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Sustainable Design: A Case Study in Energy Systems

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Chapter 16

Sustainable Design – A case study in energy systems

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Abstract: Since the publication of the UN climate report in 2007, most countries now agree that recent climate change has occurred as a result of human intervention and that it will require fast and profound measures to reduce this negative imprint imposed upon nature. Central to this is the need to radically reduce CO_2 emissions resulting from combustion of carbon-based energy resources to meet global energy demands. Greater measures must be taken to develop new non-combustion based technologies, in addition to using low-carbon energy resources. Increasing energy efficiency and using energy wisely will also feature in reducing emissions. Sustainable Energy is now to the fore in both Europe and the United States of America; with government core research agencies developing strategy and preparing scholarship research programmes, with invite to develop new ideas and provide innovative solutions to the needs of the energy sector. There is also evidence of greater critical self awareness by academics and researchers of the need to be more actively engaged in finding new solutions through interdisciplinary research. The terms 'sustainable development' and 'sustainable design' have become part of our everyday vocabulary, and there is now an active trend towards development of new curricula and degree programmes in sustainable energy. In this chapter we discuss the principles of sustainable development and sustainable design, and explore a range strategies and tools for the provision of engineering education. We provide some examples of syllabi and curricula developments in sustainable design, and we invoke a spirit of engagement in helping create a sustainable future.

Key words: sustainable development, sustainable design, energy systems, exergy analysis, engineering education.

"Then I say the Earth belongs to each generation during its course, fully and in its right no generation can contract debts greater than may be paid during the course of its existence". Thomas Jefferson, Sept.6, 1789

Introduction

Is it clear that mankind is working toward achieving a better understanding of his relationship with nature in fulfilling the dream of a "utopia of sufficiency" which spans at least the last five centuries (de Geus, 1999)? Has a new energy era - so called “The Third Industrial Revolution” - appeared on the horizon to provide a pathway by way of a number of small steps or indeed one giant leap for mankind towards sustainable social and economic development for this century and beyond? Have we started a trajectory of change or have we already developed unsustainable societies, a “utopia of abundance” with “ecological debt” on a global macro-scale to the micro example of Easter Island (Rapa Nui), facing catastrophic repercussions? The current indicators of global conditions seem to confirm worst-case scenarios and reveal how out of balance and unstable our relationship with the environment has become. Tropical forests are shrinking, new deserts are forming annually owing to land mismanagement, underground water tables are falling as demand for water rises above aquifer recharge rates, whilst we are facing the greatest extinction of wildlife since the demise of the dinosaurs. There is the ozone hole over the Antarctic and above all it is scientifically proven beyond doubt that the amount of greenhouse gases (GHG[1]) in the atmosphere is increasing at an accelerating rate, and global warming is resulting in thinning of the icecaps and melting of glaciers.

The first industrial revolution, which began in the second half of the eighteenth century, started in response to an energy shortage in Britain (Brinley, 1985). Again today, more than two and one half centuries on humankind is facing a similar though potentially a greater problem, with a need on the one hand to generate ever greater amounts of energy and the opposing necessity to reduce the damage inflicted by industrialization, transportation and existing energy production, storage and supply technologies. To quote Jeremy Rifkin *the rising cost of energy fuel and the deterioration of the earth’s climate and ecology are the driving factors that will condition and constrain all of the economic and political decisions we make in the course of the next half century* (Rifkin, 2007). In addressing these problems should we focus our efforts and resources on development of technology innovations in new energy generation, including fusion, hydrogen and renewable forms of energy, for example solar, wind, biomass, hydropower, ocean

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[1] It was not until the 1860s that an Irish scientist, John Tyndall, identified the radiative properties of water vapour and CO_2 in controlling surface temperatures. *"The waves of heat speed from our earth through our atmosphere towards space. These waves dash in their passage against the atoms of oxygen and nitrogen, and against molecules of aqueous vapour. Thinly scattered as these latter are, we might naturally think of them meanly as barriers to the waves of heat".*

(waves, tidal[2]), geothermal, and in removing of atmospheric carbon dioxide without harmful effects, or should we focus on further development of existing energy and transport systems, including clean coal technologies and nuclear energy with all the associated problems? At the present time there is no consensus on how best to balance future energy demand and supply development, with wide difference in opinion on the necessity of building new nuclear power plants and/or the lifetime prolongation of existing plants (IEA, 2007, Peter and Lehmann, 2008). In truth, development of new energy systems and improvements in both efficiency and ecological cleanliness of existing ones, will contribute to sustainable solutions. Whatever the future balance in energy development scenarios and policies, it is becoming apparent that sustainable design will be central to modern holistic engineering thinking and will be of critical importance in delivery of education to engineers of the twenty-first century (The Engineer of 2020, 2004).

The last twenty years has seen a period of transformation from one of scepticism owing to a lack of knowledge and factual scientific data in respect of global change and environmental damage, to one of enlightened consensus where it is know accepted that sustainable development and design is essential to all engineering endeavours if we are to positively influence a change in direction towards redressing the damage. In Deep Design, David Wann comments that *poor design is responsible for many, if not most, of our environmental problems* and searches a new way of thinking about design, exploring such issues as renewability, recyclability, and non-toxicity in developing design criteria (Wann, 1996). A fundamental tenet of sustainability in design is that technological developments should not harm the environment, either at the present time or going forward in time. System designs must function primarily within bioregional patterns and scales. They must maintain biological diversity and environmental integrity, contributing to the health of air, water, and soil. Designs should incorporate features that reflect bioregional conditions, with reduction of the footprint of human impact. In tandem with the undoubted benefits technological development has brought to mankind, has been the negative imprint of over urbanization, pollutant waste product creation, societal stress and damage to the natural environment. It is our view that ethical considerations to social and envi-

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[2] "Blow winds and crak your cheeks.." In King Lear, the bard of Stratford-upon-Avon casts the desolate King, invoking the power of the elements to rage in his despair. Wind and water energy have been both friend and foe to humankind for time memorial. As friend, technological developments in recent decades have again placed wind energy to the fore of renewable energy generation. Flowing water, one of the cleanest and longest serving forms on energy, is likewise on the cusp of rejuvenation as a highly significant energy source. Following success of traditional hydro generation, innovations in the harnessing of wave and tidal energy are yielding encouraging results with prototype generators connecting to national grids.

ronmental impact need to be addressed at all stages in the sustainable design process. Such considerations must apply both within the educational environment and in the professional workplace and should be informed by and be sympathetic to the social, technical, environmental and economic needs of all social stakeholders. Only by this means can truly sustainable indices be agreed upon, feeding into the design process, whether in design of renewable energy systems or in managing waste products in a safe and environmentally acceptable manner.

Owing to the multidimensional nature of sustainability, based on complex social, economic, and ecological theories, policies and practice, the concept of sustainable development and design can be difficult for students and engineering professionals to fully comprehend and understand and these topics will require critical analysis by academic leaders, teaching and learning pedagogues and university lecturers and teachers. Koïchiro Matsuura, Director General of UNESCO, postulates that sustainable development should receive a leading place in education at all levels (UNESCO, 2004): *Education - in all its forms and all its levels - is not only an end in itself, but is also one of the most powerful instruments we have for bringing about the changes required to achieve sustainable development.* Is it possible to educate twenty first Century engineers as "leaders-in-service" capable of dealing with dilemmas of complex societal settings and empowering them to internalize and implement sustainable design principles in their profession at all stages in their professional careers, so that they may consider and take account of the interactions between local – regional and community stakeholders as well as global - (economic, climate, and ecosystems of the Earth) factors. Lucena and Schneider (2008) argue that *SD* (sustainable development) *has significant limitations, particularly when it does not include theoretical and practical considerations of community* and they *would like to see the community made central in 'sustainable community development' (SCD).*

As outlined in figure 1, in this chapter we offer some commentary and attempt to answer some of the above questions by exploring the principles of sustainable development and sustainable design, in the context of engineering education and with particular emphasis on sustainable strategies and tools for energy systems. We offer by way of example an overview of syllabi and curricula development in sustainable design, commencing with an overview of the Royal Academy of Engineering guiding principles, followed by commentary on the important CDIO (Conceive-Design-Implement-Operate) concept, and finally we present an overview of a recently developed Master of Science degree in Energy Management at Dublin Institute of Technology (with a brief of one module, titled Sustainable Building Design).

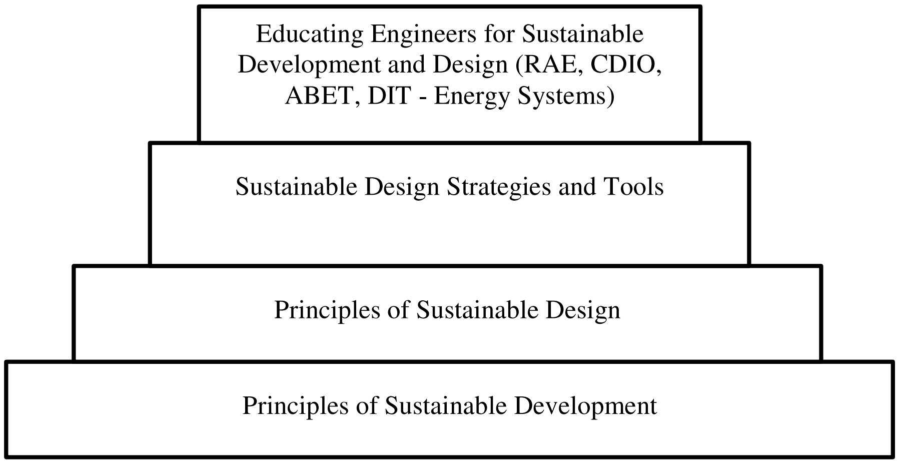

Figure 1: Steps towards engineering education for sustainable development and design.

The Principles of Sustainable Development and Design

In discussing engineering education for sustainable development and sustainable design we must initially offer clarity in definition and understanding of these concepts. In the literature there is no universal definition of sustainable development. Perhaps the reason for a plethora of definitions in sustainability is that it is a rich and complex concept. It is therefore essential that engineers and other professionals gain a deeper understanding of sustainable development so that they can recognise it as a guiding principle in the fulfilment of their creative professional endeavours. In order to nurture the planet back to good health, and to create a more stable eco-environment for all, it will be essential that national representatives, individuals and practitioners across the professions work in tandem to develop infrastructural frameworks that will meet agreed sustainable and non-harmful criteria, and be adopted globally. This is not a new concept, a great deal of excellent co-operative venture is already (and indeed has been) taking place, not least through the IEA (International Energy Agency), UNESCO, IPCC (Intergovernmental Panel on Climate Change), WCRE (World Council for Renewable Energy), and by implementation of legislation at national level and through academic and scholarly endeavour via peer review publication and cooperative research engagement. The issue today is that the stakes are higher than ever before. Not alone are we now capable of inflicting untold damage upon the planet, but we are now able to accurately measure and study the effects of this negative impact. It is therefore in the global collective interest that a one-hundred fold increase in effort be made to begin to create systems, standards, frameworks and agreements that will facilitate a return to a sustainable ecosystem with the regulating capability for survival in the short term and, perhaps even more importantly, into the long term future.

An appropriate starting definition might be with the Universal Declaration of Human Rights - the principle of inter-generational equity (UN OHCHR, 1948): *Development which meets the responsible needs, i.e. the Human & Social Rights, of this generation - without stealing the life and living resources from future generations, especially our children .... and their children.* In 1987, the World Commission on Environment and Development (Brundtland Commission) put forward a definition of sustainability and called for the development of new ways to measure and assess progress toward sustainable development (Our Common Future, 1987): *Humanity has the ability to make development sustainable – to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.* Unfortunately, this definition does not provide unambiguous meaning of the term "needs" and does not specify the ethical roles required of humanity in achieving sustainable goals. Nor does it directly incorporate the value of all other constituents participating in the global ecosystem. The concept of *Sustainability* is gradually gaining more applicability and acceptance, depicting the ability of a system to operate indefinitely and complying with the so called "triple bottom line" conditions: environmental protection (maintaining ecosystem integrity, function, and structure), economic prosperity, and social equity (meeting basic needs with inter- and intra- generational equity), when taken simultaneously, should create a truly sustainable system (Elkington, 1999, Hediger, 1999).

An important contribution in the Bellagio Principles endeavours to '*assess sustainable development in practice*' (IISD, 1997). These principles *deal with four aspects of assessing progress toward sustainable development. Principle 1 deals with the starting point of any assessment - establishing a vision of sustainable development and clear goals that provide a practical definition of that vision in terms that are meaningful for the decision-making unit in question. Principles 2 through 5 deal with the content of any assessment and the need to merge a sense of the overall system with a practical focus on current priority issues. Principles 6 through 8 deal with key issues of the process of assessment, while Principles 9 and 10 deal with the necessity for establishing a continuing capacity for assessment.* The ten principles are: 1. Guiding vision and goal, 2. Holistic perspective, 3. Essential elements, 4. Adequate scope, 5. Practical focus, 6. Openness, 7. Effective communication, 8. Broad participation, 9. Ongoing assessment, 10. Institutional capacity.

In articulating the concept of *Design*, ICSID (International Council of Societies of Industrial Design) proposes that: *"Design is a creative activity whose aim it is to establish the multi-faceted qualities of objects, processes, services and their systems in whole life-cycles"* (ICSID, 2005). On the other hand, Manzini argues and elaborates that *"it would be more appropriate to move away from this product-oriented definition to a more solution-oriented one"* (Manzini, 2006). Sustainable design must use an alternative approach to traditional design that incorporates these changes in mind-set articulated by Manzini. One must identify the potential impact of every design choice on the natural and cultural resources of the local, regional, and global environment.

A model of the design principles necessary for sustainability was presented in EXPO 2000 in Hannover by William McDonough Architects in their "Bill of Rights for the Planet" (also known as the "Hannover Principles") (McDonough & Partners, 1992). The McDonough principles purport *the right of humanity and nature to co-exist in a healthy, supportive, diverse, and sustainable condition*, r*ecognising interdependence and r*especting relationships between spirit and matter. Responsible acceptance *for the consequences of design decisions upon human well-being, the viability of natural systems, and their right to co-exist,* is a core tenet. A further core value is the reduction, if not elimination of the concept of waste in the design process.

Moreover, the concept of sustainable design should be supported on a global and intra-professional scale with the ultimate goal of becoming more environmentally responsive, more energy efficient, and conserving material and energy resources.

Sustainable Design Strategies and Tools in Energy Systems

Before considering subjective ethical motivations, development of sustainable action plans and choosing appropriate design methods and tools, engineers must consider the objective consequences of their actions, the social and ethical problems created by their technologies, in short embracing the notion of "ethics of responsibility". We are in complete agreement with Hans Jonas and Al Gore (in their separate declarations) that there is an imperative for action in finding long-term solutions, warranting human survival and well-being; *Act so that the effects of your action are compatible with the permanence of genuine human life* (Jonas, 1979).

We must take bold and unequivocal action: we must make the rescue of the environment the central organizing principle for civilization . . . we are now engaged in an epic battle to right the balance of our earth; the tide of this battle will turn only when the majority of people become sufficiently aroused by a shared sense of urgent danger to join an all-out effort. It is time to come to terms with exactly how this can be accomplished. (Gore, 2000)

Today's engineering design process requires engagement by many participants, including engineers, politicians, governmental agencies, managers, clients, anticipated customers and the general public (a detailed account is provided by Cañavate et al. in chapter 15). Defining and measuring the qualities in engineering designs that need to be preserved is a major challenge if we are to fully embrace and understand sustainability. How can engineers measure the quality of engineering systems, taking on board goals, requirements and constrains of all concerned parties, and at the same time ensuring minimal negative effect on the environment? It is important to be guided by a set of sustainable indices, including technological, ethical, environmental, economic and social. To achieve the highest possible sustainable environmental index, engineers could learn from the strategies proposed by Mulder's 'Life Design Strategies (LiDS)'. LiDS comprise a set of rules that a design engineer can adapt to create an environmental profile of a product. In applying the strategies, one should - *choose materials with low environmental impact, - reduce material requirement, - select environmentally efficient production techniques, - select an environmentally sound distribution system, - reduce environmental impact while in use, - optimize the life span, and optimize end-of-life system* (Mulder, 2006).

To implement these strategies an engineer requires analytical methods and tools. Available tools include for example, Life cycle assessment (LCA), Environmental impact assessment (EIA), Ecological footprints, Sustainable process index (SPI), Material flux analysis (MFA), Risk assessment, Exergy analysis and Ecological cumulative exergy consumption (ECEC). In particular when considering design in energy systems, LCA and exergy analysis are worthy of particular appraisal.

LCA evaluates the environmental burdens of each product, process, and activity of a business. It quantifies materials and energy used, waste produced, and environmental impact. It goes from "cradle-to-grave" or indeed "cradle-to-cradle" when recycling and re-use are included as part of the process. LCA comprises four stages: i) goal definition and scoping (the system boundaries and validation of data), ii) inventory analysis, iii) impact assessment, and iv) improvement. An out-growth of the modelling pioneered by the 'Limits to Growth' report written at MIT in the early nineteen seventies, LCA invites an optimization approach to design, seeking solutions rather than merely pointing out the problems. The Society for Environmental Toxicology and Chemistry states that *" life-cycle assessment is an objective process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and material uses and environmental releases, to assess the impact of those energy and material uses and releases on the environment, and to evaluate and implement opportunities to effect environmental improvements. The assessment includes the entire life-cycle of the product, process, or activity, encompassing extracting and processing of raw materials, manufacturing, transportation, and distribution, use/re-use/maintenance, recycling, and final disposal."* (McDonough, 1992)

A commentary on sustainable design concerning energy would not be complete without reference to the relatively new concept in thermodynamics - *exergy* (Szargut et al. 1988). The more well known term *entropy* may be defined as a measure of the amount of thermal energy 'not available' to do work. Exergy on the other hand is a measure of *energy* quality as the maximum shaft work that can be done by the system. The exergy concept is more useful than energy when used as an indicator of the environmental benefits and economics of energy technologies. Exergy provides a scientifically rigorous way of comparing the combined streams of material and energy. Since exergy is lost or effectively consumed in the operation of all processes, it has been useful in developing methodologies for improving process efficiency, in particular energy generation.

Dincer and Rosen propose that, in addition to other objectives and constraints, exergy be more widely utilized, clearly stating: *we feel in general that a strong need exists to improve the 'exergy literacy' of engineers and scientists* (Dincer and Rosen, 2007). The exergy concept applies not only to the principles of energy but to the interdisciplinary associations in professional practice in sustainability; a link exists between exergy and environmental impact and has become a common quantifier of sustainability, indeed a new sustainability index (for real sustainable development, the loss of exergy should be minimal). It can be shown that the most efficient pathway for exergy consumption available will automatically be chosen. Energy production, transformation, transport and use, impact on the Earth's environment, not least resulting in the effects of climate change. Exergy applies also to economics, with concepts of weak and strong sustainability and in respect of policy making in energy.

Excellent overviews of exergy analysis of Renewable Energy Systems (RES), including solar energy, wind power, geothermal energy, and energy from fuel cells, are provided by (Koroneos et al. 2003) and (Dincer and Rosen, 2007). A critical point in favour of RES is that they are inexhaustible and have much less adverse impact on the environment than fossil fuels. With exergy analysis, a comparison of energy efficiency in renewable and non-renewable energy sources can be achieved.

Examples of Sustainable Design Curricula

Perhaps one of the dilemmas of today is the quantity and speed of information flow in all walks of life, not least in education. Two important objectives in education should be to help students understand their physical and social environments and the changes taking place in those environments, and to create free space to think individually and collectively about and upon common authentic values and principles.

Students must be tutored in the use of multi-, inter-, and trans-disciplinary approaches and encouraged to work together in teams comprising people from different disciplinary, social, and cultural backgrounds. The education process should focus on identifying competencies and developing appropriate learning environments and processes. (The important Programme outcomes relating to the social development of the engineer, as required by ABET, EUR-ACE and under the Bologna Declaration, are thoroughly reviewed in chapter 5).

The importance of educating future engineers for sustainable development is envisioned and strongly advocated by the National Academy of Engineering in The Engineer of 2020: Visions of Engineering in the New Century (The Engineer of 2020, 2004).

"It is our aspiration that engineers will continue to be leaders in the movement toward use of wise, informed, and economical sustainable development. This should begin in our educational institutions and founded in the basic tenets of the engineering profession and its actions"

"We aspire to a future where engineers are prepared to adapt to changes in global forces and trends and to ethically assist the world in creating a balance in the standard of living for developing and developed countries alike".

In his forward to the Royal Academy of Engineering 'Engineering for Sustainable Development: Guiding Principles' document (Dodds and Venables, 2005) President Lord Broers comments that

"Sustainable development has become an increasingly important theme in local, national and world politics, and increasingly a central theme for the engineering professions around the world" .
further
"The sustainable development concept requires of all of us – as engineers and citizens – to consider much more widely than before the impact of our own lives and of the infrastructure and products we produce, both geographically and temporally" .

In (Crawley et al. 2007) *Rethinking Engineering*, a detailed explanation and overview of the CDIO concept, Conceive-Design-Implement-Operate, developed in response to a perceived critical need in meeting the desired attributes of the modern engineer, is presented. Initiated at four universities; Chalmers University of Technology (Goteborg), the Royal Institute of Technology (Stockholm), Linkoping University (Linkoping), and Massachusetts Institute of Technology, the number of programmes collaborating has expanded upwards to 30 universities worldwide. The CDIO approach builds on stakeholder input to identify the learning needs of students in a programme, and constructs a sequence of integrated learning experiences to meet these needs. A 'best-practice' framework, proffers a CDIO Syllabus supported by a set of underpinning standards. Crawley explains: *Modern engineers lead or are involved in all phases of a product, process, or system lifecycle. That is, they Conceive, Design, Implement, Operate. The Conceive stage includes defining customer needs; considering technology, enterprise strategy, and regulations; and developing conceptual, technical and business plans. The second stage, Design, focuses on creating the design, that is, the plans, drawings, and algorithms that describe what product, process or system will be implemented. The Implement stage refers the transformation of the design into the product, including hardware manufacture, software coding, testing, and validation. The final stage, Operate, uses the implemented product, process, or system to deliver the intended value, including maintaining, evolving, recycling, and retiring the system.*

The CDIO concept with potential application to sustainability and sustainable development, is briefly addressed in (Crawley et al. 2007), with parallels and correspondence drawn to the guide for teaching of engineering for sustainable development by the Royal Academy of Engineering in the United Kingdom (Dodds and Venables, 2005).

Whilst many academic programme team developers and research and development strategists reach their product goal without reference to or knowledge of the CDIO guidelines and concepts, there is benefit in comparing end product to those of CDIO and assessing how a programme may be adjusted and fine tuned by taking into account the focused principles defined in CDIO. By way of example a recently developed MSc in Energy Management, developed at the Dublin Institute of Technology, is described and offered for comparison.

Sustainable Energy Ireland, the Irish national government agency with responsibility for implementation of regulation and policy in energy, and with particular focus on sustainability, had identified a need for a programme that would educate specifically for the role of Energy Manager. The programme was planned in response to this need.

The intent in developing the programme was to enhance the present and future effectiveness of managers, engineers and scientists by providing an opportunity to study the theory and practice of seminal developments, laws, standards, and technologies, together with management, economics and finance, associated with European energy and the environment. The main objective is that graduates of the programme will be effective managers of environmental technology with critical awareness of resource management, conditional to financial and environmental constraint.

Although primarily designed for engineers, the programme will also be of interest to scientists, managers and multi-disciplinary professionals such as environmental health officers, architects and planning officers.

In proposing the programme to Academic Council and the Quality Assurance Committee, and in preparation of the required documentation, a case was presented for the provision of education on the integrated themes of energy, the environment and management. A brief statement on the core programme themes follows:

- *Energy*

The lifestyle currently enjoyed by people in the western world is fast being replicated in developing countries. This is already beginning to place a strain on current fossil fuel production as existing supply systems strain to keep up with demand. It is obvious to all that the dwindling fossil fuel resources cannot supply enough energy on a sustainable basis to meet the aspirations of all nations. A new system for the production of energy needs to be devised that seeks to maximise the useful energy output of fossil fuels as well as developing and utilising alternative renewable energy sources.

- *Environmental*

The environmental damage caused by the current production/consumption cycle of fossil fuels is causing irreparable damage on the environment and its full effect will be felt by future generations. The protection of the environment is recognised as a major international issue that has prompted new environmental legislation from the International Standards Organisation (ISO 14001). Many industrial and commercial organisations are experiencing political, social, and economic pressure and will be obliged to accept their share of the responsibility and adopt and conform to new legislation for the protection of the environment.

- *Management*

A reliable energy supply is seen as vital to the economic and political stability of a country. It is vital for a nation to produce and efficiently manage sufficient supplies of low-cost safe energy and raw materials. It is the responsibility of Governments, industrialists, commercial organizations and departments in the public sector to develop a systematic management of energy consuming activities. The objective of this programme is for the participants to develop the ability to assess the current legislation, economic pressures and social obligations and apply them to their respective professional working environments.

The programme objectives were to:

1. Develop appropriate energy policies for a variety of commercial and industrial energy users
2. Identify and evaluate present and future issues facing the Energy Supply Industry
3. Compare alternative energy sources such as Sustainable and Renewable energy technologies
4. Conduct feasibility studies on and evaluate the use of energy efficient technologies

5. Interpret the requirements of the *EU Directive on Energy Performance of Buildings*
6. Advise on implementing *Sustainable Energy Design* in new and used buildings.
7. Advise, assess and evaluate the implications of relevant European legislation and regulation in the Energy Sector
8. Implement and manage a complex energy strategy in a Commercial /Industrial facility
9. Evaluate the environmental issues surrounding energy supply and use
10. Discuss the impact of International Protocols on Energy Usage and the Environment

Following a detailed consultation process with academic, industrial and student stakeholders, a programme plan was approved with a structure (delivered on a part-time basis over 2 or 3 years) as follows. To successfully complete the programme students must earn 90 European Credit Transfer points; Module credits generally have a 5 ECTS weighting. Six core modules (*Business Organisation for energy sector, Business Law, Financial Decision Making - with case exemplars, Energy Supply, Energy Conversion and Use, Energy Management*) are taken in year 1, followed by 6 (appropriately selected) optional modules from a list including (*Strategic Management, Energy & Environment Law and Policy, Decision Making & Corporate Finance, Wind Energy for Electricity Supply, Advanced Energy Systems, Energy Management in New Building Design, Embedded Generation – Wind generation; Co-Generation - CHP, Renewable Energy Technologies - Solar/Wave/Tidal/Biomass, Energy Market Economics, Sustainable Energy Physics (e.g. LCA, Exergy), Biomass Technology/Biofuels for Transport, Transport Energy Economics and Management*) in year 2. Having completed 12 modules, following consultation with the programme committee each student is assigned a project title with a topic relevant to their particular work environment in sustainable energy.

We provide here by way of an exemplar the programme syllabus for the module Sustainable Building Design.

Module Title: Sustainable Building Design
ECTS Credits 5 Module Code EN1702
Module Aim:
This module aims to examine how both buildings and services can be designed in an integrated way to minimize energy use. This will become an increasingly important aspect of the work of engineers who will work in ever closer consultation with the architect, structural engineer and design team in the years ahead.

Learning Outcomes:
On successful completion of this module students will be able to:
1. Appraise building form, façade, orientation and construction for energy use, indoor air quality and comfort. This is to enable the successful participant to make recommendations to the design team with regard to solar shading, window design, glass selection, blinds, daylight, etc.
2. Evaluate the role that simulation modelling of buildings has to play in ensuring that the new design concept of using building thermal mass, building footplate and façade design to ensure sustainable building design, is achieved.
3. Integrate building design parameters with mechanical and electrical services in design to ensure that the services are not oversized and are run efficiently throughout the year.
4. Work in a group to develop an appropriate assignment.
5. Make oral presentations to a peer group

Learning and Teaching Methods:
Formal lectures and e-learning will underpin an action centred learning approach. Active learning using assignments, case studies, live projects (where possible), simulations, group work and presentations will all form part of the learning methodology. WebCourses will be used as a student resource and asynchronous communication medium. Guest lecturers will be invited to present some sections of the programme and will be selected on the basis of expertise and experience. Course work assignments should be designed to reinforce the module learning outcomes. Case studies involving energy related issues should be used where possible. Site visits will be also used.

Module content:
Comfort in Buildings: *- Thermal indices, - Ventilation, - Humidity, - Aural, - Visual.*
Effects of modern building techniques on comfort: *- Adaptive comfort principles, - Indoor air quality,- Sick building syndrome,*
Sustainable building design: *- Building form, façade, and orientation,*
- Energy usage and environmental impact of buildings.
- Solar shading, natural ventilation, thermal mass, window and glazing design, *- Passive cooling, heating and other cooling strategies (e.g. night cooling), - Embodied energy of building materials in building design*,
- Life cycle analysis.
Integration of fabric and services against building form, orientation, glazing etc: *- Ventilation & air-conditioning, - Cooling,- Heating,- Lighting*
Building performance: *- Energy use,- Operation,- Maintenance,*
- Control and monitoring, - Building load calculations and design margins.
Simulation in building design: *- Building models, - Solar tracking, dynamic airflow and thermal analysis,*

- Building Energy Management Systems (BEMS) and controls

This programme has been running for two years and there has been an enthusiastic take up by students, with enrolment numbers in excess of intended intake. In particular there has been a great interest shown by professionals in the workplace with responsibility for energy management.
Led by members of the MSc Energy Management Programme Committee, The Faculty of Engineering at Dublin Institute of Technology has recently joined the CDIO initiative. The intent is to contribute to CDIO with programmes embracing sustainable design concepts, both in energy systems and in a wider array of engineering disciplines.

Conclusion

Nassim Taleb in his famous book, The Black Swan, argues that we can not predict future historical events, but we have to be prepared for their consequences. Embracing sustainable development will both facilitate action in implementing corrective measures and prepare us for the unforeseen and damaging consequences resulting from climate change. Sustainable design of energy systems, including renewable energy systems will play a crucial role in fulfilment of mankind's dream of a "utopia of sufficiency" – the well-being and coexistence of all species on the Earth.
To educate engineers to be 'leaders-in-service" of sustainability, we must develop a conceptual framework. We have explored an holistic engineering approach incorporating the three stepping stones – Principles, Strategies, and Methods. These steps provide the platforms for the three main objectives of sustainable engineering education; creating awareness of sustainability and the awakening a spirit of ethics of responsibility, explaining the concepts of sustainable energy systems and providing best design practice in sustainable energy systems.

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