COURSE DESCRIPTION
Energy optimization for built heritage use

SSD: FISICA TECNICA AMBIENTALE (ING-IND/11)

DEGREE PROGRAMME: ARCHITECTURE AND HERITAGE (P53)
ACADEMIC YEAR 2023/2024

COURSE DESCRIPTION

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GENERAL INFORMATION ABOUT THE COURSE

INTEGRATED COURSE: U3991 - DESIGN STUDIO FOR ARCHITECTURAL HERITAGE
MODULE: U3996 - Energy optimization for built heritage use
TEACHING LANGUAGE:
CHANNEL:
YEAR OF THE DEGREE PROGRAMME: I
PERIOD IN WHICH THE COURSE IS DELIVERED: SEMESTER I
CFU: 6

REQUIRED PRELIMINARY COURSES

The students come from a Degree Course where they have already taken an exam with elements of thermodynamics and heat transfer.

PREREQUISITES

The student must know and understand the energy relations and physical laws governing the heat transfer between the indoor environment, the building envelope, and the outdoor climate.

LEARNING GOALS

The course aims at providing advanced theoretical and applicative tools to evaluate and design the building-plant systems and their integration into the urban context. The attention will be focused on buildings of historic value and on energy efficiency solutions that can be adequately integrated into the historical architecture.
Students will know the theoretical and applicative tools to evaluate and design buildings and outdoor spaces in view of the essential needs of energy efficiency and environmental comfort,

even by taking into account the EU Directives with reference to the necessity to reduce climate-changing emissions and above all in harmony with objectives 7 (Ensure everyone has access to energy sources, in an economic, affordable, sustainable and modern way) and 11 (Make cities and human settlements inclusive, safe, resilient and sustainable), proposed by the ONU for sustainable development (SDG - Sustainable Development Goals). These objectives will be pursued in historic buildings and in the built environment.
The course introduces the main types of building technological systems with particular reference to the Heating, Ventilating and Air Conditioning (HVAC) systems. Particular attention will be paid to technological systems in historic buildings, so that the integration of generation, distribution, and emission systems does not compromise the building's historical and/or artistic value.
Students will participate in the development of design methods aimed at satisfying energy needs, pursued through the management and use of available sources and networks, with attention even to renewable energy sources.
Students will interact in an interdisciplinary and participatory advanced way in the various stages of drafting project proposals.

EXPECTED LEARNING OUTCOMES (DUBLIN DESCRIPTORS)

Knowledge and understanding

The student has to demonstrate knowledge and understanding of the issues related to the integration of building technological systems and architectural aspects, with particular attention to historic buildings, considering energy optimization and environmental comfort. The students must also identify possible design solutions that guarantee maximum sustainability and integration with the architecture of the building, by interacting actively and consciously with other specialists in the sector.

Applying knowledge and understanding

The students should know how to identify and propose technological solutions, at different scales, to satisfy the energy needs of the buildings and the quality conditions of the indoor environment, depending on the possible intended uses. These objectives will be pursued through the rational use of energy during the design phase of the building-plant systems, taking into account the current rules and the contextual peculiarities related to the available local energy resources, preferably renewable. With reference to historical architecture, the student must be able to propose solutions in harmony with the historicity of the building and the context, in order to preserve its historical and/or artistic value.

COURSE CONTENT/SYLLABUS

A. General information on the energy efficiency of the Building-Plants-Renewable Sources System (0.3 ECTS). General overview of the reference context. Presentation of the current legislation, the building envelope, and its thermophysical properties, systems for microclimatic control, and systems exploiting renewable energy sources.
B. Thermal comfort and air quality (0.3 ECTS). Definition of the thermal comfort of the occupants. Identification of descriptors and indices of the occupant well-being, and of local

discomfort factors. Measurement of environmental parameters. Adaptive environmental comfort.
C. Thermophysics of the building envelope and outline of the relevant legislation (0.4 ECTS). The building envelope, both transparent and opaque, and its thermophysical properties. Outline of the relevant legislation (Italian Legislative Decree 192/2005 and 311/2006 and Presidential Decree 59/2009, Law 90/2013, Ministerial Decree 26/06/2015).
D. Components and Technologies for the opaque building envelope (0.3 ECTS). Energy efficiency interventions, feasible for new buildings and/or for existing buildings, and in particular for the historical ones, aimed at improving the thermal behavior, in winter and/or summer, of the building envelope including products and systems for thermal insulation, thermal plasters insulators, special blocks (thermal blocks), nanotechnological paints and coatings.
E. Components and strategies for the transparent envelope (0.3 ECTS). Traditional technologies for the transparent envelope: windows, frames, bins and blinds, solar screens.
F. Opaque and transparent envelope in bioclimatic construction (0.4 ECTS). Bioclimatic technologies for the opaque envelope (vented facades, ventilated roofs, green roofs, walls by Trombe-Michel with TIM) and for the transparent envelope (solar greenhouses, ventilated walls, the greenhouse effect, the winter gardens). Integration into historical architecture.
G. The calculation of the heating and cooling loads of the buildings (0.5 ECTS). Definition and calculation of summer and winter thermal loads. The winter thermal load and the calculation of the thermal power dispersed through the envelope surfaces and thermal bridges, due to outdoor air infiltration. The summer heat load and the calculation of the entering thermal power, through the surfaces of the building envelope, due to lighting devices and electrical devices, heat by people and other endogenous gains, and gains due to the infiltration of outdoor air.
H. The calculation of Humid Air properties and the Psychrometric Diagram (0.5 ECTS). Thermodynamic properties of Humid Air: dry bulb, wet bulb, adiabatic and dew saturation temperatures. Specific enthalpy. Specific volume. Specific humidity. Relative humidity. Hygrometric degree. Psychrometric chart. The transformations of humid air: simple heating and cooling, adiabatic mixing, cooling with dehumidification, liquid water, and steam humidification.
I. Natural ventilation and mechanical ventilation (0.5 ECTS). Air quality in confined spaces and reference standards. Natural ventilation and controlled mechanical ventilation (centralized and decentralized systems, heat recovery).
J. Air conditioning systems (0.5 ECTS). Air conditioning systems for civil use, in historical and monumental buildings. The components of an air conditioning system. All-air systems. Mixed air-water systems. Hydronic systems. The direct expansion systems. Heating and cooling with radiant panels. The issue of integrating systems in historic buildings.
K. The air handling units (0.5 ECTS). The Air Handling Unit and components (fans, filter sections, mixing chamber, control dampers, air preheating coil, air cooling and dehumidification coil, humidifiers and droplet separator, post-heating coil). The terminals of air systems.
L. Heat and cool generation (0.5 ECTS). Direct energy generators (gas stoves, electric stoves, fireplaces, split-systems) and generators with intermediate fluid (water, air, refrigerants). The fuel generators and boilers, the reversible heat pumps, the thermo-refrigeration unit, the chimneys, and flue pipes. Advantages and disadvantages of various thermal power generation systems.

M. Renewable sources in the construction sector (1 ECTS). The reference regulatory framework on renewable sources in the construction sector: the legislative overview, obligations, and incentives. Heat Pumps/Chillers and the partial "renewability" of energy. The production of thermal and cooling energy from solar sources. The production of domestic hot water from a solar source. Solar heating and solar cooling. The production of electricity from solar sources. The production of electricity from the wind. The production of thermal energy by low enthalpy geothermic. Reversible heat pump and ground coupling: borehole. The dimensioning of a field of horizontal and vertical boreholes. Potential and limits of the integration of renewable energy systems in historic buildings.

READINGS/BIBLIOGRAPHY

Professors will provide students with the necessary teaching material in the form of notes, handouts, tables, and diagrams.
Further reference texts:
- Book for further information on humid air, air and mixed air conditioning systems, and heat exchange through the building envelope: L. Bellia, P. Mazzei, F. Minichiello, D. Palma: ARIA UMIDA - Climatizzazione ed involucro edilizio. Liguori Editore.
- Gli impianti nell'architettura. Giuliano Dall'Ò, Edizioni UTET, Collana Architettura, 2000.

TEACHING METHODS OF THE COURSE (OR MODULE)

The organization of the course establishes both frontal lessons and laboratory activities.

EXAMINATION/EVALUATION CRITERIA

a) Exam type

- [ ] Written
- [x] Oral
- [x] Project discussion
- [ ] Other

In case of a written exam, questions refer to

- [ ] Multiple choice answers
- [ ] Open answers
- [ ] Numerical exercises

b) Evaluation pattern

The exam consists in an oral interview, during which the student is asked to illustrate the developed project, concerning the refurbishment and energy optimization of the investigated building, by verifying the skills and knowledge expected, through questions about the topics of the course program.
The final grade, on the basis of results and skills demonstrated in the discussion of the project, as well as the themes and elaborations of the various modules, will be weighted on the credits of each course and therefore composed as follows: Architectural design for heritage 25%;

Architectural conservation and construction aspects of historical buildings 17%; Statics and stability of historical buildings 17%; Technological design for architecture 17%; Energy optimization for built heritage use 25%.