# MCAST MASTER OF SCIENCE IN HIGH PERFORMANCE BUILDINGS

CODE: UC7-E13-18
Launching November/December 2020

Online Application and Cost Details Available at:
https://shortcourses.mcast.edu.mt/courses/MASTERS

**Entry Requisite:** First degree in engineering; ICT; architecture.

**Delivery Mode - Blended Learning over 5 Semesters (2 ½ Years):** 7 Modules taught in a total of around 30 weekend campus sessions (a weekend session consists of a Friday evening lecture from 17:30 to 20:30 and a Saturday morning lecture from 9:00 to 13:00) and 3 modules carried out online through eLearning using the MCAST Moodle Platform.

The Master of Science in High Performance Buildings (HPB) gives candidates the opportunity to develop optimized building concepts, integrating various components of holistic design methodology, building physics, building climatology and comfort, energy-efficiency, environmental sources, building services systems, building aerodynamics, thermal and fluid dynamic CFD simulations, lighting design, building operation, as well as green urban modelling. The programme provides for advanced skills in specialization and scientific research of building physics coupled with architectural design, preparing students for professional, as well as research and development settings at national and international levels.

**Learning Outcomes:**
Upon successful completion of this Masters Programme the participants will be able to:

1. Design holistically in order to unify passive and active building technology solutions and to integrate building into a larger context;
2. Responding to, and take advantage of, current environmental circumstances, potentials and synergies;
3. Integrate special aspects of hpb-related physics and design methods into the regular planning procedure;
4. Act as an interface between design participants in fields related to design and construction;
5. Use the appropriate methodology to strengthen the dialogue between the various professional disciplines, coordinating them in accordance with desired hpb project goals;

### First Year (Semesters 1 & 2: 30 ECTS) – Exit Option: Post Graduate Certificate

1. High Performance Building (HPB) Design Approach
2. Building Climatology
3. Building Energy
4. Building Aerodynamics
5. Energy and Climate Dynamic Building Simulations

### Second Year (Semesters 3 & 4: 30 ECTS) – Exit Option: Post Graduate Diploma

6. Aerodynamic Building Simulations
7. High-Performance High-Rise Buildings
8. High Performance Settlements (HPS)
9. Project 1 – Building Design Project (HPB)
10. Project 2 – Settlement Design Project (HPS)

### Third Year (Semester 5: 30 ECTS) – Final Exit: Masters

Dissertation

## STUDY UNIT 1

## High Performance Building (HPB) Design Approach

MQF Level 7

6 ECTS

E-learning: Yes

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## Rationale

Without fundamental knowledge about basic holistic building design approach, elementary planning methodology and architectural theory, it is impossible to 'go on the right path' in order to develop HPBs. The critical issue is to clarify the most important terminology in the context of sustainable construction, as well as to examine vernacular building technologies in different climatic and geographical regions. Vernacular technologies are intended for new building design, as well as being applicable in refurbishment planning of the existing building substance. These are inevitable premises to continue with widespread professional studies of HPB.

The main aim is to deliver specialised theoretical basics in complex contemporary and historical sustainable architecture. Synergies in design strategies are taught, along with the most important special design aspects and techniques. Components of elementary HPB design methodology will be deepened in further thematic study units.

The content of this study unit focuses on contemporary architectural design extending new, innovative factors, which essentially modify current planning into a multi-dimensional design process. Natural science and engineering contents complement architecture (geometry, function, structure and aesthetics) with topics of external and internal climate, energy, envelope theory, materials, aerodynamics, low-tech and high-tech technologies, bionics, furthermore efficiency increasing synergy effects and quantification methods.

Basic theoretical knowledge and methodology of a sustainable, comfortable, healthy and energy conserving – respectively carbon harmonising – building industry.

## Learning Outcomes

**Upon successful completion of this unit, learners will be able to:**

1. Analyze methodologically building design philosophy;
2. Create a comprehensive building design approach, and analyze it in different project settings;
3. Compare alternating sustainable building certification systems and assess them in terms of, complexity, resolution, sincerity and importance;

4. Derive building typology as well as active and passive construction project strategies from efficient architecture history's influences;
5. Identify building physics 'driven' design aspects in the context of sustainability in terms of space organisation
6. Compare different design supporting tools;
7. Analyse and develop basic, theoretical hpb concepts in the early design stage;
8. Identify critical performance components in existing hpb building projects;

## STUDY UNIT 2

## Building Climatology

MQF Level 7

6 ECTS

E-learning: No

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## Rationale

The detailed understanding and analysis of complex building physics is inevitable and a fundamental prerequisite for designing buildings at high comfort and energy efficiency level.

External climate (weather) circumstances, as well as indoor climate (comfort) conditions are the most important determining impacts on buildings' design in terms of space creation, structures, materials, services (heat transfer and ventilation) systems and operation management.

## Learning Outcomes

**Upon successful completion of this unit, learners will be able to:**

1. Generate and apply knowledge about the interaction between the external and internal climatic effect-mechanisms to determine building design;
2. Evaluate the effects and consequences of different climatic conditions and their impact on building design;
3. Utilize meteonorm to design construction systems in different climatic regions.
4. Evaluate internal climate criteria to create healthy and comfortable indoor environments;
5. Distinguish general from local thermal comfort variables and apply appropriate calculation methods and measurements;
6. Evaluate indoor air quality values of different buildings in different operation strategies;

# STUDY UNIT 3

## Building Energy

MQF Level 7

6 ECTS

E-learning: No

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## Rationale

Malta's building energy regulations and legislation contents must be integrated in the curriculum with their most crucial, fundamental specific calculation methods. I need this material from Maltese building energy auditors or expert, since every member of the EU has to create its own definition of NZEBs (nearly zero energy buildings). In addition, in different countries, alternating national energy calculations are legislated and used for building energy qualification. Important to mention that the MCAST teaching staff should teach this part of the curriculum content, after participating in the training the trainers programme.

Approximately 50% of the world's primary energy need is caused by building industries' activities, including construction, operation and demolition/recycling. According to prognosis, by 2050 the global primary energy consumption will be doubled, concurrently long-term supply of energy cannot be covered by – in near future depleting - fossil sources. With the "20-20-20 initiative", the EU plans to reduce the level of energy consumption and $CO_2$-emission in 1999 by 20% and increase the renewable energy use and efficiency by 20% until 2020. The EU also proposes to reduce the carbon emission level of 1990 by 80-95% till 2050. The legislative regulation background continuously tightens provisions, e.g. the EPBD 2010/31/EU directive prescribes that in all EU member states by 2019 all new public buildings, and by 2021 all new buildings must be nearly zero energy buildings (NZEB).

## Learning Outcomes

**Upon successful completion of this unit, learners will be able to:**

1. Understand buildings as holistic energy systems with a critical view in the analysis of building concepts and systems;

2. Evaluate interdependencies between architecture, climate, energy and hvac systems in hpb design through understanding real, reliable and efficient interaction between ‘house and machine’;
3. Implement ideas and concepts of energy-efficient passive and active design solutions in building energy concepts;
4. Develop a building technology system concept;
5. Solve building energy related calculations in the field of heat load of air flow, heat loss by transmission, solar heat gain, inner heat load, heat storage, heating and cooling, ventilation and natural lighting;
6. Optimize building energy concepts through quantified feedback in decision-making process;

## STUDY UNIT 4

## Building Aerodynamics

MQF Level 7

6 ECTS

E-learning: No

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## Rationale

Among thermal energy fluxes air flow phenomena are a deciding 'member' of heat distribution, heating and cooling effects due to thermal convection and wind induced fluid flow mechanisms. In addition, the air flow characteristics of buildings radically affect the indoor air quality, and as a result the level of hygienic 'healthiness' of buildings. Also in outdoor public spaces in cites and settlements comfort (wind climate), pollution and waste gas dispersion and space quality strongly depends on air flow systems in and around (between) buildings, - in one word: the aerodynamics of buildings. Without understanding and implementing knowledge about aerophysics in building design, it is not possible to create high energy and climate performance built environment.

## Learning Outcomes

**Upon successful completion of this unit, learners will be able to:**

1. Use building aero-physical context and coherence systems in the development of theoretical high performance building ventilation concepts;
2. Optimise passive building ventilation system with special regard to high thermal and air quality comfort, utilizing low energy demand;
3. Solve critically steady-state, simplified comfort and energy calculations according to natural and mechanical ventilation in buildings;
4. Optimise energy and climate performance of hpb's ventilation systems through simplified ventilation calculations;

# STUDY UNIT 5

## Energy and Climate Dynamic Building Simulations

MQF Level 7

6 ECTS

E-learning: Yes

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## Rationale

Energy, ecology and environment questions become increasing attention both in our general society, as well as in professional building industries. Closely related to this, comfort and energy performance questions are gaining more and more in importance, dealing with building climate behavioural and building physics characteristic. Until the mid-1960s only 'hand' calculations methods could determine time averaged (typically monthly resolution) values for estimating energy use in buildings. Since computational resources were limited and expensive, in heating demand calculations e.g. the degree- day method was commonly used, neglecting and simplifying important elements, such as solar and internal gains, infiltration rates, non-steady operation of HVAC systems and transient thermal storage in structure's mass, user behaviour, respectively. Different building geometries, MEP components and their components however require very complicated and time intensive algorithm handling.

Moreover, it is paradox that today's practice uses hand-calculated methods to quantify the actual, highly complex dynamic processes in our buildings. As a logical result, monthly resolution hand calculations usually don't agree with measured values. Their monthly resolution should be shortened so long, until dynamic simulations resolution is reached. To sum it up, hand calculations are getting more and more complicated and time consuming solutions in contrast to dynamic simulations, which ensure hitherto unreached accuracy, high resolution and calculation velocity. While conventional hand calculations deliver approx. 50% of accuracy, triggering over dimensioning of HVAC systems and energy related structures (design uncertainty), dynamic calculations ensure approx. 95% accuracy, with exact dimensioned, cost-efficient technical system and structure dimensioning (certainty, design reliability).

Last but not at least, dynamic simulations make it possible receive a complete video film about the behaviour characteristic of a building I time dependency that gives the opportunity to design operation management and predict interdependency effects, which are – after a certain size and complexity of project - simply not possible to model with hand calculations anymore. Building dynamic simulations means planning in four dimensions (4D), catapulting high performance building development into the next level. Due to this simulation supported design technique, project dependently 50-80% savings in investment and operation expenses can be achieved in comparison to conventional design. Also, simulations represent today's most developed and sophisticated methods to conduct research in building industries. Implemented, case study reference building's experiences and insights about thermal building dynamic simulations supported design process.

## Learning Outcomes

**Upon successful completion of this unit, learners will be able to:**

1. Implement theories of thermal building physics in simulation supported building design;
2. Use thermal dynamic building simulation tool(s) to determine preliminary boundary conditions, 3d modelling of spaces and structures, create hvac systems and internal gains;
3. Evaluate and resolve problems in modelling and solver procedure;
4. Calculate heating and cooling loads, energy and custom, time dependent dynamics applying thermal simulation software;
5. Evaluate and assess simulation results in terms of building physics background theory, thermal and visual comfort, energy demand and consumption;
6. Optimize building envelope structures and basic conceptual hvac systems in terms of thermal efficiency;
7. Optimise hpb concepts and systems by working with simulations as design supportive feedback for machine and building development;

# STUDY UNIT 6

## Aerodynamic Building Simulations

MQF Level 7

6 ECTS

E-learning: No

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## Rationale

Detailed, high-resolution calculations in the field of building aerodynamics are only possible applying fluid dynamics model experiments and numerical simulations, ensuring high-level of precision. In contrast, simplified aerodynamic calculations for natural ventilation, night cooling potential or wind effects on buildings cannot deliver design accuracy and planning certainty, as well as reliability at the level and quality of computational fluid dynamic (CFD) simulations.

Since air flow currents are not visible, humans cannot develop a correct intuition for understanding flow processes. Due to visualisation of CFD simulations (and/or wind tunnel tests) currents 'become' visible, making easy analysis and thus visual development of correct intuition without understanding of very complex mathematical models. After basic understanding of simulation methods and proper viewing of results during this study unit, - as a next step - absolvents have the opportunity to further develop their CFD skills in post study programmes (e.g. Ph.D.).

## Learning Outcomes

**Upon successful completion of this unit, learners will be able to:**

1. Apply basic CFD simulations in simplified building projects with special regard to air flow systems, natural ventilation solutions and passive cooling effect;
2. Develop building aerodynamic knowledge and CFD simulation skills;
3. Interpret CFD simulations and adapt within design of real building contexts;
4. Contextualize CFD simulations in different building operation mechanisms;

# STUDY UNIT 7

## High-Performance High-Rise Buildings (HPHRB)

MQF Level 7

6 ECTS

E-learning: No

## Rationale

The number of high-rise buildings (HRB) has increased for more efficient use of urban floor space areas without considering environmental and energy consequences. In addition, HRBs possess significantly more floors and floor space compared to regular building sizes. As a result, in consequence, the material and energy consumption of a $m^2$ specific net floor space high-rise building is significantly higher in inefficiency than in regular building substance. On the other hand, nowadays population growth becoming exponential numbers: the PNUD (Program of the United Nations for the Development) estimates that 5 billion people will live in cities until 2030, whereas in 1950 30% of our population lived in urban areas, and in 2000 the proportion of settlement dwellers climbed to 47% and till 2030, it is projected to rise over 60%. Regarding the increase of land costs as well, it is inevitable for cities to go for vertical development. HRBs enable to save cultivable land, to reduce traffic infrastructure need and according pollution emissions, as well to reduce energy consumption and carbon emissions due to less horizontal energy infrastructure losses. A next logical step seems to be the further elaboration of HRB design into, green systems with high sustainable performance: the 'birth' of high-performance high-rise buildings (HPHRB).

## Learning Outcomes

**Upon successful completion of this unit, learners will be able to:**

1. Analyse critical theoretical issues about high-performance high-rise buildings and implement them in design;
2. Evaluate hphrb solutions under different climate conditions with regards to building envelope and space organisation;
3. Analyse climate and energy concepts for hphrbs for different seasonal operation periods;
4. Develop detailed concepts for research and development in the area of tall buildings;

## STUDY UNIT 8

## High Performance Settlements (HPS)

MQF Level 7

6 ECTS

E-learning: Yes

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## Rationale

Based on extreme growing population tendencies in settlements and urban neighbourhoods, handling of urban planning aspects is critical in respect to energy and environment optimised retrofitting of historical city cores, refurbishing and extending existing settlement residential, public, office and industry building district substances. Also development of new sustainable settlements is of prime importance, since the implementation of one green, high comfort and energy performance building contributes only ‘one water droplet’ amount of improvement in our society’s’ sustainability evolution, while creation of complete districts and cities represents the ‘ocean’ amount of advancement in our World’s green development. Another reason occurs for devoting special attention to high performance settlement (HPS) design, namely the holistic character of high performance building design approach that requires extending the focus from single building on the larger context, on the connection of several buildings across districts to the level of urban context.

## Learning Outcomes

**Upon successful completion of this unit, learners will be able to:**

1. Identify sustainable development strategies in urban planning;
2. Estimate energy demand using statistical methods;
3. Develop settlement scaled energy supply and management concepts, based on energy situation and infrastructure analysis;
4. Compare and contrast different energy demand scenarios in urban planning and/ or urban renewal;

5. Develop comfortable high quality outdoor urban public spaces;
6. Analyze and recommend development procedures as urban planner, as evaluator or as a consulting design expert;

# STUDY UNIT 9

## Project 1 – Building Design Project (HPB)

MQF Level 7

6 ECTS

E-learning: No

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## Rationale

To master the acquired methodical and instrumental competencies, the students finish their master course with two practical study units. The current study unit instructs students to summarise the acquired theoretical knowledge and practical competencies from previous study unit topics, and apply them in a building project design task.

Participants are already able to demonstrate HPB philosophy, planning methods and contents, as well as impact factors of complex building physics. Dependencies and synergies between site, neighbourhood, orientation, building function, geometry, structures and aesthetics, as well as building climate, comfort, energy, environmental questions and building services systems will be merged into a meaningful relationship. In addition, participants can apply design-supporting techniques, such as climate, comfort, energy and aerodynamics simulations.

The planning development will be carried out by teams, in order to practice interdisciplinary-like working environment, as well as to enable part time study participants to absolve a high performance building (HPB) project design in more deepened and detailed resolution, thus enhancing and mastering their building design skills.

## Learning Outcomes

**Upon successful completion of this unit, learners will be able to:**

1. Design and analyze innovative strategies for hpbs adopting sustainable strategies;
2. Implement holistic design philosophy and the theoretical methods and issues of complex building physics into HPB design;
3. Create scientific planning work, applying dynamic simulations tools and models in the field of thermodynamics, lighting and fluid mechanics;
4. Collaborate at multidisciplinary level building design concepts and strategies;
5. Propose and defend building design and operational strategies;

## STUDY UNIT 10

## Project 2 – Settlement Design Project (HPS)

MQF Level 7

6 ECTS

E-learning: No

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## Rationale

To master the acquired methodical and instrumental competencies, the students finish their master course with two practical study units. Based on the nature of holistic, iterative planning approach, particular – second – exercise study unit widens the design scope and addresses the development task of a high performance settlement (HPS). This task gives students the opportunity to use the previously acquired theoretical knowledge and practical competencies in a project design task, with the main focus on study unit 8 -"High performance settlements (HPS)".

Participants are already able to demonstrate HPB philosophy, planning methods and contents, as well as impact factors of complex building physics. Furthermore, participants can apply design-supporting techniques, such as climate, comfort, energy and aerodynamics simulations. Comprehension of gained knowledge handles the interdependencies and synergies between urban neighbourhood, building typology and aesthetics, as well as city climate, comfort, energy, environmental questions and settlement infrastructure and services systems will be considered into a meaningful relationship. The exercise will be developed in group work in order to practice interdisciplinary-like work, as well as to enable part time study participants to absolve a larger scaled HPS project design, thus enhancing and mastering their urban design skills.

## Learning Outcomes

**Upon successful completion of this unit, learners will be able to:**

1. Design and analyze innovative urban planning strategies for urban developments adopting sustainable strategies;
2. Implement holistic design philosophy and the theoretical methods and issues of complex building physics into high performance settlement design;
3. Create scientific planning work, applying dynamic simulations tools and models in the field of thermodynamics, lighting and fluid mechanics;
4. Collaborate at multidisciplinary level urban settlement design concepts and strategies;
5. Propose and defend urban planning design and operational strategies;