A Trans-National Smart Manufacturing Education Hub

Intellectual Output 4

Sustainability Strategies of the Involved Institutions and Corporate Partners

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Sustainability Strategies at Smart-Edu4.0

1 Introduction

This document demonstrates the sustainability strategies that were followed within the Smart-Edu4.0 project in order to train the workforce of the future and have a mindset orientated towards environmental and social sustainability. Sustainability forms a key feature of the project and is applicable across all the programs. Several UN Sustainable Development Goals (SDGs) are closely connected to Smart Manufacturing and Industry4.0 such as Climate Action (SDG 13), Quality Education (SDG 4), Decent Work and Economic Growth (SDG 8), Industry Innovation and Infrastructure (SDG 9). The target is to embed these goals and others into the curricula of all the programs in order to create a positive mindset at the most fundamental level. The partners fully agree on the provision of high-quality education for all supporting economic growth in each country and hence aim to provide good health and well-being for everyone in the long term.

The remainder of the document is structured as follows: Section 2 presents the environmental and social responsibility policy of the partners; section 3 illustrates the sustainability modules that are being taught in the involved institutions, section 4 demonstrates the projects and actions of the partners related to the SDGs, section 5 presents the plan of the consortium for the sustainability of the project results, section 6 presents the course on Sustainability that was developed during the project, section 7 introduces the SDGDetector tool for the evaluation of a curriculum and whether it is compatible with the SDGs and finally section 8 concludes the report and highlights its most important parts.

2 Description of environmental and social responsibility policy of your organization

2.1 Queen's University Belfast (QUB)

Queen's University Belfast (QUB) is delivering a wide range of programs across the Queen's community to embed sustainability and address the Climate Crisis. QUB is committed to embedding the Sustainable Development Goals (SDGs) within their next Corporate Plan and their response to the Climate Crisis will involve the roll out of their **Net Zero** strategy.

In providing high quality educational, research and workplace facilities, the University is committed to ensuring its environmental impact is minimised. The University also accepts its responsibility to make sure it grows and develops in a sustainable way with continuous improvement in environmental performance embedded into its business model and the culture of the University.

In support of these principles, the University is committed to:

- complying with all relevant environmental legislation, regulations and other requirements,
- monitoring, controlling and improving its environmental performance,
- mitigating the University's negative impact on climate change through the implementation of the Carbon Management Plan, to reduce carbon emissions,
- reducing waste created and increasing recycling through the development of effective resource and waste management strategies,
- avoiding or limiting, wherever practical, the use of environmentally-damaging substances, materials and processes,
- incorporating sustainable construction principles and practices into the development and

refurbishment of the estate,
- promoting sustainable modes of transport including walking, use of public transport, car-sharing and cycling through the implementation of the Travel Plan,
- managing the University's grounds to protect and enhance biodiversity,
- integrating environmental sustainability considerations into university policies and procedures,
- embedding sustainability within the University's teaching and research portfolios,
- working with local, regional and national partners to realise sustainability projects,
- promoting environmental awareness and responsibility amongst all staff and students.

Further details and a full list of policies can be viewed here.

2.1.1 QUB Sustainability Initiatives

2.1.1.1 Sustainability Champion Network

QUB's Sustainability Champion Network is a mobilised network of staff and students actively encouraging others to take on positive environmental actions on a day-to-day basis and creating and delivering sustainability projects in their own areas. Students also have the opportunity to achieve an additional employability accreditation to their degree, through environmental volunteering activities across the campus.

QUB is committed to becoming a leader in sustainability. To achieve this aim QUB is striving to fulfil the SDGs not just across teaching and research but also across their operations. See this webpage for a full list of SDGs covered across QUB Operations.

https://www.qub.ac.uk/directorates/EstatesDirectorate/Services/SustainabilityatQueens/SustainableDevelopmentGoals/

2.1.1.2 QUB Student Led Initiatives

Other student led initiatives include establishing a community garden at Elms Village student accommodation and a marine explorer outreach programme to increase awareness of the value, opportunities and social benefits of our ocean wealth and identity. Schools even have their own *Sustainability Teams*, see for example, Sustainability Team in the School of Electronics, Electrical Engineering and Computer Science (EEECS) (https://www.facebook.com/eeecsSST/) where the Smart-Edu4.0 project coordinator is based.

2.1.1.3 UN SDGs and QUB Research

Staff at QUB conduct research at the forefront of new technologies which directly or indirectly affect climate change. Recently, an initiative has seen staff expertise directly linked to UN SDGs on their profile pages under 'Expertise related to UN Sustainable Development Goals' heading. This enables identification of core themes of research areas staff at QUB are involved in.

See a few examples below:

https://pure.qub.ac.uk/en/persons/se%C3%A1n-mcloone

https://pure.qub.ac.uk/en/persons/wasif-naeem

https://pure.qub.ac.uk/en/persons/nikolaos-athanasopoulos

2.1.1.4 Sustainable Energy Lab

The School of EEECS has recently invested over £2M in the new "Sustainable Energy Lab" which will be used to deliver teaching in the areas of electrical power systems, sustainable energy technology, and intelligent infrastructure. Integral to their electrical energy theme, the new laboratory facility will

be used to teach electricity as the delivery mechanism for energy in a post-fossil fuel world. Additionally, novel programmes being developed in conjunction with computer science pathways will prepare students for the data networking, data wrangling and data analytics skills recently highlighted as in demand by the IET Power Academy employers.

2.2 South Eastern Regional College (SERC)

SERC recognises that its activities have an effect on the environment and seeks to understand the impacts of these at a local, national and global level. The College seeks solutions to environmental problems by adopting sound principles and best practice, both within its immediate environment and in the wider community. The College's overarching aim in this respect is to ensure the protection of the environment through the prevention of pollution.

SERC is committed to the principles and practices of environmental responsibility through ensuring stakeholder awareness of environmental issues. Hence SERC intends not only to be a leader in environmental education but also to lead in addressing environmental issues, in ensuring staff and students are fully aware of these issues and contribute to their resolution. It is committed to instilling environmental and social responsibility as an intrinsic feature of all its practices and procedures.

SERC will endeavour to provide best value for money benefits and also help meet environmental objectives whilst ensuring the ongoing delivery of a quality service in class leading facilities. The College is committed to being guided by the following principles:

1. The practice of responsible energy management through reduced consumption and the encouragement of energy efficiency throughout each campus.
2. The protection, conservation and enhancement of the natural and cultural heritage of college facilities.
3. The creation of a high-quality working environment through the discouragement of litter, graffiti and noise pollution: this will be achieved through the acceptance by students, staff and visitors of a Code of Conduct whilst on site.
4. The encouragement of the use of public transport, lift sharing and the provision of facilities for the disabled, pedestrians and cyclists.
5. The choice of products and suppliers which minimise negative environmental impacts, subject to necessary budget constraints.
6. The minimisation of waste by reduced consumption and the development of effective waste management and recycling procedures.
7. The avoidance of unnecessary use of hazardous materials and processes and the taking of all reasonable steps to prevent damage to either public or ecological health where such materials are in essential use. This will be achieved by the assessment of hazardous substances and the requirements for disposal.
8. The continued monitoring of this policy.

2.3 University of Limerick (UL)

The University of Limerick (UL) is committed to the development and implementation of a holistic approach to sustainable development, in partnership with the communities that serves, locally and regionally and in their national and international alliances. With the aim of enabling students, graduates and staff as 'active citizens' who contribute to the well-being and future of our planet. UL is committed to enabling students to become engaged and socially responsible citizens – individuals who can create positive impact both within the region and internationally. The university is in the process of building on this commitment by wholly aligning with the UN Sustainable Development Goals (SDGs).

This commitment brings with it two central responsibilities:

1. To provide the space and mentorship for students to develop into citizens who act as stewards of sustainability, both in their personal and professional lives
2. Academic staff to fulfil its role as custodians of social and environmental responsibility by leading through example within the ground and communities of the university.

To deliver on these responsibilities, UL has established a Sustainable Development Goals (SDGs) Working Group in 2020. The working group is currently engaging in a series of online participatory design 'workathons'. These sessions are designed to collectively identify and craft a 'sustainable university strategy' across four key areas:

1. Learning, Research and Students,
2. Leadership, Governance and Staff,
3. Campus Community and Operations and
4. Partnership, Society and Engagement.

The SDGs Working Group is committed to the principles of the UN SDGs:

- Pioneering educational experiences for students to acquire the knowledge, skills and attitudes needed to promote sustainable development.
- Undertaking research that provides insights and potential solutions to the SDGs.
- Contributing to the achievement of the SDGs by ensuring that the campus is environmentally sustainable and socially inclusive.
- Shaping interactions with external stakeholders to support the implementation of the SDGs across university region and beyond.
- Reporting on the activities accomplished in support of the SDGs.

The Journey from a Sustainable to a Regenerative University

Phase One: Transition to a Sustainable University

UL's initial short-to medium-term ambition is to become a sustainable university. This ambition is closely aligned with the United Nation's Sustainable Development Goals. The SDGs Working Group at UL is currently co-designing and developing an ambitious 'Sustainable University Strategy 2030.' This holistic strategy is designed to be mission-driven. It will identify strategic missions and mission projects across the areas of: 1) campus community and operations; 2) leadership, governance and staff; 3) learning, research and students; and 4) partnership, community and engagement. We are committed to taking the required steps to continue on our journey towards sustainability.

Phase Two: Transition to a Regenerative University

UL's long-term ambition is to become a regenerative university. This means that academic staff must actively explore their role and responsibility as stewards or custodians of a regenerative world. This paradigm shift will require to move beyond the existing human-centered paradigm of individualism and competition towards a regenerative mindset that sees the world as a living system. To this end, 2022 will see UL begin by collectively exploring regenerative futures with our campus community and in partnership with the broader region.

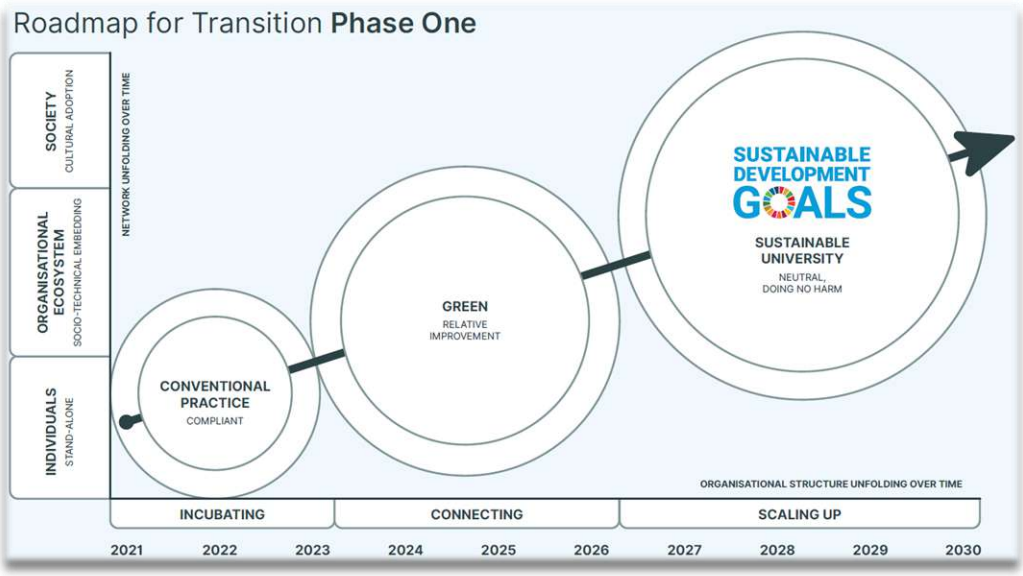

Figure 1 - UL roadmap for transition – Phase 1 (Source: UL Sustainability Report 2020)

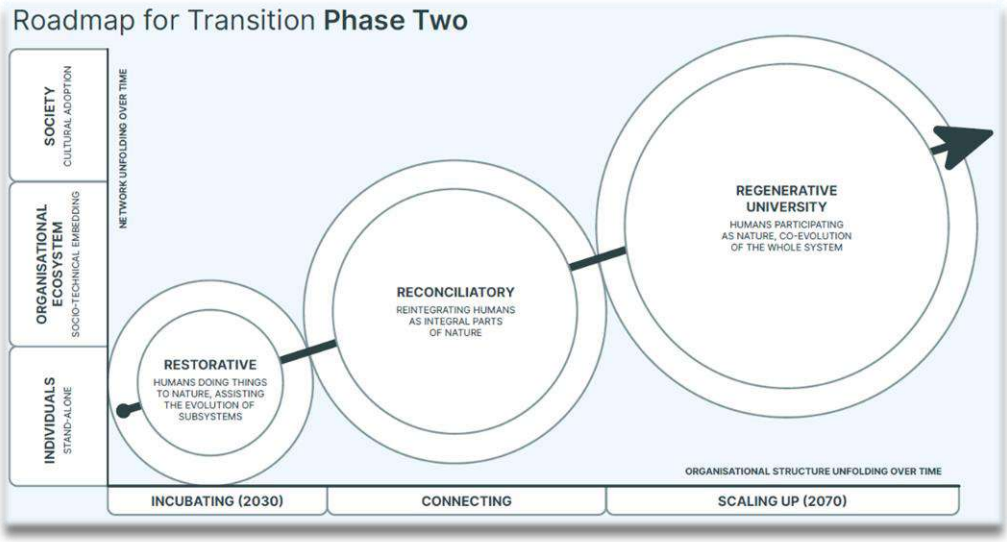

Figure 2 - UL roadmap for transition – phase 2 (Source: UL sustainability report 2020)

2.4 National Technical University of Athens (NTUA)

The National Technical University of Athens, NTUA is the oldest and most prestigious educational institution of Greece in the field of science and technology.

Regarding NTUA's social dimension, one of its primary missions is to provide free of charge advanced higher education for students. As students pay no tuition fees, everyone who has the knowledge base, can have access to this internationally recognised public university.

Also, NTUA has recently established the Committee for Gender Equality (CGE)[1] that aims to promote equality on all functional levels and processes of academic life. In particular, CGE has the following responsibilities:

1. Puts together action plans for the promotion and securement of true equality in educational, research and administrative processes of the institution and compiles an annual report, which is submitted to the Rectorate.
2. Introduces to the relevant bodies measures for the promotion of equality and the combat of sexism.
3. Offers information and education to the members of the academic community where matters of gender and equality are concerned.
4. Offers mediation services in the case of complaints against discriminatory conduct or harassment.
5. Promotes the conduct of master's study programs, seminars and lectures focusing on gender studies.
6. Promotes studies and research on issues pertinent to the areas of its capacity.
7. Consults victims of discrimination when they report discriminatory treatment.

Concerning environmental policy, NTUA as a university of science and technology has the vision not only to educate people regarding environmental issues but also participate actively towards the protection of the environment by inheriting "green practices". In particular, NTUA environmental policy includes:

- the participation in research activities regarding the energy efficiency in various sectors (e.g., green ICT technologies, energy efficiency, water resources management);
- the decrease of travels by making video conferences;
- the adoption of recycling policies in the various schools across the campus;
- the reduce, reuse and recycle of the technological equipment, as well as the upgrade of the network and computational infrastructure with energy efficient equipment.

3 Description of existing sustainability modules in courses

3.1 Queen's University Belfast (QUB)

Although sustainability is taught in several programmes at QUB, these are not necessarily delivered as dedicated courses in that area, rather an embedding of sustainability aspects in different courses. One of UK's main accrediting bodies, IET (Institute of Engineering and Technology) requires sustainability to be embedded within the curriculum and key learning outcomes in that area met. A module review of relevant programmes at QUB indicated that sustainability aspects, as dedicated modules, are covered mostly at postgraduate (PG) level. However, as mentioned above, most undergraduate (UG) courses also have concepts of sustainability integrated within a range of core modules. In the next section, both UG and PG courses are outlined together where environmental sustainability can be clearly identified from the title.

A Masters in *Environmental Engineering* and an UG (MEng) in *Environmental and Civil Engineering* are two dedicated programmes offered at QUB to prepare students for a career in the environmental, consultancy, regulatory, management and engineering industry and for an appreciation of the value of Environmental Engineering to a sustainable society. Other initiatives are also in the process of being developed such as a new Masters in *Net Zero Engineering* and an MSc in *Climate Change*.

[1] http://gender-equality.ntua.gr/en/

Undergraduate and Postgraduate Studies

3.1.1 School of Natural and Built Environment

Assessment of Environmental Impacts

This MEng UG module introduces students how the impacts of engineering projects are assessed within the framework Life Cycle Assessment (LCA), Environmental Impact Assessment and sustainability evaluations. Particular emphasis is given to environmental impacts, although societal impacts are also considered. Regulatory drivers are introduced for Environmental Impact Assessment/Strategic Environmental Assessment. Additionally, current standards and guidance for quantifying environmental impacts through LCA, including defining the scope of an LCA, inventory analysis and interpretation of results are also part of the syllabus.

Additionally, solid waste and resource management and renewable energies are also studied in detail within this context. An understanding of the science and technology behind advanced waste management processes and an appreciation of the financial, social and environmental factors that may restrict the adoption of particular technologies is also part of the curriculum. An introduction to a variety of renewable energy technologies, such as wind, solar, tidal and wave power as well as geothermal and biomass energy is taught. An introduction to the policy framework for renewable energies within the UK and Ireland is also introduced.

Advances in Environmental Engineering

This PG module deals with scientific advances across the discipline of Environmental Engineering. The course includes selected topics across the discipline, such as air quality, noise, land & water quality & remediation, geohazards, environment and public health, waste management, environmental sustainability, renewable energies, resilience engineering, big data approaches to environmental problems, etc.

The course provides an introduction to selected topics and demonstrates recent scientific advances in the respective research areas such as creating filters/reactive barriers or water treatment set-ups for contaminated water using natural, made and/or repurposed waste material, building air cooler from plastic bottles that uses no electricity, creating green walls with ornamental and/or edible plants for better air quality in buildings and treating the green wall drainage water with reactive or other materials, evaluating and/or repurposing waste materials such as plastics, aluminum and building materials.

Environmental Interaction of Assessment of Marine Renewables

The aim of this PG module is to introduce students to the environmental concerns of wave and tidal energy developments. Modelling, acoustic, telemetry and quantitative methods used to assess the environmental interactions will be evaluated. Analysis of flow velocity in the environment is fundamental to understanding environmental interactions, therefore students are introduced to tools such as numerical modelling and flow measurement devices.

Water and Wastewater Treatment

This PG course introduces students to the basic principles and underlying concepts of water and wastewater treatment. The course includes: water quality; water treatment techniques (clarification, filtration, disinfection etc.), wastewater treatment (preliminary, primary and secondary processes), sludge treatment, disposal of wastewater and sludge; environmental impacts, health and safety.

3.1.2 School of Chemistry and Chemical Engineering

Energy Systems: Oil and Gas to Renewables

This MEng UG course covers the modern oil and gas sector utilizing the following topics: Thermodynamics of oil and gas reserves, downstream and upstream separation technologies, Energy transitions in the Oil and gas sector, Introduction to Renewable Energy systems, Biomass and Biofuels, Modern renewable energy technologies, Energy recovery and storage, Environmental impacts of energy, Renewable energy in transport systems, Future cities, Introduction of biomass gasification, Tar reduction from biomass gasification and Carbon capture using solid sorbents.

Green Chemical Engineering

This MEng UG module includes concepts such as Principles of Green Chemistry, E-Factor, Atom Economy, role of chemical industry in sustainable development, criteria for Benign process design, resource conservation and waste reduction, sustainable resource management (water, air, carbon balance, feedstocks), sustainable waste management, renewable chemicals from cellulose, hemicellulose and lignin, biorefinery products. Additionally, traditional chemical processes vs more recent developments, small modular, flexible chemicals production and relevant case studies are also included.

Environmental Engineering Design

This MEng UG module reviews Bioenergy content and latest developments, review of LCA principles and application of LCA to Bioenergy systems, selection and critical evaluation of feedstocks and processes for bioenergy production, analysis and evaluation of case studies of the application of LCA to Bioenergy systems, key issues and challenges in application of LCA/CF to bioenergy processes. Development of Life Cycle Inventory (LCI) of feedstocks and processes, development of model for LCA of Greenhouse Gas (GHG) balances of biogas production and utilisation options, integration of UK GHG Inventory data for electricity and gas production, comparative evaluation of GHG balances for Bioenergy and fossil sources, identification and modelling of innovative technologies for biogas production and utilization, sensitivity analysis of data and technology performance assumptions. Detailed study of photocatalytic technologies is also taught including the design principles of photocatalytic reactors, design and construction of immobilised film, fluidised bed and suspended catalyst photoreactors, mass transport and kinetic modelling and control in photocatalytic reactors, irradiation sources and light distribution in photocatalytic reactors, determination of conversion efficiencies, quantum yields and economic evaluation of photocatalytic reactors, applications of photocatalytic technology for energy conversion/storage and treatment of contaminated water and air.

Industrial and Green Chemistry

This UG course demonstrates how important industrial chemicals can be synthesised using catalysed reactions, starting from the feed stocks of the current chemical industry. Course content includes comparison of homogeneous, heterogeneous and bio-catalysis, heterogeneous catalysis and the synthesis of building blocks: CO, H2, NH3, olefins, large scale homogeneous processes, separations in homogeneous catalysis, introduction to industrial biocatalysis for chemical synthesis.

This course will introduce the concepts of “green” chemistry and the development of a sustainable future for chemical manufacture. Topics covered include techniques for greener synthesis and the application of these techniques to real industrial problems, the case for sustainability in chemical manufacture, the twelve principles of “green chemistry”, methods for evaluating and comparing the “greenness” of chemical processes, the green chemist’s toolbox: an introduction to enzyme-catalysed transformations, heterogeneous acids and bases, greener reductions and oxidations; greener process

design. This course will also introduce the topic of applied materials and an introduction, including green approaches to polymers, polymer synthesis and applications of polymer from bulk to medical.

3.1.3 School of Electronics, Electrical Engineering and Computer Science

Sustainable Energy and Smart Grids

This Master level course constitute topics such as Sustainable Energy Resources, Load Frequency Control, Dynamics and Inertia, System Non-Synchronous Penetration (SNSP), Demand Side Management, Deferrable Loads, Battery Energy Storage, Electric Vehicles, Substation Automation, Telecommunications, Phasor Measurement Units, Power Quality, Design & Deployment, Market Liberalisation and Economics and Renewable Energy Operations and Integration.

3.1.4 School of Mechanical and Aerospace Engineering

Sustainable Energy Systems

This PG course offers fundamental principles, applications and potential of key mature sustainable and renewable power sources used globally including: 1) wind power, 2) hydro power, 3) biomass, 4) solar power, and 5) nuclear energy. Other non-mature and/or less widely utilised technologies including a) wave and tidal, b) compressed air energy storage, c) geothermal, and d) energy storage are introduced at a higher level. Current trends and perspectives on development and application of sustainable energy systems with guest lectures from industry and research, and site visits are some of the key features of this module.

3.2 University of Limerick (UL)

3.2.1 Sustainable Resource Management: Policy & Practice MSc

https://www.ul.ie/gps/course/sustainable-resource-management-policy-practice-msc

This one-year MSc programme is a multidisciplinary approach to environmental sustainability devised by UL and NUIG to respond to the continuing interest among students in an environmental/resource management taught MSc., and to market demands for graduates with more applied knowledge of the environmental sector. Strongly research led, it is unique in that it combines the expertise of both institutions in relation to urban form and function and landscape evaluation and management for conservation in a jointly awarded MSc postgraduate degree.

The 12-month long course comprises new modules taught only at postgraduate level and aims to provide participants with the skills, knowledge and experience that are needed to pursue successful careers in managing environmental resources sustainably. The course will help develop government policy and economic recovery by producing top quality graduates who can contribute to a smart economy and hasten implementation of green technologies. Given the pressure on and competition for limited resources, the course applies an evidence-based approach to developing solutions for all system users. Graduates will become technically fluent in selected environmental science theory, policy development, implementation and best practice.

Students who undertake this course will:

- develop a technical and scientific understanding of sustainability issues and problems associated with management of resource use and management in relation to (a) urban form and function and (b) landscape evaluation and management for conservation.
- comprehend a range of policy responses in relation to enhancement of sustainability in Irish urban and rural settings, and selected international case studies.

- synthesise an understanding of the complexity of both natural and socio-economic-natural systems, together with an understanding of existing and innovatory sustainability policy options, to develop a competency in identifying and evaluating optimal policy options.

3.2.2 Bachelor of Science in Environmental Science

Link: https://www.ul.ie/courses/bachelor-science-environmental-science

NFQ Level 8 major Award Honours Bachelor Degree

Entry Route: Biological and Chemical Sciences (Common Entry) - LM123

Duration: 4 years

The degree programme is four years in duration. Early modules are concerned with building up student understanding of science relevant to the environment (biology, ecology, chemistry, computing, maths and physics). The basic concepts used in these subjects are applied to specific environmental science applications. Later modules in the programme focus on the areas of environmental management, environmental technology, environmental impact assessment, waste management, environmental monitoring and health & safety. In the third year, the University organises Cooperative Education for all students. This is a period of approximately eight months of paid employment in a position which is relevant to environmental science. In the final year of the programme students undertake a research project in some aspect of environmental science. The project is supervised by an academic member of staff with specific expertise in the area and the project runs over both semesters.

The main areas of study within the programme include

- Environmental Science - the application of the fundamental sciences to environmental issues
- Environmental Management - how strategies can be developed and implemented in protecting all aspects of the environment
- Clean Technology - the use of cleaner technologies and processes to minimise the negative impacts of technology on the environment
- Waste Management - the study of the physical methodologies and techniques for dealing with increasing levels of waste generated by the manufacturer and consumer

Health & Safety - a complementary area to environmental science which specifically deals with significant health and safety issues both in the workplace and in outdoor environments.

3.3 National Technical University of Athens (NTUA)

All NTUA Schools support courses about environmental sustainability, while limited modules are available regarding social and economic sustainability.

Undergraduate studies

3.3.1 School of Civil Engineering

Environmental Geotechnics

The goal of this course is to develop environmental thinking related to assessing the severity of a contaminant release in the subsurface, recognizing the physical-chemical-biological mechanisms that affect the fate and transport of the released contaminant and selecting appropriate remedial measures and technologies.

Course contents include:

- Cases of restoration of contaminated sites.
- Legislation.
- Sources and characteristics of contaminants.
- Risk assessment.
- Groundwater flow.
- Soil-contaminant interaction.
- Mechanisms affecting the fate of contaminants, contaminant transport, applications (practice in the use of educational software in the School's PC lab).
- Landfill liner design and materials.
- Remediation technologies for contaminated sites.

Department of Water Resources and Environmental Engineering

The Department of Water Resources and Environmental Engineering was established in 1982. The main scientific areas it is dealing with are the qualitative and quantitative aspects of the aquatic environment and the related civil engineering works. However, students are also investigating ecology, sanitary engineering, as well as pollution and protection of the aquatic environment.

Department of Transportation Planning and Engineering

The mission of the Department of Transportation Planning and Engineering is to educate scientists in the field of transportation planning and engineering. The vision of the Department is a future with highly efficient, green and safe transport systems in Greece, in Europe and globally. It comprises all transport modes (road, rail, water, air, combined), all transport types (people and goods, urban and interurban, national and international, terminals) and all phases of transportation projects (planning, design, tendering, construction, delivery for operation, operation, management, maintenance).

3.3.2 School of Mechanical Engineering

New and Renewable Energy Sources

This course present and analyze the following subjects: historical evolution of energy technologies, energy sources and energy consumption (worldwide, in Europe, in Greece), towards a sustainable energy future, the development of Renewable Energy Sources (RES) in Greece, in Europe and in the world, short and long term perspectives of RES, the potential of RES (wind potential, solar radiation, biomass, hydroelectric potential, geothermal resources, ocean waves/ocean currents), RES technologies and application systems (wind turbines, passive solar systems, bioclimatic architecture, active solar thermal systems, photovoltaic systems, bioenergy, small hydro, marine energy systems, geothermal energy, hydrogen, fuel cells. Moreover, the course includes technoeconomic analysis of RES systems such as energy costs (conventional, environmental, external), environmental impacts, economic evaluation, investment analysis.

Wind energy

This course is also an introduction to renewable energy sources. It investigates meteorological elements of wind, types and subsystems of wind turbines, wind energy potential, aerodynamic design of horizontal and vertical axis wind turbines, static and dynamic loading of wind turbines, electrical motors for wind turbines and their cooperation with the grid, analysis of aerodynamic performance and optimized design of wind farms, practical elements for wind turbine selection, applications and economics of wind turbines.

Occupational Safety and Health

The course gives different approaches to the problem of Occupational Safety and Health (OSH) and presents accident analysis methods, occupational risk assessment methods, statistical analysis of

occupational accidents and work related diseases, OSH cost, OSH legislation, OSH management at the enterprise.

Solar Energy

The course explores areas like solar radiation (basic concepts, angles, direct and diffuse radiation, spectral distribution, attenuation by the atmosphere, tilted and tracking systems, correlations, measurement of solar radiation, values in the Athens area), theory of flat-plate collectors (heat transfer analysis, temperature distribution on the absorber plate, collector efficiency factor, heat removal factor and flow factor, collector efficiency, measurement of collector performance, various designs of flat plate collectors), concentrating collectors, solar systems for space and service water heating (design methods, the f-chart method), design methods for thermal solar systems (Utilizability, the f-chart method), energy storage and other applications (Solar cooling, conversion to mechanical energy, solar ponds, passive systems, economics).

Hydroelectric energy

The scope of this module is gaining knowledge regarding hydroelectric energy. Among others, the module illustrates the current conditions and prospects for further development of hydroelectric energy, the advantages and disadvantages of its utilization, and the hydraulic potential of rivers, lakes and oceans. It also investigates basic configurations and categorization of conventional hydroelectric plants, based on size (power), type (with or without reservoir), usage (e.g. pumped storage) and type of hydro turbines. Electrical and electronic equipment such as generators, transformers, power factor, measuring equipment, automation and control are presented. Many more aspects of hydroelectric energy are investigated during this course.

Pollution Abatement Technology for Thermal Plants

The module identifies energy technologies for reducing the environmental impact, studies climate change and international environmental policy, environmental legislation, emissions Trading System (ETS), mechanisms of formation and capture capabilities of main gas pollutants (NOx, SO2), CO2 emissions and the greenhouse effect. It also investigates the reduction of CO2 emissions in different countries, the reduction of CO2 emissions in electricity generation, technologies regarding CO2 capture and storage in thermal power plants. Other subjects that this course examines are large-scale energy storage systems (Power-to-X) that include the reuse of CO2, the energy recovery of waste and residues, the production of secondary fuels from recovered waste materials, measurement techniques for gas pollutants (O2, CO2, O, SO2, N2O, CxHy, NOx) and particles.

3.3.3 School of chemical engineering

Environmental Science and Technology

The course aims to scientifically examine the quality and pollution of the environment, as well as the global extent of environmental disturbances from predominantly anthropogenic causes, to approach and address environmental problems, and to become familiar with the available technological options for waste/resource management, developing the optimal solution and promoting integrated development. Units Included: Introduction to Environmental Science. Atmospheric and Air Pollution. Water Environment and Water Pollution. Liquid waste and environmental pollution. Soil and soil degradation. Solid waste and environmental pollution.

Industrial Waste Management

Some of the subjects this course deals with are the general characteristics of solid wastes, classification codes, characterization (toxicity, corrosivity, flammability, etc.), physico-chemical, biological and thermal methods for the treatment and disposal of hazardous wastes, risk storage and transportation, risk assessment, environmental impacts, special types of solid wastes such as End-of-

Life Vehicles (OTKZs), Used Tires, Excavation, Construction and Demolition Wastes (AEKK), Wastes of Electrical and Electronic Equipment (WEEE), agricultural wastes, hospital wastes.

Green Chemistry and Engineering

Green Chemistry and Green Engineering Development Framework: Objectives, Principles, Tools. Indicators for measuring the efficiency of reactions and processes (metrics). Reaction and process efficiency. Calculation of atomic yield and chemical reaction mass. Process optimization, modifications and product redesign. Alternative Raw Materials, Solvents and Catalysts in the Chemical Industry. The contribution of Green Chemistry to sustainable agriculture. Performance evaluation based on chemical structure, chemical reaction and chemical transformation. Examples and exercises of green raw materials, reactions, reagents, solvents, reaction conditions and chemicals. Large-scale case studies of green processes. The role of ionic liquids (ILs, ionic liquids) and deep eutectic solvents (DES, Deep Eutectic Solvents). Chemical reactions of increased energy efficiency. High Energy Techniques (microwave, ultrasound). New Trends in Green Chemistry and Engineering - Biomimetic and Multifunctional Systems.

Environmental Assessment and Optimization of Industrial Processes

The aim of the course is to analyse the environment as a recipient of pollution. Mechanisms and familiarizing students with the methodology of industrial processes design to minimize the use of raw materials and energy while maximizing the production of products using environmental criteria. Contents: Criteria and "tools" for environmental assessment in the design and operation of industrial processes. Introduction to the logic and necessity of rational use of raw materials and energy in industry. Environmental Technologies and Reuse and Recycling Technology. Water and carbon footprint. Circle of life. 'Boundary point' analysis as a 'tool' for the evaluation and environmental optimization of industrial processes. Design of "clean" industries based on the "limit" of water use. Methodology for designing industrial processes to minimize waste generation. Methodology for the design of industrial processes for the re-use of generated waste. Design methodology for the recycling of processed waste through the analysis of the boundary point. Integrated industry design methodology to minimize the production of liquid waste while optimizing the required heat loads. Integrated Design to minimize waste generation and value-added production. By-products of bio-refineries.

Water Management

The aim of the course is to cover a wide range of issues related to water resources and water quality. These include environmental importance, management, chemistry, quality, uses of natural water resources and seawater utilization. Contents: 1. Distribution, uses and quality of water. Current situation regarding water at international and national level. National and European legislation. Water Resources (conventional - non-conventional). Climate change and impacts on water resources. 2. Aquatic Chemistry: Natural aquatic systems-water composition - aqueous phase chemicals. Main pH variables, p. Acid-base effects (pC-pH diagrams). 3. Drinking (urban) water (Quality-management) Gray water (Quality-management) Irrigation water (Quality-management). 4. Reuse of treated waste, 5. Desalination of brackish and sea water (thermal, membranes, electrodialysis), 6. Water & Energy. Water footprint and Virtual water concept. Blue Growth.

Dispersion of Pollutants

Analysis of the environment as a receiver of pollution. Mechanisms and Processes in Nature. Dispersion of pollutants in the atmosphere. Calculations of air pollutants dispersion from various sources. Air dispersion computational models. Applications of atmosphere dispersion modeling software. Pollutants dispersion in water and soil. Water Pollution Transfer: Fully Mixed Systems. Systems not fully mixed. Conventional pollutants, dissolved oxygen, pathogens, toxic compounds.

Transport of pollutants in water: Rivers. Streeter-Phelps models. Water Pollution Transfer: Lakes. Eutrophication. Soil pollutants transportation: Groundwater. Pollution and transport of dissolved pollutants. Unsaturated zone.

Sustainable Management of Energy Systems

The aim of the course is to familiarize students with the basic principles and general methods of energy saving. The objectives of the course are: (a) development of basic energy and energy analysis tools for physical and chemical processes, their application to power generation and the steam system (generation, distribution, use, saving, cogeneration), (b) study of basic systems of co-production (c) industrial freezing and air conditioning; (d) the use of renewable energy resources in industry. Course content includes: Energy Needs in Industry-Principles of Energy Optimization/Energy and Thermodynamics/Basic and Complex Power Generation Cycles/Energy/Energy Analysis of Heat Transfer Systems/Steam Generation Systems/Cogeneration/Cooling.

Environmental Biotechnology

The course aims to familiarize students with the bio-processes that aim both at environmental protection of ecosystems from pollution and the exploitation of liquid gases and solid wastes in the production of high value-added products, as well as the design and optimization of these biological systems. The course content is about the description of ecosystems, organic stabilization of organic substrates, organic waste stabilization bioreactors, natural wastewater treatment ecosystems, biological nitrogen removal and microbial production of high value-added products.

3.3.4 School of Rural, Surveying and geoinformatics engineering

The school is divided into three departments. The Department of Geography and Regional Planning is dealing with subjects related to environmental sustainability and specifically with environmental planning and impact assessment. The courses provided by this department investigate the impacts of human activities (plans, projects etc.) on the natural and built environment. The department provides a range of lectures supporting students in coping with: the study of physical variables, the management of natural resources, the impact assessment emerging from the implementation of plans and projects. In particular, lectures are discussing topics related to Physical Geography and Environment, Natural Resources Management, Environmental Impact Assessment, Sustainable Development and Environment and Environmental Planning.

3.3.5 School of Mining and Metallurgical Engineering

Applied and Environmental Mineralogy

Industrial rocks and minerals of Greece. Clay minerals in the cement industry. Minerals in the color industry. Minerals in the paper industry. Ore mineralogy and its importance on mineral beneficiation processes. Sedimentary mineralogy with emphasis on the mineralogy of marine sediments. Introduction to Environmental Mineralogy. Minerals and natural ecosystems. Mineralogy of anthropogenic environment. Environmental toxicity of minerals. Acid-generating and acid-consuming minerals. Soil mineralogy in industrial, with emphasis placed on mining areas. Geogenic-anthropogenic interaction fingerprint on soil mineralogy. Asbestos and asbestiform minerals. CO2 mineralization.

Applied Environmental Protection

The course presents theoretical concepts and practical approaches to the effects of the mineral resources industry (mining – metallurgy), the major geotechnical projects and the materials industry. The main categories of impacts are analyzed, the available technologies for the protection of the environment are described as well as the conditions for management, treatment and disposal of the gaseous, liquid and solid waste of this activity.

Health and Safety

The course aims to introduce the students to the basic principles of Occupational Health and Safety with an emphasis given on the Extractive Industry, Mines and Quarries, and the Metallurgical Industries, i.e. covers the whole Raw Materials Life Cycle. The course is organized in separate thematic sections that allow the student to get familiarized with the prevailing Health and Safety Legal framework in Greece and EU, to recognize the importance of Occupational Risk Assessment for the identification of prevention and mitigation measures and their incorporation in the design and operation of productive activities and to define and apply the suitable indicators for monitoring safety at work.

Air pollution control

The course provides insight on the theoretical background, the various aspects of air pollution resulting from industrial activities and focuses on the detailed design of air pollution control systems. Emphasis is given on the increasingly strict legal framework related to anti-pollution technology. The introduction to the course includes topics related to suspended particles (characteristics, behavior of particles in fluids (traction force, Stokes Law), external forces, gravitational precipitation, aerosols). Students are then taught detailed design issues including gravitation chambers for flue gas dedusting, centrifugal collectors (cyclones, polycyclones), electrostatic precipitators, bag filters and wet scrubbers (Spray chamber and cyclonic spray scrubbers, Venturi, etc). The advantages and disadvantages of each specific air pollution control system and its relative energy consumption are discussed in detail.

Energy and environment

Presentation of the basic forms of energy as well as the energy sources, renewable and non-renewable. The main technical characteristics of each technology for the utilization of each energy source are analyzed with special emphasis on their interaction with the environment. Important aspects of energy policy and energy economics are also presented.

Presentation of the basic forms of energy as well as the energy sources, renewable and non-renewable. The main technical characteristics of each technology for the utilization of each energy source are analyzed with special emphasis on their interaction with the environment. Important aspects of energy policy and energy economics are also presented.

- Historical context, Introductory concepts
- Energy mixture. Environmental impacts of energy projects and technologies. Introduction to impact assessment methodologies (environmental footprint, life cycle analysis, economic impact assessment).
- Fossil fuels (solids, liquids, gases), types of energy utilization units, combustion equations and environmental impact
- Wind energy utilization and environmental impacts
- Utilization of solar energy and environmental impacts
- Utilization of energy from Biomass and environmental impacts
- Geothermal utilization and environmental impact
- Energy saving, energy studies and energy efficiency certificates
- Energy Poverty, concept, impacts, treatment.

Environmental and Natural Resources Management

- Environment, natural resources, economy and society: the economic view of the environment in the light of neoclassical economics, externalities, property rights.
- Regulatory and economic instruments of environmental policies: optimal level of pollution, command-and-control policies, market-based policies: taxes, subsidies, pollution permits, etc.

- Optimal use of renewable and exhaustible resources: basic analysis of optimal use of exhaustible natural resources (Hotelling rule), general model of exploitation of a renewable resource
- Economic valuation of environmental goods and services: use and non-use values, stated preference valuation methods, revealed preference valuation methods, applications.
- Single-criterion decision-making: Basic Principles, Definitions, Advantages-Disadvantages, Pareto Optimization, Hicks-Kaldor Criterion, Cost-Benefit Analysis, Cost-Effectiveness Analysis.
- Multi-criteria decision making: Basic principles, Applications of Multi-criteria methods, Estimation of Weights, Multi-criteria methods, Weighted summation, Analytical Hierarchy.
- Participatory decision making: Stakeholder Analysis, use of communication tools and methods, use of financial tools (e.g. “low bid” and “high bid” auctions).
- Risk Analysis: Basic Principles, Semi-Quantitative and Quantitative methods, Fuzzy Data Management, Use of stochastic analysis with Monte Carlo simulation.

Environmental Geochemistry

Basic and introductory concepts in Environmental Geochemistry including the behavior of major and trace elements in the near-surface environment, focused on the interaction between rock, soil, water, and atmosphere. Environmental degradation and pollution related to anthropogenic and geogenic processes, and the way these processes affect the biosphere. Products of chemical decomposition, bioavailability, and solubility of potentially hazardous and toxic elements. Basic concepts on environmental pollution, focused on pollution sources related to human activities (e.g. mining). Environmental degradation approach based on state-of-the-art technologies (e.g. high resolution analytical techniques, use of stable and radiogenic isotopes in environmental geochemistry, specialized software for assessment and evolution – modeling of potential hazards). Geochemical mapping, nuclear radiation in the environment, geochemical cycle of elements.

Geostatistics for Environmental Applications

Spatiotemporal mapping in geosciences. Sources of physical knowledge: natural laws, empirical rules, obvious correlations, etc. The principle of maximum entropy for measuring information. Knowledge assimilation through Bayesian statistics. The Bayesian Maximum Entropy (BME) method.

Pollution mapping based solely on statistical moments of measurements. Certain and uncertain data. Data transformations. Analysis of spatial correlation through the covariance function. Confidence intervals and risk assessment. Error mapping and evaluation of an existing sampling network. BME Lib open source applications.

Spatiotemporal mapping with incorporation of the occurring natural law. Stochastic differential equations. Solution with numerical analysis via Matlab and Excel. Applications in underground pollutants transportation and public health.

Groundwater Management and Protection

The content of this course refers to: (i) Analysis of hydrogeological systems (aquifer types, groundwater flow hydrology and hydraulics), (ii) Groundwater chemistry (hydrochemical analysis, water-rock interactions), (iii) Principles of isotope hydrology (applications in the hydrological cycle), (iv) Nitrate contamination (nitrification/denitrification processes, agrochemical diffuse sources), (v) aquifer vulnerability (vulnerability index, application in diffuse and point sources), (vi) aquifer ecosystem services, (vii) Managed Aquifer Recharge (methods and technologies, monitoring and management of MAR facilities, Soil-Aquifer-Treatment systems, EU legislation in wastewater reuse), (viii) Introduction to groundwater modeling (emphasis in mass and contaminant transport, variable density flow), (iv) Application of hydroinformatics in groundwater chemistry.

Solid waste management – Material Recycling

The course introduces to undergraduate students the basic concepts and methodological tools required to understand the processes and procedures involved in solid waste management with an emphasis on municipal solid waste. The course syllabus aims at understanding the social, environmental and political dimensions of solid waste management. Through the course, both the current European and the national institutional framework are presented and analyzed, as well as the available technologies and the future research objectives in this field. All actions related to solid waste management are analyzed, such as identification of quantitative and qualitative characteristics of waste, methods of storage, collection and transfer of waste. Particular emphasis is placed on solid waste separation methods, waste sorting facilities process flow charts and final treatment of solid waste. Furthermore, the principles of construction and operation of sanitary landfills are presented and analyzed.

Special Topics of Environmental Protection in Mining and Geotechnical Engineering

The course presents theoretical concepts and practical approaches to the environmental, social and economic impact of the exploitation of mineral and energy resources as well as the best ways to manage them. More specifically, the environmental risks associated with the exploitation of mineral and energy resources and large geotechnical projects are analyzed and the best techniques for dealing with them are presented.

Environment and Development

This is an inter-departmental course offered from all nine faculties of NTUA and it deals with the dialectic relationship and interaction between the environment and development, that future engineers should be ready to deal with and benefit personally and socially.

The main goals of the course are to:

- demonstrate the complex nature of modern development, environmental technology issues and familiarize them with the necessity of an interdisciplinary and integrated approach,
- bring together students in front of real dilemma that may face tomorrow, many of which could not be only solved based on a technological perspective,
- provide the theoretical background for the analysis of complex environmental design problems,
- provide a learning environment where the students will not just listen to scientific presentations, but will try to efficiently establish an informed position.

The course is built as a series of lectures. Faculty members from all schools of NTUA and guest lecturers from the industry, public authorities and other research and academic institutes are participating in a form of a debate and/or round table.

At each lecture, at least 2 speakers will argue on the relationship 'Environment and Development', with emphasis on highlighting the differences between various approaches and not on proposing a specific opinion. The continuous and active participation of the students from all spectrum of engineering and science that could take this course is a prerequisite for the success of this course.

Post-graduate studies

3.3.6 School of Civil Engineering

Water Resources Science and Technology

The School of Civil Engineering of the National Technical University of Athens in cooperation with the School of Rural and Surveying Engineering and the School of Mining and Metallurgical Engineering organize the Inter-Departmental Program of Post-graduate Studies in the scientific field "Water Resources Science and Technology".

The scope of this master program is the research of an effective water policy. Such a policy requires an interdisciplinary approach to challenges. Specifically, it is necessary to explore both the quantitative and qualitative aspects of management, study relevant policies (energy, agricultural, etc.), use appropriate tools (e.g. finances) and promote the participation of the wider using-water community in decision-making.

3.3.7 School of Rural, Surveying and Geoinformatics engineering

Energy Production and Management

The Inter–Departmental Postgraduate Course "Energy Production and Management", coordinated by the National Technical University of Athens (NTUA), aims at the systematic professional development of mechanical engineers in the field of energy production and management. The Programme offers a full postgraduate education in the following areas: energy production, renewable energy sources, power plants and electricity production system, fuels (carbon, oil, natural gas, biofuel, bioethanol etc), energy use, energy and housing constructions (passive and active design of heating and cooling systems, housing constructions with a minimum loss, energy management systems etc), energy and industrial installations (thermoelectric applications, cogeneration, recuperation of heat etc), energy and transportation (conventional means of transport, electric drive etc), energy saving, energy management (automatic control systems, measuring systems, accounting methods), energy saving and programming

4th Industrial Revolution and Smart Cities

The course "4th Industrial Revolution and Smart Cities" is part of the post-graduate program "Engineering-Economic Systems" and investigates the effect of the 4th industrial revolution (Industry 4.0) in energy and environmental systems. It also examines methodologies and models that can support the sustainable energy transition, keeping pace with modern technologies accomplishments.

3.3.8 School of architecture

Protection of monuments

It includes lectures, seminars and tutorials carried out individually in parallel with the equivalent lectures. Additionally, students have to complete five individual projects and carry out an individual dissertation. The active involvement in research is considered an integral part of the studies. The whole programme includes core lectures and seminars, on: Historical review of conservation theory and philosophy, historic structure techniques, recording and surveying methods, evaluation criteria, etc, pathology of monuments and building materials, deterioration causes, environmental impact assessment, conservation and restoration techniques, selecting materials strategy, earthquake protection, urban conservation and sustainable development, protecting landscape and natural environment, regional planning and architectural heritage, new architectural interventions in historic entities, international and Greek legislation and regulations, European Union and cultural heritage.

3.3.9 Interdepartmental Programme of Postgraduate Studies

Environment and Development

The scope of this programme is to contribute in the formation of a common code of communication, as well as of appropriate methods and practices of co-operation amongst scientists of different disciplines, aiming at the integrated and interdisciplinary approach to analysis and confrontation of today's multi-dimensional and extremely serious Environmental and Development issues.

The program focuses on the following fields:

- The integrated investigation, survey, mapping and monitoring of all elements, relationships and interactions of physical and socio-economic reality.
- The spatial, legal, social, political, economic and cultural aspects of development and environment and relevant planning.
- The environmental protection sciences and technologies.

4 Existing projects/actions related to Sustainable Development Goals (SDGs)

4.1 Queen's University Belfast (QUB)

4.1.1 Green Fund Projects (Internal to QUB)

The Queen's Green Fund empowers staff and students to create and deliver projects within their area that benefit the environment, Queen's and our local community. Financial funding of up to £1500 for each team will be provided for the best proposals.

We look for original projects which will promote environmental awareness amongst staff and students, impact the wider Queen's community, support the University's low carbon vision and commitment to becoming a world leader in environmental sustainability, and demonstrate collaboration across Schools and Faculties and between staff and students.

A list of Green Fund projects is listed here.

https://www.qub.ac.uk/directorates/EstatesDirectorate/Services/SustainabilityatQueens/GreenFund/

4.1.2 Externally Funded Projects

Over the last 3 years, 30+ projects related to sustainability are awarded to QUB researchers by external funding bodies. In 2021 alone, at least 16 projects were awarded by a variety of external funders. This includes both European and UK-based organisations.

One of the ongoing projects in which the Smart-Edu4.0 coordinator is directly involved is related to the Decarbonisation of Maritime Transportation. The project "Decarbonisation of Maritime Transportation: A Return to Commercial Sailing" is funded by UK Research and Innovation (UKRI Strength in Placement Fund investment: £33 million) and led by Artemis Technologies. It aims to produce the world's first autonomously controlled fully submerged electric hydro foiling vessel and develop the technical and operational requirements for a maritime transport system of the future. It is building on Belfast's maritime heritage and world-leading expertise in advanced manufacturing and renewable energy to develop zero emissions hydrofoil ferries. It will also enable Belfast Harbour one of the world's most environmentally friendly regional ports.

A list of all relevant projects funded in 2021 is provided below.

Title	*QUB School*	*Funding Organisation*
Exploring the potential for biocatalytic gas-hydrate formation (BioGHF)	*School of Biological Sciences*	*Leverhulme*
Pyrolysis-plasma-catalysis of MSW for upgraded biofuels via Aston University	*School of Chemistry and Chemical Engineering*	*EPSRC*
DUO-DS Wave Powered Desalinisation System	*School of Natural and Built Environment*	*Invest Northern Ireland*
Hydrogen Generation to support Fuel-Cell Fleet	School of Mechanical and Aerospace Engineering	*Invest Northern Ireland*
UltraCompHy: Ultra-lightweight composite pressure vessels for safe and cost-effective hydrogen storage	*School of Mechanical and Aerospace Engineering*	*Dept for Transport*
City-centered approach to catalyze nature-based solutions through the EU Regenerative Urban Lighthouse for pollution alleviation and regenerative development UPSURGE	*School of Natural and Built Environment*	*EC-Horizon 2020*
Transforming UK Offshore Marine Algae Biomass Production	*School of Natural and Built Environment*	*Seagrown Ltd*
Next Generation Fuel-Cell Electric Buses to Accelerate a Low-Carbon Hydrogen Economy	School of Mechanical and Aerospace Engineering	*Innovate UK*
Sustainable Nutrient Management within Northern Ireland: Ostara struvite fertiliser trial on a potato field crop	*School of Biological Sciences*	*Astara Europe*
Building a 'photon-platform' development of a photocatalytic system to enhance biomass valorisation and facilitate collaborative engagement	*School of Chemistry and Chemical Engineering*	*EPSRC*
Glass cullet conversion to waterglass and used, with cement bypass flue dust, for cementless concrete building products	*School of Natural and Built Environment*	*Innovate UK*
Sustainable biogas upgrading technologies	*School of Chemistry and Chemical Engineering*	*Royal Society*
Converting Waste Biomass into Biofuels using VFAs Bio-Refining Platform	*School of Chemistry and Chemical Engineering*	*Leverhulme*
Decarbonisation Of Heat from Agricultural Waste	*School of Chemistry and Chemical Engineering*	*Invest Northern Ireland*
KESTREL: Knowledge, Evaluation, Systems, Technologies for the Reduction of Electricity Losses	*School of Electronics, Electrical Engineering and Computer Science*	*Innovate UK*

Carbon Neutral Towards net zero carbon livestock farming (C-NEUTRAL FARMING)	*Institute of Global Food Security (IGFS)*	*European Institute of Innovation and Technology*

4.2 University of Limerick (UL)

UL has project running that address each of the SDGs:

SDG1 – End poverty in all its forms everywhere

- 'Enactus' UL awarded European funding to integrate refugees and asylum seekers
- 'Anytime of the Month' aims to alleviate the effects of period poverty
- Executive Leadership Programme: Limerick City and County

SDG 2 - End hunger, achieve food security and improved nutrition and promote sustainable agriculture

- Food production with zero carbon emissions
- UL Bernal institute study finds that food preservatives show potential for development into the next generation of antibiotics
- First 'social grocery' in Irish province/region of Munster to open in Limerick in fight against food poverty
- Roof garden brings together UL community to collectively learn about organic farming on campus

SDG 3 - Ensure healthy lives and promote well-being for all at all ages.

UL researchers are active in multiple ongoing heath Science related projects at national and EU level including the IDEA-FAST project – to Identify Digital Endpoints to Assess Fatigue, Sleep and Activities of daily living – a European research project focusing on the neurodegenerative disorders (NDD) Parkinson's disease and Huntington's disease and the immune mediated inflammatory diseases (IMID) rheumatoid arthritis, systemic lupus erythematosus, primary Sjögren's syndrome and inflammatory bowel disease.

SDG 4 - Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

- FLEURIR – French language learning as part of the UL Academy for Children
- UL secured 700 funded education places for upskilling as part of COVID-19 response
- Outreach initiatives in Educating for sustainability at second level (UL schools partnership)
- New level 8 education programmes launched at UL for upskilling registered post-primary teachers
- International Structured PhD (ISPhD) programme at the Faculty of Arts, Humanities and Social Sciences, University of limerick

SDG 5 - Achieve gender equality and empower all women and girls.

- First ever woman president of an Irish university appointed at UL
- UL Chemical Sciences receives Bronze Athena SWAN award
- Same-Sex Parenting and the Best Interests Principle monograph published with Cambridge University Press.

- The Call it Out Campaign, run by the Transgender Equality Network Ireland and the Hate and Hostility Research Group (HHRG) at UL (now incorporated into the European Centre for the Study of Hate), was part of a 10-country project funded by the European Commission Rights, Equality and Citizenship Programme.
- UL and TENI launched a gender identity e-resource for schools

SDG 6 - sustainable management of water and sanitation for all.

- Wastewater treatment - Led by Bernal Chair of Process Engineering Professor Vivek Ranade, a research collaboration between CSIR National Chemical Laboratory (NCL), Pune, India and the Bernal Institute, UL has demonstrated a cost-effective green methodology to remove ammoniacal nitrogen from effluent streams
- UL initiative to remove seven million plastic water bottles a year from circulation on campus
- Water stewardship action plan developed at UL
- UL sports pitches modernised to enable the harvesting of rainwater for irrigation

SDG 7 - Ensure access to affordable, reliable, sustainable and modern energy for all.

- Collaboration between UL and industry leads to plan for Europe's largest battery energy storage facility -200 MW of electricity grid stabilisation systems in Co. Offaly, Ireland
- Molecular switch device co-discovered at UL could improve smartphone battery life

SDG 8 - Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

- €16m national investment in UL under the Irish Higher Education Authority (HEA) Human Capital Initiative (HCI). The projects include the use of virtual laboratories in higher education; a new hub to upskill the building sector on green construction; and the establishment of a Creative Futures Academy to support digital and screen culture, cinema, literature and broadcasting, art, design, and fashion. Innovative methods of teaching and delivery will be promoted on these projects so that learners will benefit from improved quality and more engaging ways of learning on enterprise focused courses, providing lifelong learning and upskilling opportunities for all.
- €2.3m national investment in UL to provide extra free and subsidised higher education places under the Irish Government's COVID-19 jobs stimulus/recovery package.

SDG 9 - Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

University of Limerick hosts three Science Foundation Ireland research Centres, the Confirm Centre for Smart Manufacturing, the Solid-State Pharmaceutical Centre, and the Lero centre for Software research.

- UL-hosted CONFIRM research centre launched a 16oom62 dedicated digital manufacturing facility in 2021.
- ULSSPC is developing a national advanced drug product manufacturing facility in the UL Bernal Institute.

SDG 10 - Reduce inequality within and among countries.

- Researchers at UL's Kemmy Business school are undertaking a project examining zero hours and low hours work in Ireland: regulation and the 'grey zone' of work

- The European Centre for the Study of Hate - Building on and incorporating the successful Hate and Hostility Research Group, the European Centre for the Study of Hate (ECSH) was established at UL in 2020 and awarded the status of Priority Research Centre the same year. The ECSH explores the prevalence, manifestations and impact of hate and the means by which hate can be challenged within and across societies.

4.3 National Technical University of Athens (NTUA)

4.3.1 Lavrion Technological Cultural Park

The Lavrion Technological and Cultural Park was founded in 1992 in the facility of the old French Mining Company of Lavrion (Compagnie Française des Mines du Laurium), at the initiative of the National Technical University of Athens, aiming to host and promote research and business activities[2]. The LTCP's facilities include industrial, laboratory and professional premises of a high aesthetic and architectural value, most of which were built during the period 1875-1940.

NTUA-AMDC undertook the project "Soil Remediation and Complementary Projects at the Technological Cultural Park of Lavrio", as a part of the Competitiveness Project, lead by the Ministry of Development with a total budget of € 7,800,000. The projects were targeted on the implementation of vital environmental projects in the area. More specifically, these projects concerned:

- Excavation, transportation and safe deposition of polluted soils, derived from various positions within the borders of LTCP, at a specially formed location, within the park.
- Formation of an underground space, within the borders of LTCP, for purposes of accepting special hazardous waste which, for technical and environmental safety reasons, cannot mix with soils deposited at the Landfill Site.
- Targeting on the environmental reinforcement of the aforementioned large scale technical projects, a Laboratory specialized in environmental measurements was founded, in LTCP.

Furthermore, another important environmental project is under implementation, concerning the decontamination and rehabilitation of a heavily polluted and with significant structure issues building ("Konofagos Building").

Especially as far as it concerns the Environmental Impact Assessment of the Landfill Site, it was approved by the local Municipality Board. Besides, there was a continual and assiduous monitoring for the proper construction and operation of the projects, with the assistance of the LTCP's lab and other NTUA Laboratories. Monitoring is not restricted to the implementation of the environmental terms concerning the particular projects, but it expands to the implementation of additional measurements and tests, so as to highlight the rehabilitation project as a prototype for the construction of similar projects, especially in terms of safety and environmental protection.

4.3.2 The Metsovion Interdisciplinary Research Center (M.I.R.C.)

The Metsovion Interdisciplinary Research Center (M.I.R.C.) was founded in 1993 by the National Technical University of Athens (NTUA). Since 2015, it is an interschool laboratory of the NTUA. Its establishment and operation constitute a symbolic act of paying back a part of the debt of the NTUA to the homeland of its founders and great benefactors. It is the sole research center in Greece which is specialized in mountainous regions, in a country with a surface over 70% mountainous. M.I.R.C. aims at the revival of the mountainous Greece on a sound basis, the equal participation of mountainous and remote societies to the opportunities for development and the protection of the fragile ecosystems. The advancement of the knowledge about mountains is a worldwide priority, today. The

[2] https://en.ltcp.ntua.gr/about/

mountains of the world suffer, to a great degree, from the same problems, the confrontation of which is essential for the equilibrium of the planet.

The objective of the research activity of M.I.R.C. is the mountainous environment and the local cultures. More specifically, the characteristics of the natural environment are studied - forests, water, ecosystems, resources, energy, etc., as well as the elements of the communities and the local cultures that have been developing in mountains - social structures, institutions and functions, traditional cultures, built environment, etc. In addition, the current development of mountainous areas and the forefront, crucial issues between the environment (natural and manmade) and the development of mountainous areas. Geographically, the research objective focuses on Greece, mainly, but also on Europe and other countries of the world. The support of the educational activities of the MSc programme is one of the main priorities of M.I.R.C. In addition, it is aiming at the collaboration with several research centers and organizations of the country and from abroad. Also, at the implementation of research programmes and the collaboration with public and private organizations for the provision of support to the mountainous regions of the country. An important part of M.I.R.C.'s activities is the organization of conferences, meetings, seminars, lectures and a variety of other relative scientific activities. Since 1995 (until 2017) M.I.R.C. has organized eight (8) conferences regarding issues of environment and development of mountainous and remote areas.

The aim of M.I.R.C., in collaboration with the MSc Programme, is to bridge the gap regarding the lack of research and education for mountains at national level, to build, substantiate and armor the knowledge on mountainous Greece, to function as the central pole of concentration and diffusion of this knowledge to the net of mountainous Municipalities of the country and to become the official institute for an integrated policy and planning for the mountains in Greece. Although the main research objective of M.I.R.C. is the mountainous space, it also focuses on a further investigation of issues regarding isolated areas, in general, with an emphasis on small islands.

4.3.3 The first Greek Energy Competence Center at NTUA-ICCS

The National Technical University of Athens (NTUA) and the Institute of Communication and Computer Systems (ICCS) have recently announced the establishment of the first Energy Competence Center in Greece, a cluster that aims to support and promote innovation, entrepreneurship and technical competencies among enterprises that are operating in the energy sector - a fundamental pillar of the Greek economy.

According to the recent decision of the General Secretariat for Research and Innovation (GSRI) that announces the successful evaluation and approval of the Energy Competence Center, the Competence Center will be formed as a spinoff company targeting to the capitalization of relevant research results and know-how produced by universities or other knowledge-producing public organizations in Greece or abroad. In this context, the Energy Competence Center will constitute a public-private partnership scheme, aiming to bridge the gap between demand and supply of specialized innovation services and technology transfer in the energy sector.

The National Technical University of Athens (NTUA)/Special Account for Research Funding has undertaken the coordinating role for the establishment of the Energy Competence Center on behalf of the collaborating bodies. Twelve additional bodies – significant Greek higher education institutions, research institutions as well as companies active in the energy, environment and economy sectors – are participating to the Energy Competence Center, namely: Institute of Communication and Computer Systems, University of Western Macedonia, DEPA COMMERCIAL SA, Motor Oil Hellas Corinth Refineries SA, MYTILINEOS SA, EYDAP SA, OASA SA, DANAOS Management Consultants SA,

HYDRUS ENGINEERING LTD, Trikala Development Agency SA, National Observatory of Athens, Environmental Protection Engineering SA.

According to the medium-term strategy of NTUA and ICCS, the main activities of the Energy Competence Center will relate to:

- Joint use of facilities and equipment, exchange knowledge and expertise, networking, information dissemination and collaboration between enterprises and other organizations/bodies of the Energy Competence Center.
- Encouraging transfer of technological solutions and innovations to production processes and/or for the production/supply of products/services resulting from the development, adoption, and diffusion of new technologies to companies, to improve their competitiveness.
- Staff training for companies, aiming to the acquisition of relevant skills.
- Implementation of innovative research projects and the development of services/products, actions to promote innovation in domestic entrepreneurship.

In particular, for the business sector and towards their technological and digital transformation, the Energy Competence Center will set priorities focusing on the encouragement of transferring technological solutions and innovations in production processes, the orientation of companies to products and services of high added value, development of comparative advantages, the development of extrovert entrepreneurship and their further networking. Additionally, an important goal is the training of companies' staff for the acquisition of skills in industry with an emphasis on Industry 4.0.

4.3.4 Participation in Research and Innovation Projects

NTUA participates in a series of projects targeting environmental challenges. Following, we refer to some indicative projects that are active during this time period.

H2020 ARSINOE - Climate Resilient Regions Through Systemic Solutions and Innovations

Acknowledging that climate change is complex and strongly connected to other global challenges, such as food security, water scarcity, biodiversity depletion and environmental degradation, it is insufficient to use traditional approaches to innovation that focus on one aspect of the problem.

Systems Innovation Approach (SIA) addresses the developing complexity, interdependencies and interconnectedness of contemporary societies and economies, covering the functions of the cross-sectoral system as a whole and the respective variety of stakeholders. The Climate Innovation Window (CIW) refers to the European Union's innovations marketplace for climate adaptation technologies.

Towards this direction, the ARSINOE project aims to develop a methodological framework for the combination of SIA with the CIW to create an ecosystem under a three-tier approach: (a) integration of multi-faceted technological, digital, business, governance and environmental aspects with social innovation for the development of adaptation pathways to climate change, so as to meet EU Green Deal targets for specific regions; (b) linkage with CIW to form innovation packages by matching innovators with end-users/regions; (c) fostering the ecosystem sustainability and growth with cross-fertilization and replication across scales, at European level and beyond, using appropriate business models and exploitation-outreach actions.

ICCS/NTUA participates at the ARSINOE consortium, being responsible for the development of knowledge management and agent based modeling solutions for supporting participatory socio-environmental systems modeling and analysis.

H2020 BD4NRG[3] - Big Data for Next Generation Energy

The rising decentralization of the energy system is unveiling an enormous opportunity for energy stakeholders to leverage on big data & AI technologies to improve decision making. There are however some barriers hampering the exploitation of this potential, such as the lack of standardized big data architectures for smart grids and regulatory frameworks not enabling data sharing. In that respect BD4NRG will:

- deliver a reference architecture for Smart Energy, which aligns BDVA SRIA, IDSA and FIWARE architectures, SAREF standard and extend COSMAG specification to enable B2B multi-party data exchange, while providing full interoperability of leading-edge big data technologies with smart grid standards and operational frameworks
- evolve and upscale a number of TRL 5-6 technology enablers, such as scalable sovereignty-preserving hybrid DLT/off-chain data governance, big data elastic pipeline orchestration, IoT/edge AI-based federated learning and multi-resource sharing tokenized marketplace, loosely integrate and deploy them within the TRL 7-8 BD4NRG framework
- deliver a TRL8 open modular big data analytic toolbox as front-end for one-stop-shop analytics services development by orchestrating legacy and/or third-party assets (data, computing resources, models, algorithms)
- validate such framework through the delivery of predictive and prescriptive edge AI-based big data analytics on 13 large scale pilots, deployed by different energy stakeholders (TSOs and DSOs power network operators, aggregators, storage/renewable assets operators, local energy communities, ESCOs, power market operators, municipalities, financial institutions, and ENTSO-E), fully covering the energy value chain
- setup a vibrant data-driven ecosystem through the SGBDAA Alliance, which will federate new energy data providers, attract SMEs for novel energy services provisioning through cascading funding and validate a hybrid energy/industry value chain supporting B2B joint digital platforms.

H2020 CALIPER[4] - The CALIPER project: Linking research and innovation for gender equality

The CALIPER Project is an Horizon2020 Action that aims to support 7 Research Performing Organisations (RPOs) and 2 Research Funding Organisations (RFOs) across Europe to design, implement, evaluate and expand Gender Equality Plans (GEPs).

CALIPER will create strong linkages between the research and local innovation ecosystems in the countries of the involved Partners to ensure structural and institutional changes targeted at the following levels:

- Recruitment, working conditions and career development of women.
- Governance/management structures and the role of women.
- Research content and programs and their gender dimension.
- Research funding.
- Innovation and its transfer to the market.

COST Action - European Energy Poverty: Agenda Co-Creation and Knowledge Innovation

In November 2017, a major COST action started, under the title European Energy Poverty: Agenda Co-Creation and Knowledge Innovation. M.I.RC. participates in the Management Committee of the action

[3] http://www.bd4nrg.eu/

[4] https://caliper-project.eu/

and its researchers are going to introduce the issue of the vulnerability of mountainous areas to energy poverty and their need for specialized energy policies.

5 Sustainability of the project results

All the results produced during the three years that the project lasted, are uploaded on the project website https://smartedu40.eu. On the website, there is information such as the description and the aim of the project, the deliverables that have been created, the news of the project, the dissemination material that have been produced and used to advertise the project, as well as very interesting courses that were developed within the project.

Some of the courses that were designed from scratch and developed within the Smart-Edu4.0 Erasmus+ project is the "Sustainability" course and the "Introduction to Mechatronics" course. The Sustainability course consists of ten individual lectures. A power point presentation and a brief description of the subject of the lecture are available for each one. The Mechatronics course consists of eight short YouTube videos that highlight the essence of Mechatronics and explore some practical applications.

The consortium will maintain the website for three years after the end of the project, i.e., until August 2026 in order all interested parties to have sufficiently long period of time to access it and take advantage of the material produced by the project.

Finally, the partners will continue their great collaboration on many levels such as in research papers and projects but also in terms of exchanging course material and knowledge sharing.

6 Development of a course on Sustainability

For the needs of the Smart-Edu4.0 Erasmus+ project, the NTUA team developed a course about Sustainability. This course is available on the project's website under Course Material in the Results page.

The course introduces and analyses the following topics:

- What is Sustainability
- Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs)
- Sustainability in Industry4.0
- How industry4.0 can help to achieve SDGs? The Ceramic Industry Case Study
- Sustainability Indicators and Performance Metrics
- Sustainability and IoT (Part 1 & Part 2)
- Sustainability and Mechatronics
- Sustainability and Edge Cloud Computing
- Sustainability and Agriculture and Food Technology

For each one of the above fields, there is a power point presentation of approximately 30 slides and a brief description of what is included in the presentation. The lectures are independent from each other however, there are presented here in such an order to maintain clarity and continuity. Below there is a brief description for each lecture.

Finally, we developed two additional summary presentations on sustainability **here** where the most important topics on sustainability are briefly presented.

The sustainability course is planned to be used by QUB as part of an existing university course. It has not been determined yet in which course it will be taught and whether this course is part of an undergraduate or postgraduate program.

6.1 What is Sustainability

This lecture is an introduction to Sustainability. Sustainability is a term used to describe the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs. It is a broad concept that encompasses environmental, social, and economic dimensions.

Sustainability has three pillars: economic, social, and environmental. The economic pillar involves ensuring that resources are used in a way that is financially sustainable, meaning they can be used in a way that is profitable in the long term. The social pillar involves ensuring that resources are used in a way that promotes social well-being, meaning they benefit society as a whole. The environmental pillar involves ensuring that resources are used in a way that is environmentally sustainable, meaning they do not harm the environment and can be used indefinitely.

Other key notes on sustainability are inter-generational equity and holistic approach. Inter-generational equity refers to the idea that current generations have a responsibility to preserve resources for future generations. Holistic approach recognizes the interconnectedness of environmental, social, and economic systems.

Sustainability is important because it is the key to a better future. By practicing sustainability, we can ensure that we are leaving a better world for future generations. We can reduce our impact on the environment, reduce waste and pollution, and promote social and economic well-being.

There are workplace strategies that promote sustainability and enable conservation of energy and resources in the workplace. Also, there are many ways to practice sustainability in our daily lives. Some examples include reducing energy consumption, recycling, using public transportation, and supporting sustainable businesses. By making small changes in our daily lives, we can contribute to a more sustainable future

Overall, sustainability is a complex and multifaceted concept that involves balancing the needs of the present with the needs of future generations. It requires a comprehensive and collaborative approach to decision-making that recognizes the interconnectedness of environmental, social, and economic systems.

6.2 Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs)

The second lecture “Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs)” illustrates the two sets of global development goals that were developed by the United Nations to guide global efforts towards poverty reduction, sustainable development, and social equity.

Below are some key notes on the MDGs and SDGs:

Millennium Development Goals (MDGs):

1. The MDGs were developed in 2000 and consisted of eight goals with specific targets to be achieved by 2015.
2. The goals focused on reducing poverty and hunger, improving education and health, promoting gender equality, and addressing environmental sustainability.
3. The MDGs were successful in reducing poverty, increasing access to education and healthcare, and promoting gender equality. However, progress on environmental sustainability was limited.

Sustainable Development Goals (SDGs):

1. The SDGs were developed in 2015 and consist of 17 goals with 169 targets to be achieved by 2030.
2. The goals are more comprehensive than the MDGs and aim to address a wide range of social, economic, and environmental challenges, including poverty, hunger, health, education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice, and strong institutions, and partnerships for the goals.
3. The SDGs are more inclusive and participatory than the MDGs and were developed through an extensive process of consultation with a wide range of stakeholders, including civil society, business, and academia.
4. The SDGs are intended to be universal and apply to all countries, regardless of their level of development.

Overall, the MDGs and SDGs represent important milestones in global efforts towards poverty reduction, sustainable development, and social equity. While the MDGs made progress in many areas, the SDGs aim to build on this progress and address a broader range of challenges. Achieving the SDGs will require strong political will, innovative partnerships, and sustained effort from all sectors of society.

6.3 Sustainability in Industry4.0

This lecture highlights the reason why sustainability is becoming an increasingly important consideration in Industry 4.0. It refers to the current trend of automation and data exchange in manufacturing technologies, demonstrates the importance of sustainable practices in manufacturing and explores how Industry 4.0 can be used to achieve sustainability goals.

There are four pillars of sustainability: environmental, social, economic, and cultural. These pillars are crucial in achieving sustainable development goals (SDGs).

The Triple Bottom Line (TBL) concept is presented as a framework for assessing an organization's performance in three areas: environmental, social, and economic. The TBL approach ensures that companies take into account their impact on people, the planet, and profit.

The United Nations' Sustainable Development Goals (SDGs) are explored. The SDGs are a set of 17 goals that aim to end poverty, protect the planet, and ensure prosperity for all. The presentation highlights the importance of using technology to achieve these goals.

There is a discussion about the technologies employed in Industry 4.0 (I4.0), which encompass the Internet of Thing, robotics, cloud computing and big data analytics. These technologies are essential in achieving sustainable development goals.

The benefits and drawbacks of Industry 4.0 are discussed, with emphasis on its potential to enhance productivity and lower expenses, as well as its tendency to cause unemployment and harm the environment. The application of Industry 4.0 to sustainable architecture, is presented showcasing how technologies can be utilized in the construction and design of buildings to minimize energy consumption and waste.

There are advantages and disadvantages of Industry 4.0. While I4.0 has the potential to increase efficiency and reduce costs, it can also lead to job displacement and environmental degradation.

Industry 4.0 can help achieve sustainability goals. Important is the use of IoT in tracking and monitoring energy and resource usage, as well as the implementation of circular economy principles to reduce waste and improve resource efficiency.

Overall, sustainability is an important consideration in Industry 4.0, as it offers opportunities to reduce environmental impact, improve resource efficiency, and promote a more sustainable economy. Industry 4.0 technologies can enable more efficient and sustainable production and consumption practices, while also facilitating greater collaboration and innovation towards sustainability goals.

6.4 How industry4.0 can help to achieve SDGs? The Ceramic Industry Case Study

The lecture “How industry4.0 can help to achieve SDGs? The Ceramic Industry Case Study” presents approaches for industry 4.0 to achieve the Sustainable Development Goals (SDGs). Enabling more efficient and sustainable production and consumption practices, reducing waste and emissions, promoting sustainable supply chains, facilitating collaboration and innovation towards sustainability goals are some of the practices discussed in the presentation.

The presentation focuses on the intersection of Industry 4.0 (I4.0) and Sustainable Development Goals (SDGs). The first section explores the technologies used in I4.0, which include, the Internet of Things, robotics, additive manufacturing, cloud computing, big data and analytics.

Next, the presentation highlights the potential benefits of I4.0 in achieving SDGs, including increased efficiency, productivity, and reduced waste. Industry 4.0 technologies can help improve resource efficiency by optimizing processes and reducing waste. This can help achieve SDG 12 (responsible consumption and production). Industry 4.0 can help promote a transition towards a circular economy by enabling the reuse and recycling of materials. This can help achieve SDG 12. Also, Industry 4.0 can help promote more sustainable supply chains by providing greater transparency and traceability. This can help achieve SDG 8 (decent work and economic growth) and SDG 12. Last, but not least Industry 4.0 can help promote the use of renewable energy sources and improve energy efficiency. This can help achieve SDG 7 (affordable and clean energy) and SDG 13 (climate action).

This lecture also discusses some of the challenges associated with the adoption of I4.0, such as the high cost of implementation and potential job displacement.

The case study features a manufacturing company in the ceramic industry and explores the company's initial production characteristics, three production phases, and their current adoption of I4.0. The economic impact of the company's adoption of I4.0 is discussed, along with the environmental impact and social impact achieved results.

Overall, the presentation highlights the potential of I4.0 towards achieving the SDGs, while acknowledging the challenges and opportunities associated with its adoption. The case study provides real-world examples of the benefits and limitations of I4.0 in a specific industry context.

6.5 Sustainability Indicators and Performance Metrics

As sustainability indicators and performance metrics are essential tools for measuring and evaluating sustainability efforts, this lecture is dedicated to them. They provide a way to track progress, identify areas for improvement, and communicate sustainability performance to stakeholders.

Sustainability indicators are quantitative or qualitative measures that provide information about the environmental, social, and economic aspects of sustainability. They can be used to assess the impact of activities, policies, or programs on the sustainability of a system.

Performance metrics are specific, measurable, and time-bound targets used to evaluate the performance of an organization or system. They are typically used to track progress toward achieving sustainability goals.

Reporting on sustainability indicators and performance metrics is an essential part of sustainability management. Organizations can use sustainability reports to communicate their sustainability performance to stakeholders and demonstrate their commitment to sustainability.

The presentation focuses on the importance of measuring and monitoring sustainability performance metrics, particularly as they relate to the United Nations' Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs). The presentation covers the use of indicators as a tool of measurement, their role in SDGs, and the characteristics of a good indicator. Additionally, the presentation explores the four steps to build an indicator and the standardization of indicators. It highlights different types of sustainability indicators, including OPI, MPI, ECI, and the AIChE Sustainability Index. The presentation also discusses CSBR Sustainability Performance Metrics, which includes environment and human health, and sustainability reporting tools. The different types of sustainability indicators and the reporting tools have an important role in promoting sustainable development.

Overall, sustainability indicators and performance metrics provide a valuable way to measure and evaluate sustainability efforts, track progress, and communicate sustainability performance to stakeholders. When developed and used effectively, they can help organizations to achieve their sustainability goals and contribute to a more sustainable future.

6.6 Sustainability and IoT (Part 1)

Sustainability and the Internet of Things (IoT) are two important and interrelated topics. The IoT refers to the network of physical devices, vehicles, home appliances, and other items embedded with sensors, software, and connectivity which enable them to connect and exchange data. Sustainability, on the other hand, is the ability to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. In this context, the IoT can play a crucial role in promoting sustainable practices and addressing global challenges such as climate change, resource depletion, and environmental degradation.

The presentation on "Sustainability and IoT – Part 1" covers a wide range of topics related to the application of the Internet of Things (IoT) in various industries and domains. It begins by introducing the concept of IoT and how it works, along with the key factors for developing IoT applications.

The presentation then delves into the different consumer and enterprise IoT applications, including those in industry, smart cities, agriculture, waste management, healthcare, and transportation. One

of the most well-known examples of IoT in transportation is Google Traffic, which uses real-time data from various sources to provide users with accurate traffic information.

The use of sensors in IoT and their applications in various domains are also demonstrated. The use of IoT in waste management, healthcare, and agriculture is highlighted, along with the role of IoT in smart grids and power management.

Furthermore, the various IoT technologies that contribute to sustainable energy and environment are displayed, and how the rise in energy demand is propelling the adoption of smart grid and smart city IoT solutions. Industry, building, and homes IoT solutions, along with data center IoT solutions, are also presented.

Finally, the presentation concludes by emphasizing the importance of transforming data from IoT and how sustainability and IoT can create connected technologies that contribute to a sustainable future. Overall, an insightful overview of the role of IoT in sustainability and its potential to revolutionize the way we live, work, and interact with the world around us is demonstrated.

6.7 Sustainability and IoT (Part 2)

Sustainability and the Internet of Things (IoT) are two important and interrelated topics. The IoT refers to the network of physical devices, vehicles, home appliances, and other items embedded with sensors, software, and connectivity which enable them to connect and exchange data. Sustainability, on the other hand, is the ability to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. In this context, the IoT can play a crucial role in promoting sustainable practices and addressing global challenges such as climate change, resource depletion, and environmental degradation.

The presentation on “Sustainability and IoT– Part 2” covers several aspects of the Internet of Things (IoT) and its contribution to achieving Sustainable Development Goals (SDGs). The first section highlights the role of IoT in achieving SDGs, while the second section presents various examples of IoT technology applications, such as smart city architecture, efficient IoT radio units, and IoT-based solutions for ambient assisted living (AAL) domain.

Other examples include monitoring and tracking systems for patients with medical problems, RFID solutions for steel mills, integrated frameworks to track and monitor shipped packages, and IoT and block chain technologies for smart logistics and food traceability systems. The presentation also explores the potential of IoT in changing aspects of artificial light and water management.

IoT adoption in developing countries and the challenges associated with it are also discussed. Moreover, various policy aspects related to IoT and sustainable development, including the Alliance for Internet of Things Innovation (AIOTI), key challenges in the EU, and EC call for proposals are included.

Overall, an insightful overview of the role of IoT in sustainability and its potential to revolutionize the way we live, work, and interact with the world around us is provided.

IoT can play a vital role in promoting sustainability by optimizing energy use, reducing waste, promoting efficient transportation, and improving resource management.

6.8 Sustainability and Mechatronics

Sustainability and mechatronics are two areas that are increasingly interconnected. Mechatronics is a field of engineering that combines mechanical, electrical, and computer engineering to design and develop intelligent systems and products. Sustainability, on the other hand, is the ability to maintain or improve the well-being of the planet and its inhabitants for the long term.

The presentation on “Sustainability and Mechatronics” starts by defining what Mechatronics is and explaining its relationship with Engineering and Sustainability. It highlights the challenges and opportunities that come with combining Mechatronics and sustainability, and also discusses related domains like Cyber-Physical Systems, Robotics, and Autonomous Robots.

The presentation focuses on the Concurrent Engineering Workflow, which is an approach to designing and manufacturing Mechatronic systems that takes into account their sustainability impact. The relationship between manufacturing processes and Industry 4.0 is also discussed, along with approaches to design and communication issues.

Sustainable Manufacturing (SM) is a crucial aspect, and the main approaches to SM over time are discussed. The 6R and TBL dimensions are introduced as a sequence of SM processes, and their importance is highlighted.

Moreover, the Applications of Mechatronics, including the use of Big Data and Analytics, and Industry 4.0 to enhance sustainable manufacturing are demonstrated. The data acquisition, munging, storage, management, analytics, and user access layers are all explained.

A case study of a cement factory is presented to illustrate the implementation of sustainable manufacturing models in industry. The Smart Production and Smart Maintenance architectures are discussed, along with the configuration of the sustainable manufacturing model for cement plants.

Finally, the presentation concludes with a discussion of the future of Mechatronics Applications and Sustainability, highlighting the need for continued research and development in this important area.

Overall, mechatronics can play a vital role in promoting sustainability by designing and developing intelligent systems and products that reduce energy consumption, promote the use of sustainable materials, support the use of renewable energy sources, and reduce waste.

6.9 Sustainability and Edge Cloud Computing

Sustainability and edge cloud computing are two important topics that are becoming increasingly intertwined. Edge cloud computing is a model where data processing and storage occur closer to the end-users or devices generating the data, rather than in a centralized data center. Sustainability, on the other hand, is the ability to maintain or improve the well-being of the planet and its inhabitants for the long term. Some topics on the relationship between sustainability and edge cloud computing are the following.

- **Energy Efficiency:** Edge cloud computing can contribute to sustainability by reducing the energy consumption required for data processing and storage.
- **Renewable Energy:** Edge cloud computing can also support the use of renewable energy sources by processing data closer to renewable energy sources.
- **Reduced Latency:** Edge cloud computing can also contribute to sustainability by reducing the latency required for data processing and storage. This reduced latency can reduce the overall energy required for data processing and storage.

- **Smart Grids:** Edge cloud computing can also support the development of smart grids. Smart grids are intelligent power distribution networks that can balance the supply and demand of energy, reducing waste and increasing efficiency.
- **Reduced E-Waste:** Edge cloud computing can also contribute to sustainability by reducing e-waste. This reduced need for device upgrades can reduce the overall amount of e-waste generated.

The benefits of adopting sustainable cloud computing practices are outlined, such as cost savings, reduced carbon emissions, and improved corporate social responsibility.

The presentation also includes case studies such as smart cities, sustainable agriculture, face recognition, etc. to showcase the benefits of edge cloud computing.

Furthermore, the presentation addresses challenges and limitations of using edge cloud computing for sustainability and concludes by summarizing the main points discussed.

Overall, edge cloud computing can play a vital role in promoting sustainability by reducing energy consumption, supporting the use of renewable energy sources, reducing latency, supporting the development of smart grids, and reducing e-waste.

With the increasing importance of environmental sustainability in today's world, edge computing has emerged as a promising tool that can help promote more sustainable practices and reduce the environmental effects of human activities.

6.10 Sustainability and Agriculture and Food Technology

Sustainability and agriculture and food technology are two areas that are increasingly interconnected. Agriculture and food technology involve the use of technology to improve the efficiency and sustainability of agriculture and food production. Sustainability, on the other hand, is the ability to maintain or improve the well-being of the planet and its inhabitants for the long term. The following are some notes on the relationship between sustainability and agriculture and food technology:

1. Sustainable Agriculture Practices: Discussing sustainable agriculture practices such as crop rotation, cover cropping, intercropping, conservation tillage, and integrated pest management that can improve soil health, reduce water usage, and minimize environmental impacts.
2. Precision Agriculture: Precision agriculture is a technology-based approach to farming that involves using sensors, drones, and other tools to gather data about crop health, soil quality, and weather patterns. This information is then used to optimize crop production, reduce waste, and minimize the use of resources such as water and fertilizer.
3. Sustainable Food Processing: Examining how sustainable food processing practices, such as energy-efficient technologies, use of renewable energy sources, and waste reduction techniques, can help reduce environmental impacts and enhance the sustainability of the food industry.
4. Sustainable Packaging: Sustainable packaging is an important part of the agriculture and food technology industry. By using sustainable packaging materials, such as biodegradable plastics, companies can reduce the environmental impact of their products.
5. Food Waste Reduction: Agriculture and food technology can also contribute to sustainability by reducing waste. By using technology to optimize production and reduce food waste, companies can reduce the environmental impact of agriculture and food production.

6. Sustainable Supply Chain: Highlighting the importance of sustainable supply chains in the food industry, including responsible sourcing of raw materials, reducing carbon footprint, and minimizing waste and emissions throughout the supply chain.
7. Plant-Based Alternatives: Plant-based alternatives refer to products that are made from plant-based ingredients as a substitute for animal-based products. Here are some key points on plant-based alternatives in agriculture and food technology.
8. Underutilized Ingredients: Underutilized ingredients refer to food items that are often overlooked or discarded, despite being nutritious and flavourful. These ingredients can include plant-based foods such as fruits, vegetables, and grains, as well as animal-based foods such as offal and bone broth.

Overall, agriculture and food technology can play a vital role in promoting sustainability by optimizing crop production, reducing waste, promoting the use of sustainable packaging, developing plant-based alternatives to animal products, and reducing the environmental impact of agriculture and food production.

7 Curriculum evaluation for compatibility with the SDGs

Using the software tool SDGDetector that was developed by the NETMODE laboratory of the School of Electrical and Computer Engineering at NTUA, we evaluated the courses related to manufacturing mechatronics that offered by the institutions of the project partners. In order to accomplish a sustainable and climate-resilient future, the development of education programmes that integrate information in accordance with the targets defined in the Sustainable Development Goals (SDGs) is considered crucial.

The SDGDetector software library provides the relationship of a given text with the SDGs. It gets as input text and provides as output indexes for the relationship of the text with the SDGs. It combines two machine learning techniques: i) a keywords extraction and mapping technique, and ii) a deep learning Natural Language Processing (NLP) technique. In the first technique, mapping of the keywords identified in the given text is provided with existing well-known keywords classifications for the SDGs (https://sustainability.utoronto.ca/inventories/sustainable-development-goals-sdgs-keywords/, https://ap-unsdsn.org/regional-initiatives/universities-sdgs/). An overview of the functionality of the SDGDetector is illustrated in Figure 3.

Figure 3 - High level overview of SDGDetector functionality

Below, there are the most relevant to manufacturing mechatronics courses whose content was analysed through the SDGDetector tool in order to find out whether they meet the SDG goals.

National Technical University of Athens (NTUA)

1. Industrial Electronics
2. Sensors and Microsystems Technology
3. Robotics I: Analysis - Control - Laboratory
4. Robotics II: Intelligent Robotic Systems
5. Engineering Mechanics
6. Logic Design of Digital Systems
7. Computer Programming
8. Structure and Electrical Properties of Materials

Queen's University Belfast (QUB)

1. Robotics and Intelligent Systems
2. Research and Data Analytics
3. Engineering Enterpreneurship
4. Employability Skills and Placement Preparation
5. Embedded systems
6. Control methods for Cyber-Physical Systems
7. Control and Estimation Theory
8. Computer Aided Engineering

South Eastern Regional College (SERC)

1. L4 Digital Manufacturing Infrastructure
2. L4 IIOT
3. L4 Mechatronic Systems & Control
4. L4 Programming Fundamentals
5. L5 Computer Aided Engineering
6. L5 Data Analytics & AI
7. L5 IIoT Data Security
8. L5 Manu Sys Management

University of Limerick (UL)

1. LOW-COST AUTOMATED SYSTEMS
2. MECHATRONICS PROJECT 1
3. MECHATRONICS DESIGN PROJECT
4. AUTOMATED SYSTEM DESIGN
5. 3D CAD MODELLING AND MACHINE DESIGN
6. ADVANCED AND EMERGING MANUFACTURING TECHNOLOGIES
7. SYSTEM INTEGRATION
8. AUTOMATION AND CONTROL
9. DIGITAL CONTROL
10. GLOBAL BUSINESS STRATEGY
11. PROJECT MANAGEMENT IN PRACTICE
12. MACHINE VISION

The produced results are provided in Figures 4, 5, 6 and 7. Figure 4 presents the courses of the National Technical University of Athens. It is clear that the SDG #7 “Affordable and clean energy” has the highest relevance with the provided courses, followed by the SDG #9 “Industry, innovation and infrastructure” and the SDG #4 “Quality education”.

Figure 5 illustrates the relevance of the provided courses in mechatronics by the Queen’s University Belfast with the SDGs. We notice that the SDG #4 “Quality education” has the highest score, but also SDG #8 “Decent work and economic growth”, SDG #9 “Industry, innovation and infrastructure” and SDG #16 “Peace, justice and strong institutions” are highly represented.

Figure 6 demonstrates the courses of the South Eastern Regional College where the SDG #9 “Industry, innovation and infrastructure” clearly dominates.

Finally, figure 7 shows the courses in mechatronics that are offered by the University of Limerick. The SDGs #4 “Quality education”, #9 “Industry, innovation and infrastructure” and #7 “Affordable and clean energy” are the most relevant to the content of the courses.

The produced results seem reasonable, given the technical nature of the courses. However, we should consider the importance of including educational material for more SDGs such as the SDGs #11 (Sustainable cities and communities) and #12 (Responsible consumption and production) and increase the relevance of the material to the already related SDGs.

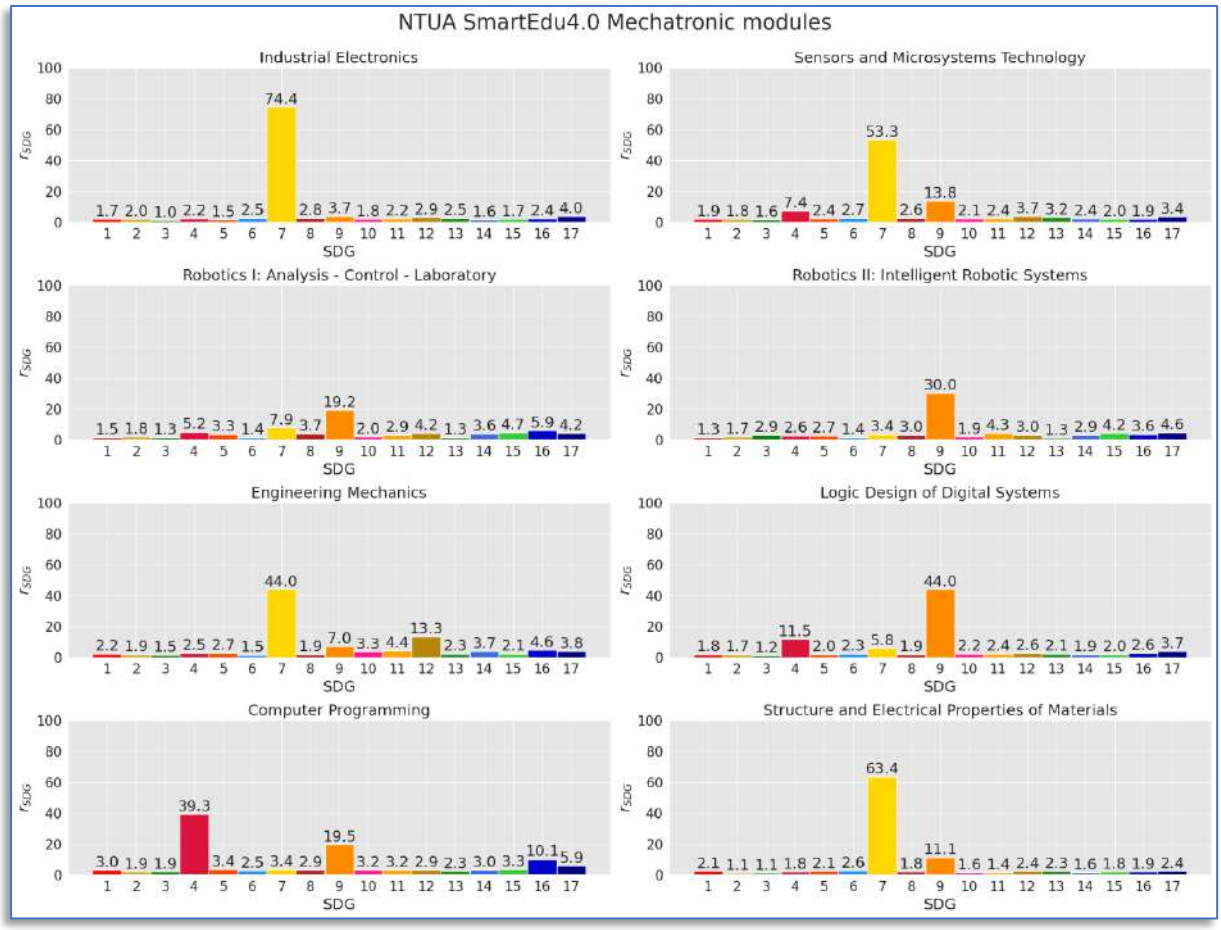

Figure 4 - Relationship of NTUA’s courses with the SDGs

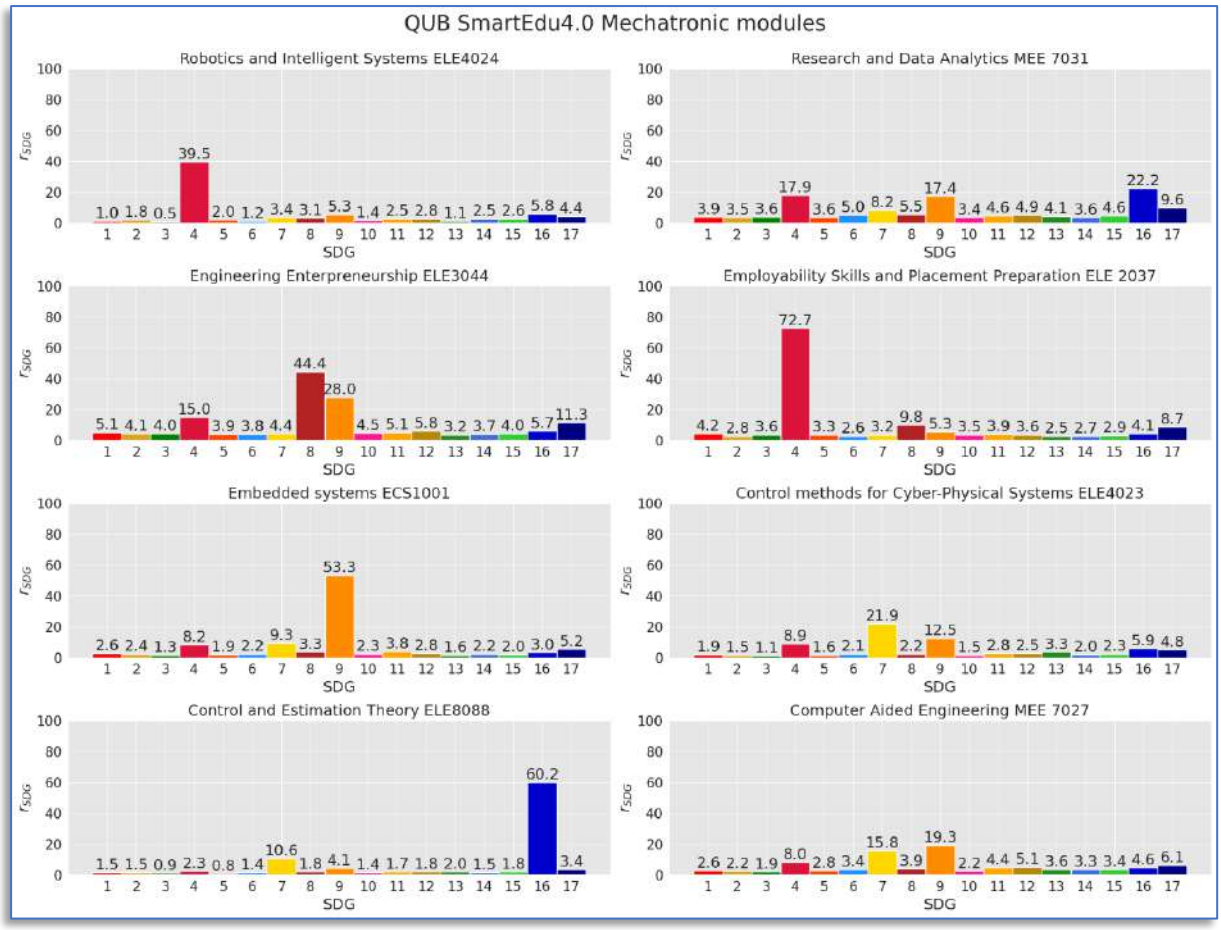

Figure 5 - Relationship of QUB's courses with the SDGs

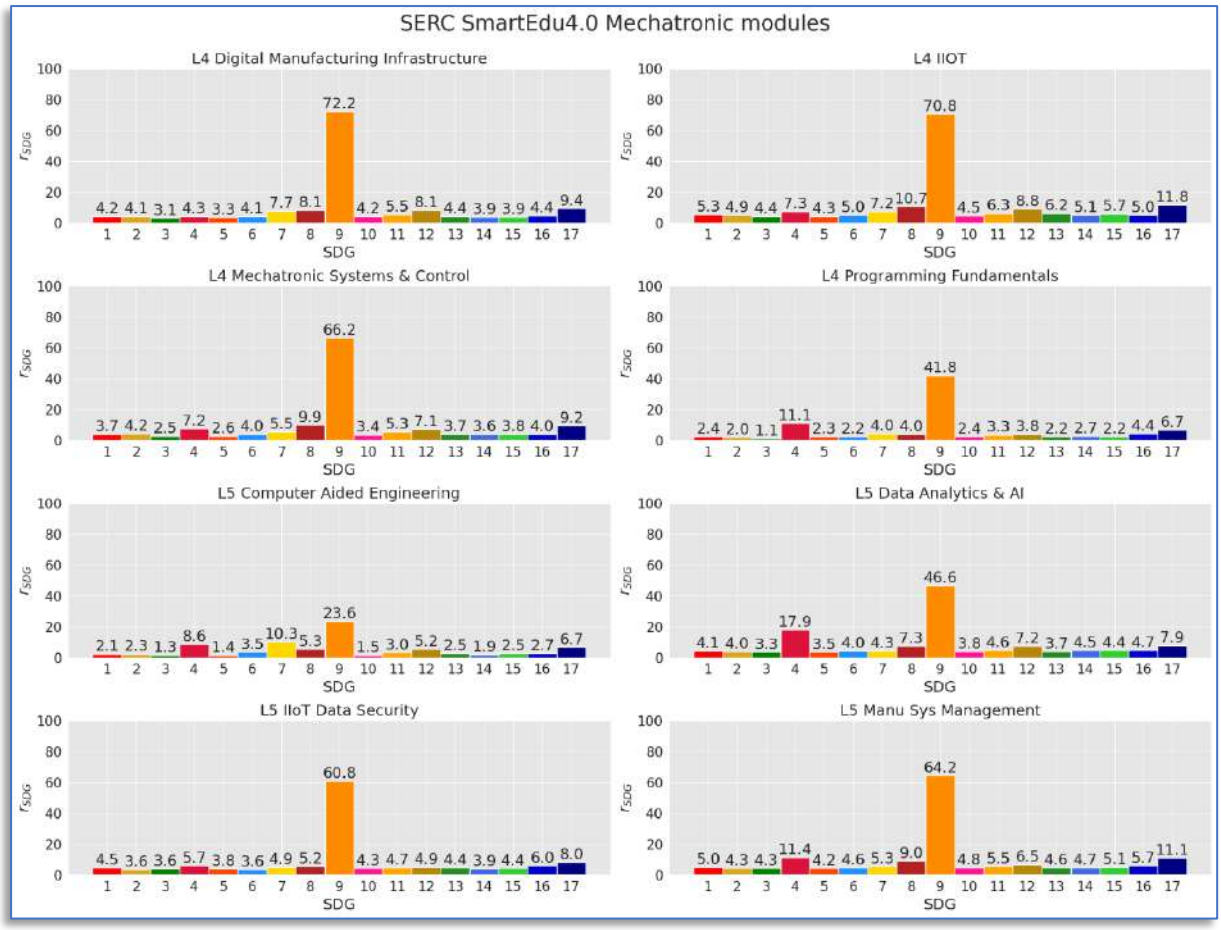

Figure 6 - Relationship of SERC's courses with the SDGs

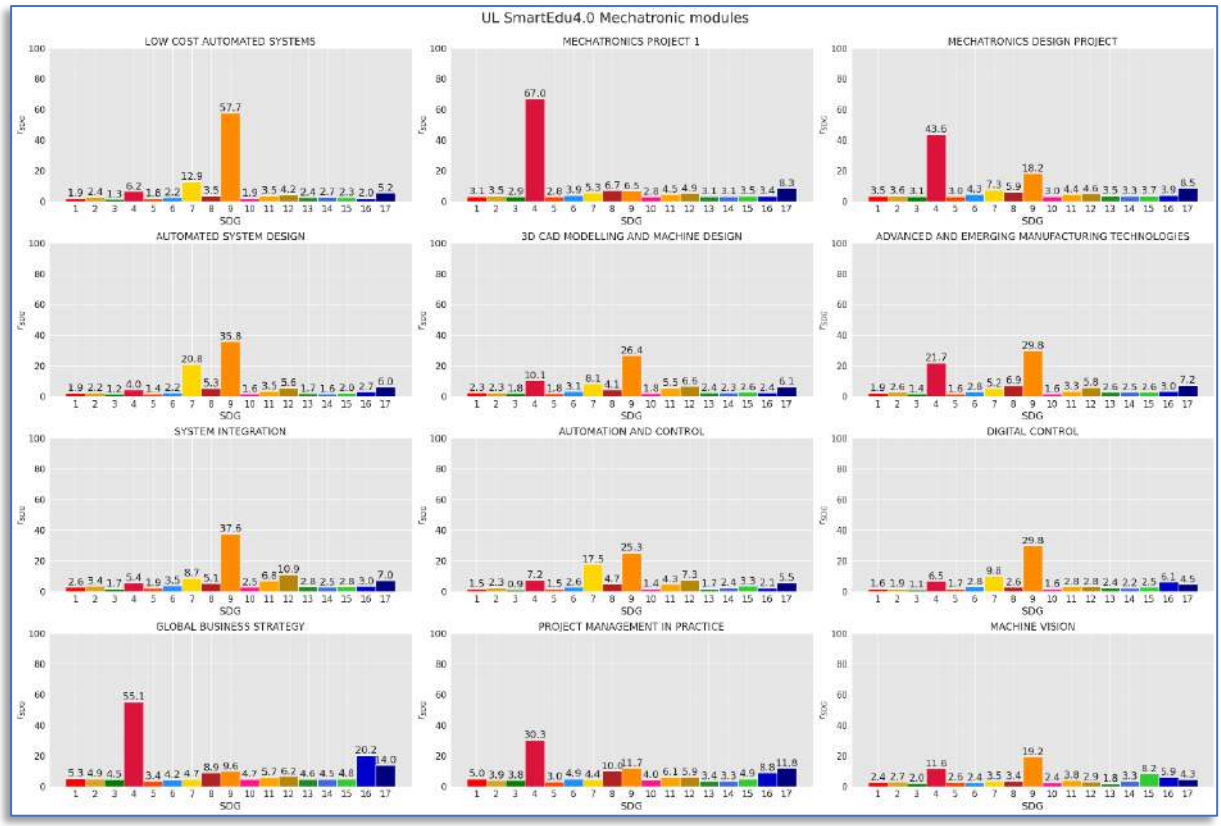

Figure 7 - Relationship of UL's courses with the SDGs

8 Conclusions

This document presents the sustainability actions that were implemented within the project. Initially, there are presented the practices of the partners in terms of the policy they follow for social and environmental sustainability and in this context, the available sustainability courses of the partners' institutions are demonstrated. Moreover, the actions and projects the partners are involved and are related to Sustainable Development Goals are illustrated. The sustainability of the results of the project is introduced and the course about Sustainability that was developed for the needs of the Smart-Edu4.0 project is thoroughly presented. Finally, the SDGDetector tool is displayed to evaluate educational programs.