



Module 5 – Energy and Buildings: Indoor Climate; Heating, Cooling, and Ventilation System

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1 Introduction

This module introduces the fundamentals of heating and cooling in buildings, emphasizing their role in maintaining thermal comfort and reducing energy use. The focus is on designing an energy-efficient and moisture-safe building.

2 Background and Motivation

The heating and cooling of buildings account for a significant portion of global energy consumption and greenhouse gas emissions. Improving energy efficiency and indoor climate control is essential for meeting environmental targets and enhancing occupant well-being.

3 Theoretical Framework

3.1 Key Concepts and Definitions

Key terms include thermal comfort, HVAC (Heating, Ventilation, and Air Conditioning), energy- and moisture calculations, energy efficiency, passive and active heating/cooling systems, and indoor air quality (IAQ). Understanding these concepts is essential for designing systems that meet user needs while minimizing energy use.

3.2 Project

This project aims to design a building to meet low energy use demands and high moisture safety based on building physics-related performance criteria. The building is a one-family detached house with a wooden structure (timber-framed), a slab on ground, and an outdoor air-ventilated attic, also known as a cold attic.

The project contains the following parts:

- **U-value:** calculate the U-value for different parts of the building envelope and the mean U-value for the whole building. A U-value of $1 \text{ W}/(\text{m}^2 \cdot \text{K})$ can be used for windows and doors. Thermal bridges for the entire building can be assumed to be equal to 15 % of the total UA value.
- **Wall:** choose an external wall with a wooden structure from literature, the internet, etc. Calculate temperature and moisture content distribution in the external walls during steady-state conditions. The outdoor temperature is -10°C , and the relative humidity is 90 %. The indoor temperature is $+21^\circ\text{C}$, and the relative humidity is 65 %. Calculate the relative humidity at the interfaces between the different layers and compare the results to the critical moisture level for mold growth on building materials. If condensation occurs anywhere within the wall construction, calculate the least required vapor resistance, s_d , to avoid condensation.
- **Cold attic:** calculate the temperature and the relative humidity in the outdoor ventilated attic using heat and moisture balances. For the calculation of this



part, DWOT for the location in question must be used. Consideration must be taken to long-wavelength radiation in the sky. Sky temperature can be assumed to be equal to $-30\text{ }^{\circ}\text{C}$. Air exchange of outdoor air with the attic can be considered equal to 4 1/h. Leakage from inside the house to the attic, mainly due to the slot around the hatch on the ceiling, must be calculated and considered in the calculations.

- **Energy:** Calculate design heat power and annual energy consumption for space heating. Calculate the primary energy number, PEN, according to BBR. Does your building meet BBR requirements? Input data can be chosen from the site energiberakningar.se.
- **Analyze and discuss the results.**

4 Practical Applications

The module will empower students with cutting-edge knowledge and technologies regarding energy efficiency in buildings. State-of-the-art research on energy-efficient buildings will be raised and discussed. The keywords of this module are HVAC, energy balance calculations, energy-efficient buildings, and indoor climate. Learning objectives include:

- Develop in-depth knowledge of energy-smart solutions in the built environment.
- Design heating, cooling, and ventilation systems for various kinds of buildings.
- Calculate and account for energy in buildings and energy efficiency measures without negative impacts on the indoor climate. Perform energy balances and carry out energy and moisture calculations using different software.
- Account for the relationship between a building's indoor climate and the dweller's well-being.
- Critically analyze the energy efficiency from a holistic and sustainability perspective.

5 Summary and Take-home learning messages

Students will learn to assess and design heating and cooling systems that optimise indoor climate and minimise energy use. Applications include system sizing, selection of efficient equipment, and implementation of control strategies for various building types. The expected outcomes are:

- Demonstrate understanding of basic principles of HVAC
- Understand energy use in buildings from a sustainability and holistic point of view
- Showing the ability of performing advanced calculation for energy in buildings and assess the impact on sustainability
- Demonstrate ability of designing HVAC-system

6 Further Reading and Resources

List of additional resources for students who wish to explore the topic further:

- Linden V., Gaalen K-V., Zeegers A. (2024). *Building Physics*. TU Delft, Faculty of Architecture and the Built Environment, Architectural Engineering and Technology, Group Building Physics and Building Services.
- Pinteric, M. (2021). *Building Physics, From physical principles to international standards*, Springer.
- Abel E., Elmroth A. (2007). *Buildings and Energy - a systematic approach*, Formas.
- Hall F., Greeno R., *Building Services Handbook*, Routledge.
- Energy calculations: <https://www.energiberakning.se/default.aspx>

7 Assignments and Assessments Strategy

In this module, students will be given 1 assignment. Assignment involve analyzing the heating and cooling strategy of a hypothetical building. Students will evaluate energy performance, indoor climate quality, and propose improvements based on smart and efficient technologies. Group discussions will foster comparison between different building types and usage scenarios.

Assessment is based on a written report including:

- Description of the building and cross-section drawings on the external wall, slab on the ground, and attic, including material data.
- Calculations, the results of all calculations, analysis, discussion, and conclusions

Calculations must be done thoroughly, correctly, and as accurately as possible. All assumptions must be justified. All solution steps and input data must be clearly presented.