Fresh Air. Fresh People.

Life cycle assessment

A design element for ventilation system selection

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 global warming potential (GWP) with CO_2 equivalent (CO_2-eq) as the metric 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 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.

Rambøll has completed environmental calculations in accordance with EN 15978 for the GWP and LCC analysis, both over a 50 years assessment period. Norconsult designed the mechanical ventilation system and carried out the energy calculation for two ventilation systems. This study was carried out from 2022-2023.

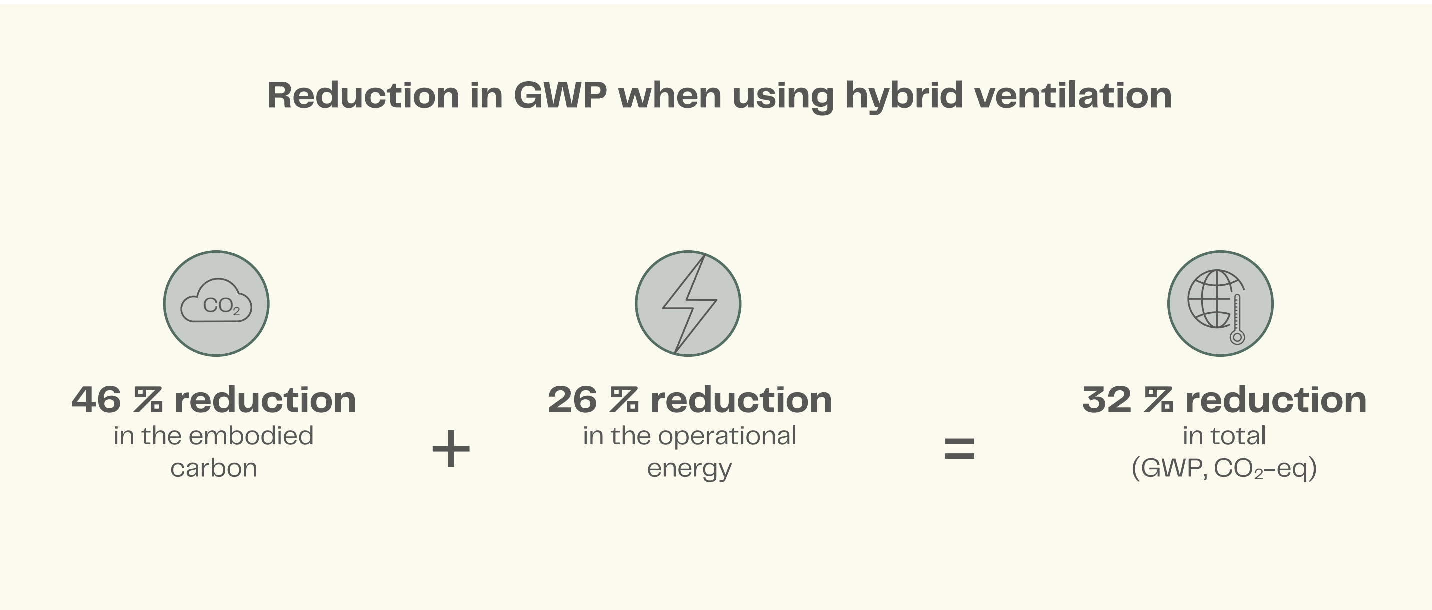


Figure 1: Reduction in GWP using a hybrid ventilation system compared to a mechanical ventilation system

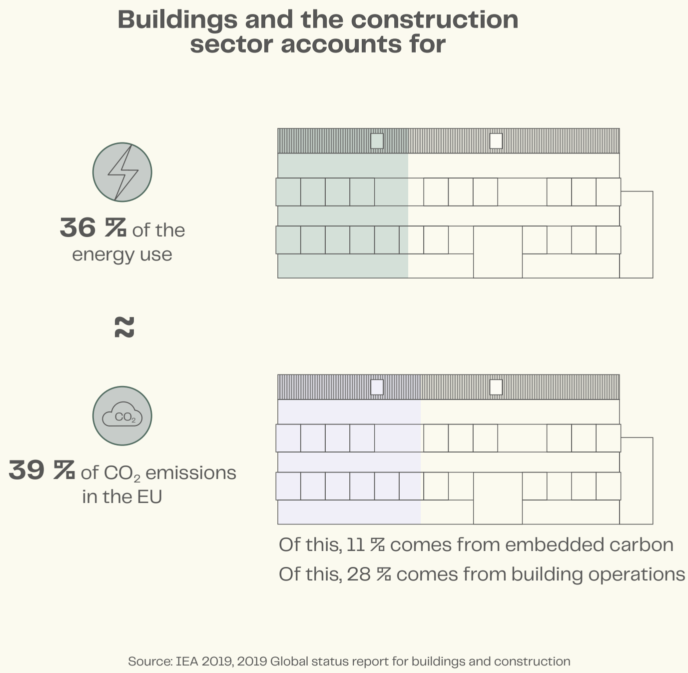


Figure 2: Buildings and construction share of global energy and energy-related CO_2 emissions

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_2-eq in the building design has been a well-known and used methodology for measuring adverse environmental impacts for several years. However, it is only recently that there has 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 CO_2-eq as an indicator.

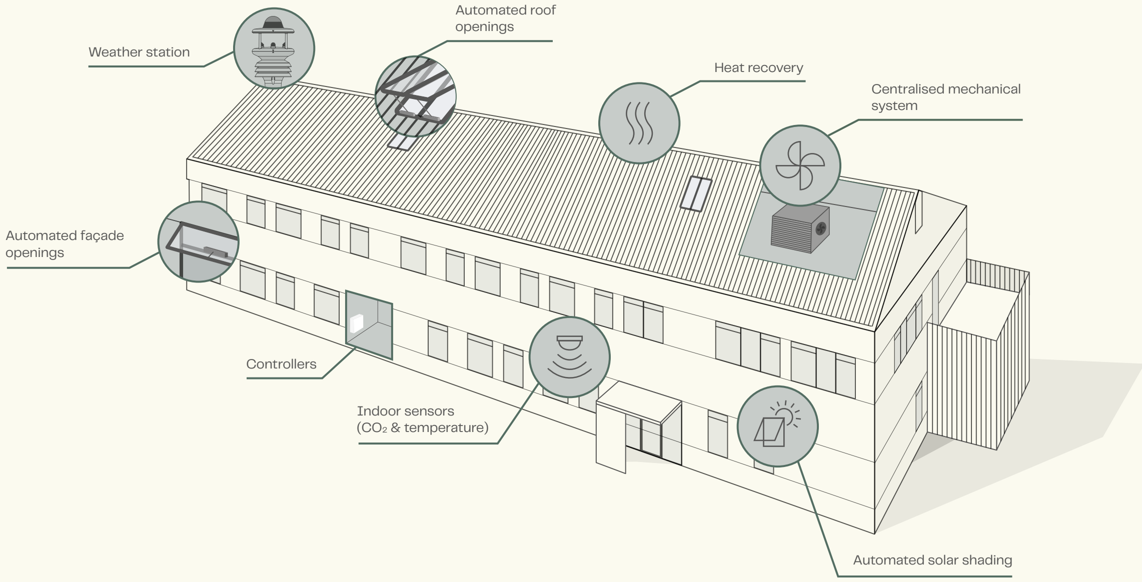
LCA for buildings is a comprehensive approach used to evaluate the environmental impact of a building throughout its entire life cycle. This assessment considers various stages, from raw material extraction and construction to operation, maintenance, and eventual demolition or recycling. LCA involves 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 performance, 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.

Methodology

An 1230 m² 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 fully 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 to a scenario in which the building would solely be using a mechanical ventilation system. Both systems are sized to fulfil the same requirements regarding thermal comfort and indoor air quality.

1 **Hybrid ventilation**
- Natural ventilation (during cooling season)
- Downscaled mechanical ventilation system (during heating period)



2 **Mechanical ventilation**
- Full mechanical ventilation system (all year round)

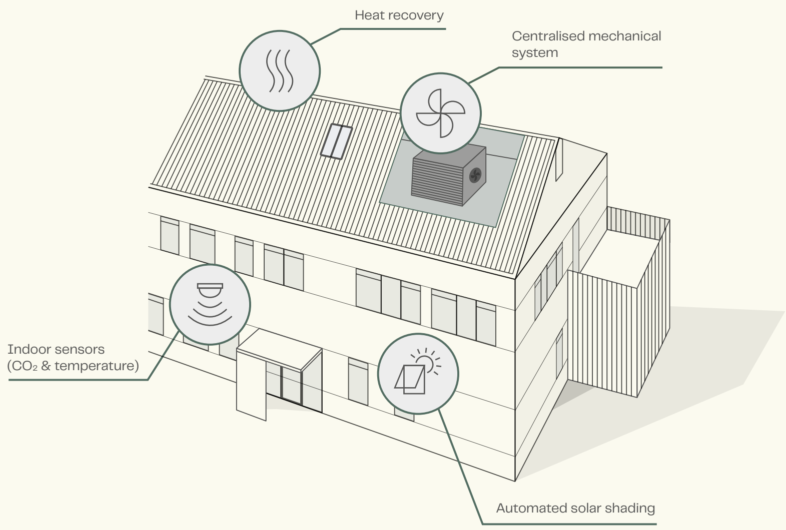


Figure 3: Main components for the mechanical and hybrid ventilation solution

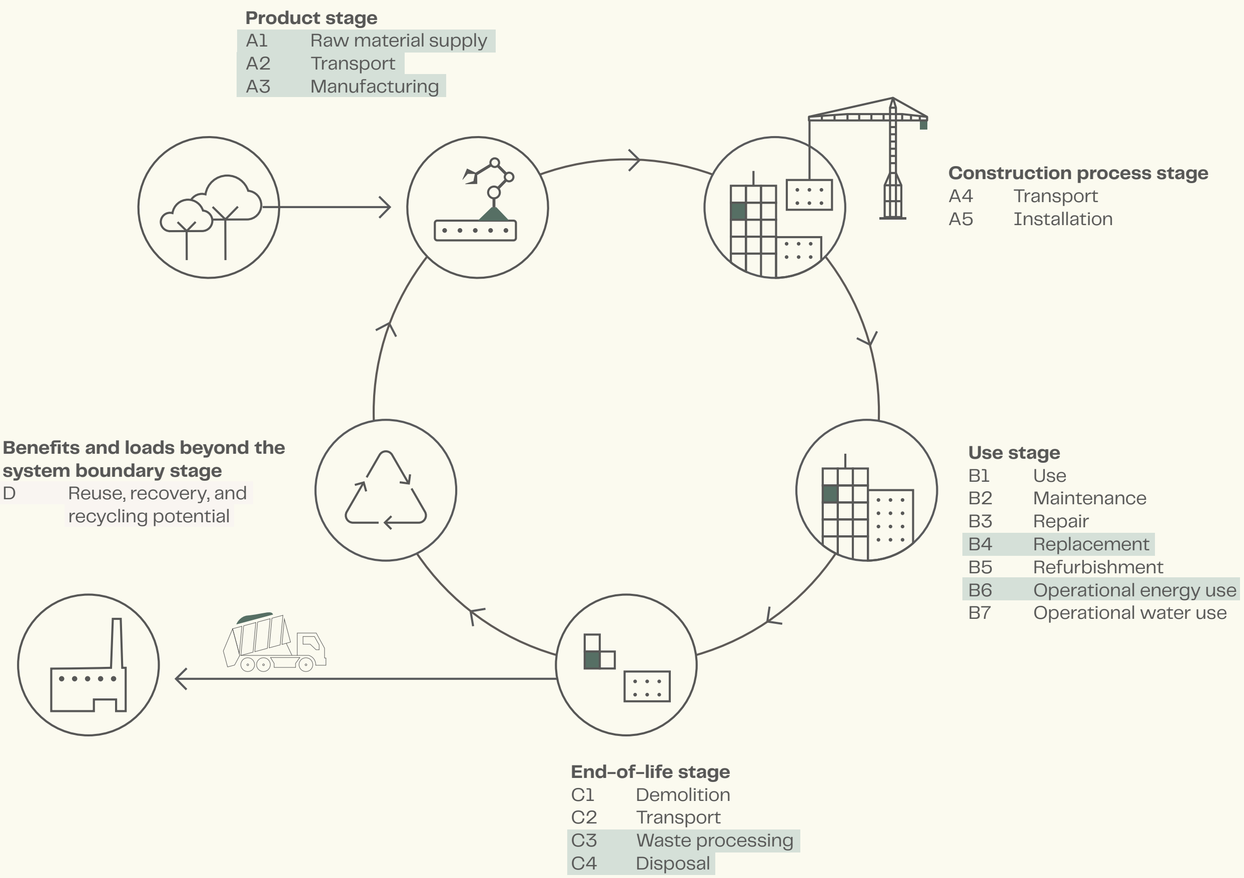


Figure 4: Building life cycle stages included in the LCA, according to EN 15978 "Sustainability of construction works – Assessment of environmental performance of buildings – Calculation methods"

An LCA comparison between the two systems has been establish on the basis of embodied carbon and operational energy (heating and electricity) from the usage and products of the systems. The LCA includes eight of the total seventeen stages of the LCA. The once included in the current study are marked in green in Figure 4.

Stage 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.

In LCAbyg, the in-use phase is set to start in 2020, with electricity and heating supply set to "Electricity – Projection for 2020-2040" and "District heating –

projection for 2020-2040" respectively. The use of these projections is compliant with the requirements in the 2023 Building Regulations in Denmark.

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. EPD data has been used for the natural ventilation components (actuators and controllers, which enable intelligent control of the actuators).

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.

Key results

Figure 5 shows the LCA results focusing on GWP with CO_2–eq as an indicator for the two assessed ventilation systems. The embodied carbon includes all components in the hybrid and mechanical 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–eq)

The embodied carbon of the intelligent controlled natural ventilation is 0.033 kg CO_2–eq/m²/year out of the 0.38 kg CO_2–eq/m²/year using the hybrid ventilation solution.

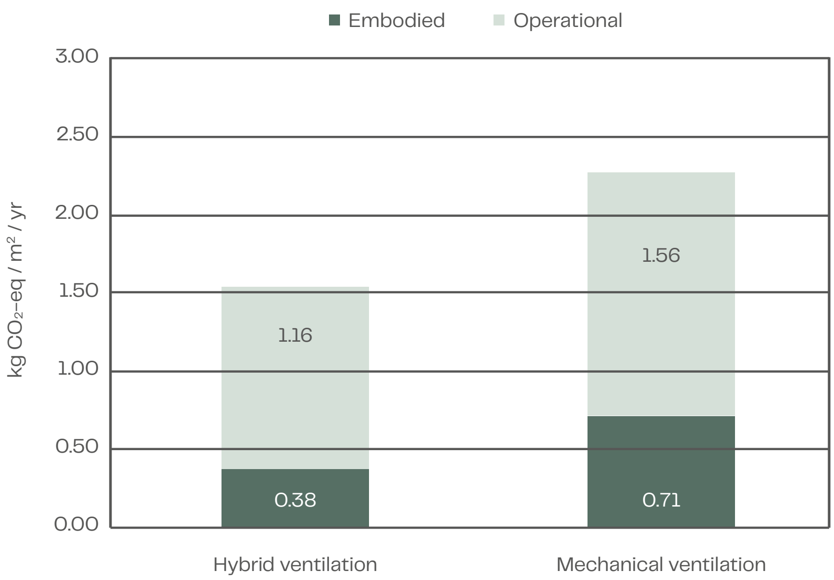


Figure 5: GWP results for the ventilation systems

Figure 6: Reduction in GWP under construction and maintenance when comparing hybrid ventilation and mechanical ventilation

In many cases, e.g. in the Danish Building regulation, the embodied carbon for ventilation systems includes only the air handling unit, ducts, silencers, and insulation for the mechanical ventilation system. Hence, no other components are considered, not even the natural ventilation components are to be included.

If including these components only, the embodied carbon would be 0.5 kg CO_2-eq/m^2/year and 0.26 kg CO_2-eq/m^2/year for the mechanical and hybrid ventilation system, respectively. Mechanical ventilation has a 40 % increase in CO_2 emission from embodied carbon compared to what should be included according to the Danish Building regulation. Figure 7 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 8 show the LCC for the hybrid and mechanical ventilation system.

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

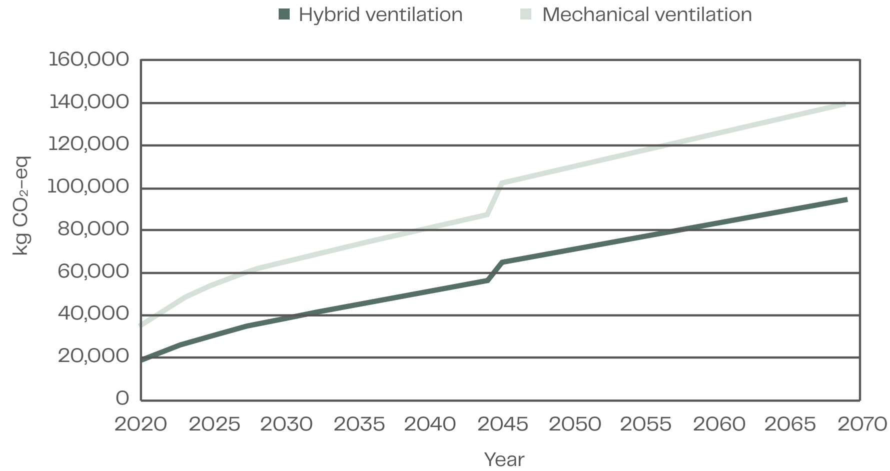


Figure 7: Total cumulative GWP, CO_2-eq

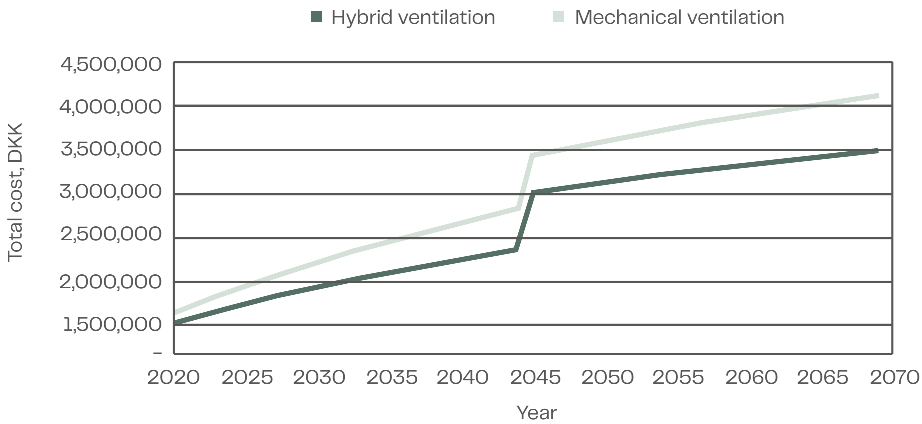


Figure 8: Cumulative cost over the 50-year assessment period, in DKK

Conclusion

An 1230 m^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 fully mechanical ventilation system. An LCA comparison between the two systems has been established based on embodied carbon and operational energy (heating and electricity) from the usage and products of the systems focussing on global warming potential (GWP) with CO_2 equivalent (CO_2–eq) as the metric.

The LCA calculations indicate that there is a significant potential for reducing the total GWP (CO_2–eq) 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 their 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.

WindowMaster aspires to protect people and the environment by creating a healthy and safe indoor climate, automatically ventilating spaces with fresh air through facade and roof windows in buildings. We offer the construction industry foresighted, flexible and intelligent window actuators and control systems for natural ventilation, mixed-mode ventilation, and smoke ventilation – of the highest quality.

WindowMaster employs highly experienced cleantech specialists in Denmark, Norway, Germany, United Kingdom, Ireland, Switzerland, and the United States of America. In addition, we work with a vast network of certified partners. With our extensive expertise built up since 1990, WindowMaster is ready to help the construction industry meet its green obligations and achieve their architectural and technical ambitions.

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