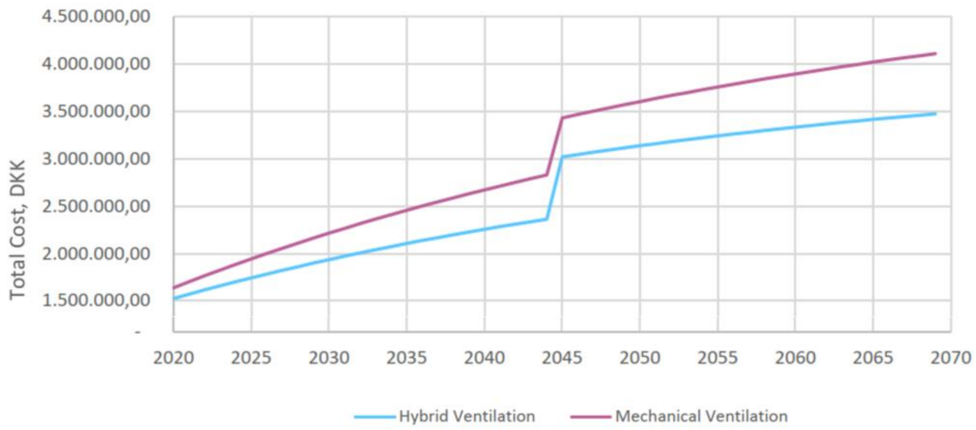

Figure 4: Cumulative cost over the 50-year assessment period, in DKK

Comparing hybrid and mechanical ventilation, hybrid ventilation is 7 % cheaper to acquire, and the overall life cycle cost is 16 % cheaper than mechanical ventilation.

3 CONCLUSION

An 1230m^2 office building located in Denmark has been used as reference to compare different ventilation solutions. The office building is designed with a hybrid ventilation system which has been compared to a full mechanical ventilation system. An LCA comparison between the two systems has been establish based on embodied carbon and operational energy (heating and electricity) from the usage and products of the systems focusing on CO_2-equiv.

The LCA calculations indicates that there is a significant potential for reducing the total GWP (CO_2-equiv.) by 32% choosing the hybrid ventilation system. This is due to a 46% reduction in the embodied carbon and a 26 % reduction in the operational energy.

Based on a Life Cycle Cost (LCC) including the overall economic costs of the given ventilation systems over its life cycle the hybrid ventilation was found to be 7 % cheaper to acquire, and the overall life cycle cost was 16 % cheaper than mechanical ventilation.