Syllabus

Course Description

Course Title	Building HVAC Systems
Course Code	45528
Course Title Additional	
Scientific-Disciplinary Sector	IIND-07/B
Language	English
Degree Course	Master in Energy Engineering
Other Degree Courses (Loaned)	
Lecturers	Ing. Alessandro Prada, Alessandro.Prada@unibz.it https://www.unibz.it/en/faculties/engineering/academic-staff/person/32626 dr. Vittoria Benedetti, Vittoria.Benedetti@unibz.it https://www.unibz.it/en/faculties/engineering/academic-staff/person/36228
Teaching Assistant	
Semester	Second semester
Course Year/s	1
CP	9
Teaching Hours	90
Lab Hours	0
Individual Study Hours	135
Planned Office Hours	27
Contents Summary	This course comprises hours of lectures and practical design applications. In the initial part, students will focus on determining heating loads and ensuring occupant comfort to accurately size HVAC systems for buildings. Following this, they will learn to prepare a building's energy balance by technical standards. The course will then cover various types of HVAC systems, including all-water, mixed air-water, and all-air systems. The fundamentals of

	HVAC design will be outlined in the concluding part of the course. Additionally, students will complete a design project, such as developing an HVAC system for a building.
Course Topics	The course will cover the following topics: Design Load Calculation: · Domestic hot water, heating and cooling load calculations · Natural and mechanical ventilation · User profiles and operation schedules · Indoor environmental quality HVAC Systems: · Design of heating, cooling, ventilation, and air conditioning systems · Hydronics, all-air, and mixed air/water systems · Design of domestic hot water systems · Distribution networks (piping and air ducts) · Terminal units and heat recovery equipment · Equipment for heating and cooling, including boilers, unitary air conditioners, water chillers, storage tanks, and circulation pumps · Renewable energy systems such as thermal solar panels, PV and heat pumps · Equipment operating curves and partial load operation · Safety devices and safety standards Energy Demand of HVAC systems: · Building's energy balance · HVAC systems efficiency · Basics of energy performance evaluation and certification Operation and maintenance: · Control systems and strategies · Capital and operational costs · Monitoring systems and data analysis · Systems optimization Energy Balance of a Building: • Preparation of a building's energy balance • Heat losses due to transmission and ventilation • Effects of solar radiation

	• Heat gains • HVAC systems efficiency • Basics of energy performance evaluation and certification Domestic Hot Water System: • Energy needs • System design and integration HVAC Systems: • Design of heating, cooling, ventilation, and air conditioning systems • Hydronics, all-air, and mixed air/water systems • Distribution networks (piping and air ducts) • Terminal units and heat recovery equipment • Equipment for heating and cooling, including boilers, unitary air conditioners, water chillers, storage tanks, and circulation pumps • Renewable energy equipment such as thermal solar panels and heat pumps • Equipment operating curves and partial load operation • Safety devices and an introduction to safety standards.
Keywords	HVAC, Energy Efficiency, Renewable Energy, Building Simulation, Design Load
Recommended Prerequisites	To successfully achieve the intended learning outcomes, students are expected to possess basic knowledge of: • thermodynamics; • heat and mass transfer; • building physics; • energy systems engineering. Attendance of the courses Applied Energetics and Advanced Applications of Building Physics is strongly recommended, as this course builds upon several concepts introduced therein. Familiarity with basic numerical calculation tools and engineering problem-solving methods is also beneficial.
Propaedeutic Courses	
Teaching Format	The course is delivered through: • Lectures, aimed at introducing theoretical principles and engineering methodologies related to building HVAC systems. • Guided design exercises, focused on heating and cooling load calculations, system sizing, energy performance assessment, and

	HVAC component selection. • Computer-based activities, involving spreadsheets, coding and building energy simulation tools (e.g., EnergyPlus, TRNSYS). • Hands-on control laboratory activities, based on Arduino control kit boards, allowing students to implement and test HVAC control logics, analyze sensor measurements, tune control parameters, and evaluate the impact of control strategies on comfort, energy consumption, and system operation. • Project-based learning, through the development of a team HVAC design project. • Discussion of engineering case studies, illustrating real-world applications of HVAC technologies. To achieve the intended learning outcomes, students are required to: • actively participate in lectures and design activities; • complete the assigned engineering calculations and exercises; • study the recommended technical standards and reference materials; • design and evaluate basic HVAC control strategies, interpreting the interaction between sensors, actuators and control algorithms; • collaborate within a project team; • prepare a technical report and oral presentation describing the proposed HVAC design solution.
Mandatory Attendance	Strongly recommended.
Specific Educational Objectives and Learning Outcomes	Knowledge and understanding: By the end of the course, students should be able to: 1. Master key concepts related to heating and cooling loads and the overall energy performance of buildings. 2. Understand the operation and functionality of various HVAC systems. 3. Acquire knowledge on the content of the main technical standards on the topics currently in force. Applying Knowledge and Understanding: • Apply the learned concepts to the practical design and implementation of HVAC systems.

	Making Judgments: • Assess the heating and cooling loads of buildings, evaluate HVAC system performance, and analyze the energy usage of buildings. Communication Skills: • Effectively convey engineering concepts using technical drawings and reports. Learning Skills: • Self-train and stay current with evolving technical standards and market innovations.
Specific Educational Objectives and Learning Outcomes (additional info.)	The course provides students with the knowledge and engineering tools required for the design, sizing, control, analysis, and performance assessment of HVAC systems in buildings. Emphasis is placed on thermal comfort, building energy demand, heating and cooling load calculations, HVAC system configurations, energy efficiency, renewable energy integration, control strategies, and compliance with current technical standards. The course also contributes to the development of practical design skills, quantitative analysis capabilities, economic evaluation methods, and engineering judgement required in the fields of building energy engineering and sustainable building design. By the end of the course, students will be able to: • Explain the principles governing thermal comfort, indoor environmental quality, and the energy performance of buildings. • Calculate building heating, cooling and domestic hot water design loads according to relevant technical standards and operating conditions. • Analyze the energy balance of a building, accounting for transmission losses, ventilation losses, solar gains, internal gains, and HVAC system efficiencies. • Evaluate the energy demand associated with space heating, cooling, ventilation, and domestic hot water production. • Compare and select appropriate HVAC system configurations, including hydronic, all-air, and air-water systems, according to building requirements.

	• Design and size the main components of HVAC systems, including generation, distribution, emission, ventilation, and heat recovery subsystems. • Assess the performance of HVAC equipment operating under full-load and part-load conditions. • Integrate renewable energy technologies, including heat pumps and solar thermal systems, into building energy systems. • Apply relevant EN ISO standards and engineering procedures to HVAC design and energy performance assessment. • Design, implement and evaluate basic HVAC control strategies, understanding the interaction between sensors, actuators, controlled variables, and control algorithms. • Analyze the dynamic response of HVAC systems through laboratory activities involving Arduino-based control platforms and building automation applications. • Perform techno-economic assessments of alternative HVAC solutions by considering investment costs, operating costs, energy savings and economic feasibility indicators. • Develop and communicate engineering solutions through technical calculations, design drawings, simulation outputs, and written reports. • Critically justify design choices by considering energy efficiency, occupant comfort, controllability, technical feasibility, economic performance, and sustainability criteria. • Work effectively in multidisciplinary teams to complete an HVAC design project and present engineering results in a professional manner.
Assessment	The final grade is expressed on a 30-point scale and is based on the following components: 1. HVAC Design Project (50%) The project consists of the design and sizing of an HVAC system for a building, including the assessment of: • domestic hot water, heating and cooling loads; • indoor thermal comfort; • energy performance; • HVAC equipment selection, design and control; • system efficiency. Students are required to work in small groups (3-5 people), submit a technical report within the exam date, and present the project

	results during the exam. The assessment considers: • technical correctness and level of detail; • application of standards and engineering methods; • quality of the design solution; • critical evaluation of alternatives; • clarity and professionalism of the report and presentation. 2. Individual Oral Examination (50%) Admission to the oral examination is subject to successful completion and presentation of the project work. The oral examination consists of two or three open-ended questions covering all course topics. The examination assesses: • understanding of HVAC system principles; • ability to analyze engineering problems; • capacity to justify design decisions; • use of appropriate technical terminology; • ability to connect theoretical concepts with engineering practice.
Evaluation Criteria	Formative Assessment Throughout the semester, feedback is provided during the development of the design project and classroom activities, enabling students to monitor their progress toward the intended learning outcomes. ILO assessed: 2,3,5 Summative Assessment The final assessment evaluates both theoretical knowledge and practical engineering competences through the combined evaluation of the project work (ILO assessed: 3,4,5,6,7,8) and oral examination (ILO assessed: 1,2,3,4).
Required Readings	• EN ISO 12831 and other relevant EN ISO standards (especially the EN ISO 52000 family) • Notes taken during the lessons • W. T. Grondzik. "Air-Conditioning System Design Manual" 2nd ed-, ASHRAE/Butterworth, 2007

	• J.W. Mitchell and J.E. Braun "Principles of Heating, Ventilation and Air Conditioning in Buildings" Wiley 2013
Supplementary Readings	• ASHRAE, HANDBOOK - Vol. 1-4 ed. ASHRAE 2017-2020 (or other recent editions). • G.F. Hundry, A.R. Trott, and T.C. Welch. "Refrigeration, Air Conditioning and Heat Pumps" 5th ed, Butterworth-Heinemann. 2016 • I. Beausoleil-Morrison "Fundamentals of Building Performance Simulation" Routledge. 2021 • L. Socal and B. Grassi. "Compendium of hydraulics for heating technicians". IVAR 2018 • R. McDowall. "Fundamentals of HVAC systems". ASHRAE/Elsevier 2007 • R. Montgomery and R. McDowall. "Fundamentals of HVAC Control Systems". ASHRAE/Elsevier 2007
Further Information	Connections with other courses The course Building HVAC Systems complements the knowledge acquired in Advanced Applications of Building Physics by shifting the focus from the building envelope to building energy systems and HVAC technologies. The course also builds upon topics such as solar radiation, which are explored in greater depth in Special Issues of Building Physics, and introduces the integration of renewable energy technologies in buildings, including photovoltaic (PV) and solar thermal systems, which are further developed in Solar Energy Systems. Fundamental concepts related to Applied Energetics are recalled and applied to the analysis of HVAC systems and building energy performance. Finally, the course establishes strong links with District Energy Systems Design, enabling students to understand the interaction between individual buildings and district energy networks, as well as the role of buildings within smart energy systems and future low-carbon energy infrastructures. Professional applications of the covered topics The knowledge and skills acquired in this course are applicable to a wide range of professional activities involving the design,

	operation, optimization, and control of HVAC systems in residential, commercial, and industrial buildings. The course provides a solid foundation for careers in building services engineering, including consulting and engineering firms specializing in HVAC and integrated building energy systems, as well as companies involved in the design and implementation of energy-efficient building technologies. The acquired competencies are also relevant to professionals working in building energy performance assessment, energy certification, building energy auditing, commissioning, building performance monitoring, and facility and energy management. In addition, the course prepares students for roles related to the integration of renewable energy systems into buildings and the development of sustainable and smart building solutions.
Sustainable Development Goals (SDGs)	Good health and well-being, Affordable and clean energy, Climate action, Responsible consumption and production, Sustainable cities and communities