

ENERGY ENGINEERING A NEW ENGINEERING DISCIPLINE OR SIMPLY A PICK AND MIX?

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Abstract: The aim of this paper is to explore whether energy engineering is a new engineering discipline or a combination of existing disciplines. It is primarily a case study based on the experience in University College Cork (UCC), Ireland but also draws on available papers in the literature and other documented evidence from elsewhere. The paper discusses UCC's two programmes in energy engineering, a level 9 Masters Degree and level 8 Bachelor Degree. In the academic year 2009/2010, UCC attracted 290 applications for 25 places in its MEngSc Programme in Sustainable Energy. In addition, the minimum entry requirement for UCC's BE Programme in Energy Engineering was the highest for any undergraduate engineering programme in Ireland (510 points). This demonstrates the demand that exists for energy engineering programmes. The paper explores whether energy engineering is a new topic area in engineering, whether it is similar in this respect to building services engineering or environmental engineering. It also discusses whether in fact civil, mechanical and electrical engineering are the core disciplines or whether engineering itself is the only discipline. It concludes that energy engineering is certainly more than a pick and mix, that it is necessary and is here to stay.

Keywords; engineering education, energy engineering, discipline, Ireland, third level.

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1. INTRODUCTION

Over the past five years, University College Cork (UCC) in Ireland has developed two engineering degree programmes, a level 9 Masters (MEngSc) Degree in Sustainable Energy and subsequently a level 8 Bachelor (BE) Degree in Energy Engineering. These new programmes build on the research interests of UCC's engineering academic staff and complement existing undergraduate and post-graduate programmes in the more traditional engineering disciplines, namely civil and environmental engineering, electrical and electronic engineering, process and chemical engineering and mechanical engineering.

In the academic year 2009/2010, UCC attracted 290 applications for 25 places in its MEngSc Programme in Sustainable Energy and was the most sought after engineering post-graduate programme. In addition, the minimum entry requirement for UCC's BE Programme in Energy

Engineering was the highest for any undergraduate engineering programme in Ireland (510 points). This demonstrates the clear demand that has developed for energy engineering programmes.

A question that arises however, is whether energy engineering is a clearly defined new engineering discipline, or is it a combination of existing engineering disciplines that focuses on a key emerging area of interest, economic activity and employment? This paper attempts to address this question using the experiences within UCC to carry out a case study analysis.

Section 2 traces the origins and development of the taught Masters Programme in Sustainable Energy. Section 3 discusses the evolution of the BE undergraduate programme, highlighting some interaction with stakeholders. Section 4 discusses the issues surrounding discipline and Section 5 provides some conclusions.

2. MENGSC IN SUSTAINABLE ENERGY

UCC launched its MEngSc in Sustainable Energy in 2005/2006, the first institution in Ireland to offer such a programme. The programme was developed by UCC's Faculty of Engineering, which had been involved in research, applied research and demonstration projects in the field of sustainable energy for over 25 years. It was designed to harness UCC's research experience (Ó Gallachóir, 2005) into a structured teaching programme at postgraduate level to meet growing demands.

2.1 Demand

The demand for the MEngSc programme had two dimensions, the evidence internally through increased applications for post-graduate training and the external market driving further expected steep growth.

The number of applications from graduate engineers responding to postgraduate positions offered in the field of sustainable energy in UCC and those requesting a postgraduate programme in sustainable energy¹ had grown significantly between 1999 and 2004. There were 26 applicants for an EU Marie Curie Post-Doc position in 2000, 51 applicants for postgraduate and post-doctoral positions in 2001 and 36 applicants for an EPA funded Masters in 2003. These numbers relate to Civil and Environmental Engineering alone and even at that are incomplete.

2.2 Focus

The learning objectives of the MEngSc in Sustainable Energy focus on equipping the students with the information base and skill set to actively participate in this growing global market where energy / environment policy and technological innovation meet. The objectives are to provide the students with knowledge and understanding of

- energy trends, their impacts on the environment and the engineering solutions to mitigate the damage

¹ In the absence of a taught programme most applications were for a Research Masters and to a lesser extent for Doctoral studies.

- engineering of individual renewable energy sources of wind, hydro, biomass, wave, solar and geothermal
- energy conversion processes for electrical, thermal and transport energy supply
- the integration of intermittent renewable energy with the electricity network
- sustainable energy end use in building design, construction and management
- modelling sustainable energy systems incorporating technical and financial engineering, energy market structure and dynamics and fiscal policies.

It provides graduates from any engineering discipline with a programme comprising taught modules and a research dimension. The taught modules cover renewable energy technologies (wind, ocean, bioenergy, hydro, solar and geothermal), energy end use and systems in buildings, electrical power systems, energy policy and energy systems modelling. The research provides the students with an opportunity to develop greater depth of knowledge in one of these areas through two stages, a preliminary research project and a minor thesis.

Within the field of energy engineering, sustainable energy was rapidly evolving as technological advances are made in all elements of sustainable energy deployment, e.g. wind turbine design and control, building energy management systems, fuel cell development and the emerging hydrogen economy. The course was designed to provide students with the opportunity to become aware of the latest developments and innovations and also to appreciate the interdisciplinary nature of this subject.

2.3 Distinctness

The MEngSc programme is deliberately not restricted to renewable energy supply technologies. Indeed, some elements relating to renewable energy technologies contain similar content to renewable energy supply course available in a small number of European universities. The programme however also covers additional topics that UCC also has a track record and expertise in, namely energy end use (in particular energy systems in buildings), and enabling sustainable energy policies.

2.5 Progress to Date

There were 20 applicants in the first academic year 2005/2006. This increased year on year to 77 in 2006/2007, 122 in 2007/2008, 155 in 2008/2009 and 290 in 2009/2010. While the entry requirement is for a level 8 BE degree with a minimum 2H2 grade, the majority of successful applicants in the current academic year had secured a 1H degree. The student quota is 25 and this is limited by the number of permanent academic staff available to supervise the minor theses in the summer months.

In December 2009, there were 18 graduates of the programme, of whom 14 secured a Distinction (i.e. greater than 70%). They will join the others who are engaged in Doctoral research in energy engineering or who are working in Airtricity, Bord Gais, Eirdata, ESB, ESBI, SEI and SWS to name a few employers. Regarding the former point, there are currently six graduates from the MEngSc Programme undertaking PhD research in UCC's Environmental Research Institute.

3. BE IN ENERGY ENGINEERING

Building on the success of the MEngSc Programme, UCC launched a BE in Energy Engineering in 2008, again the first institution in Ireland to do so (Ó Gallachóir and Kavanagh, 2007). This followed two years of programme development, internal discussions within UCC, consultation with industry and external peer review.

The BE Degree covers the many dimensions of energy engineering i.e. sourcing, assessing, designing, converting, transmitting and supplying useful energy to meet our needs for electricity, transportation and heating and cooling.

3.1 Programme content

The discussions within UCC regarding the structuring this new programme raised a number of interesting questions regarding the 'distinctness' of the other established engineering programmes.

As with all undergraduate engineering programmes, the student learning experience is a layered one, with a mathematical and scientific underpinning. The 1st Year of the curriculum is dominated by foundational subjects in physics, mathematics, applied mathematics and chemistry. This raised a question – should we use the applied mathematics modules that are taught to electrical engineering undergraduates, or to civil engineering undergraduates? The process of formulating the 1st Year Energy Engineering programme has pointed to and questioned the differences between the 1st Year of the existing programmes. This in turn has led to a rethink with a proposed rationalisation of modules and a move towards a common 1st Year in engineering. In this way, 1st Year Energy Engineering is effectively a 'pick and mix' but the resulting content is likely to be mirrored in the other programmes.

The 2nd Year of the Energy Engineering Programme could certainly be described as a 'pick and mix' in that it draws together the fundamental engineering modules from civil, mechanical and electrical engineering, including fluid mechanics, thermodynamics, heat transfer, electronic circuits and power engineering. Interestingly, the 2nd Year set of modules is the only set of modules that are drawn entirely from established existing programmes. However, no other engineering degree currently contains this combination of modules that form the basis for most disciplines and are essential building blocks for energy engineering. Indeed, it could be argued that the 1st and 2nd Year Energy Engineering programme forms the basis for a common 1st and 2nd Year for all engineering programmes.

The 3rd Year starts to show the distinct identity of this programme through the inclusion of energy specific modules such as Energy in Buildings, Sustainable Energy, Energy in Transportation, in addition to carefully selected modules from electrical engineering (Power Electronics, Electrical Machines), from civil engineering (Hydraulics, Engineering Construction) and mechanical engineering (Applied Thermodynamics, Mechanical Systems). This is further reinforced in 4th Year with clearly energy specific modules in Wind Energy, Ocean Energy, Bioenergy and Energy Systems in Buildings again combined with more familiar modules such as Electrical Power Systems and Applied Power Electronics.

The structure of the programme demonstrates that it is both a new distinct engineering programme in addition to drawing extensively on relevant existing modules from other programmes.

The programme differs substantially from other UCC engineering degree programmes in that it is designed in an integrative manner: the foundation subjects developed in the first three years lead to a focused fourth year that is designed to ensure that graduates possess all the principal knowledge strands required by the energy sector. The discipline also requires a broad but well-definable set of skills which are packaged within the fourth-year programme. Providing the students with this targeted set of skills is the paramount learning objective of the programme.

The professional and industrial focus of the programme is highlighted by the inclusion of a paid work placement of approximately five months duration between the third and fourth years, while fourth year includes a major design exercise. The professional requirements for subjects such as ethics and economics, the ability to communicate well and to work in teams are all infused into the programme.

3.2 Is this Programme Unique?

UCC is the first university in Ireland to provide such a level-eight programme. While it is not the first university internationally, it remains one of a small number of institutions internationally offer engineering undergraduate programmes focussing specifically on energy engineering.

Stanford University offers a Degree in Energy Resources Engineering. Penn State University's has an energy engineering programme since Autumn 2007. University of New South Wales has been offering a B.E. degree in Renewable Energy Engineering since 2003 and also has a B.E. degree in Photovoltaics and Solar Energy.

Additionally, several courses currently focus on a subset of the energy engineering discipline or have energy as a partial focus of the degree including

- In the island of Ireland, Limerick Institute of Technology offer a Bachelor of Science in Renewable and Electrical Energy (Level 7) and the University of Ulster Engineering Faculty offer a B.Eng.(Hons) in Building Services and Energy Engineering.
- In Britain, Heriot-Watt School of Engineering and Physical Sciences offer a B.Eng.(Hons) in Mechanical Engineering with Energy Engineering; the University of Leeds offers both a B.Eng. in Chemical and Energy Engineering and a BEng in Energy and Environmental Engineering
- Further afield, the University of Reykjavik and the University of Northern Texas both offer degrees in Mechanical and Energy engineering.

3.3 Progress to Date

In September 2008, 24 students registered for the 1st Year of the BE programme in Energy Engineering. It proved a very attractive programme with entrants requiring the highest minimum entry points (535 points) of all engineering degree programme in Ireland (Ó Gallachóir, 2009). In the second year, the entry points for incoming students remained higher than other programmes (510 points) even though the quota was raised and 37 1st Year students were admitted.

The programme has met and addressed a number of teething problems and is evolving with a number of streams of modules that progress over the four years to enable graduates to engage with the many facets of energy engineering whether it be a focus on energy in buildings or transport, or on power systems, renewable energy supply or energy policy and modelling.

4. NEW DISCIPLINE OR NEW TOPIC AREA?

The programme is certainly a new programme, but does energy engineering represent a new discipline or is it just responding to a market need? During the course of internal discussions within UCC, engagement with industry and discussions subsequent to the launch of the BE in Energy Engineering programme, this question arose.

There is consensus that the energy sector is growing and requires engineers. Since there exists already an energy industry, clearly there are people working as energy engineers, in the sense that they are working in the areas covered by: sourcing, assessing, designing, converting, transmitting and supplying useful energy to meet our needs for electricity, transportation and heating and cooling. These engineers have typically been trained in one of the traditional disciplines, namely as civil engineers, electrical engineers, mechanical engineers or process engineers. They subsequently may have received in-house training and are working in the energy industry.

One of the questions asked during the early stage discussions with the energy engineering industry was, 'why do we need specifically energy engineers?' and this gets to the core of the question of whether energy engineering represents a new topic area as a minimum and if so, does it go further and represent a new discipline or not.

4.1 Environmental Engineers / Building Services Engineers

It is instructive to consider environmental engineers, building services engineers, and the same question could be asked here. These represent distinct topic areas within engineering that draw on the core engineering disciplines. They require specific skill sets, represent specific job titles and professional bodies but do represent engineering disciplines?

Emerging alongside the growth of activity within the energy sector is an increase in job advertisements that use 'Energy Engineer' as the position title. This is anticipated to continue as the sector grows in line with energy demand growth and investment in energy infrastructure. There is a danger in developing programmes that respond to short term market demand but in the case of energy, due to the requirements and challenges that exist, it would seem unlikely that demand will diminish.

4.2 Is 'Engineering' the only discipline

Another way of approaching the discipline question is to ask whether the future energy engineering graduates could be employed as civil engineers, or as electrical engineers, i.e. are they being trained effectively as engineers with a hint of energy?

As the four years progress, there are more instantly recognisable energy modules, in particular in third year (for example Energy in Buildings, Transportation and Energy) and fourth year (Wind Energy, Bioenergy, Energy Systems in Buildings, etc.) The programme is structured with a focus on energy engineering from the outset however. The elements relating to electronic engineering that are not core to energy engineering are excluded. Similarly the graduates will not have the core elements of civil engineering except those that are also relevant to energy engineering. The streams of energy engineering (energy in buildings, power systems, renewable energy supply) are traceable throughout the four years in a way they are not found in any other engineering programme and thus the training is different in terms of focus and learning outcome.

To a certain extent all engineering graduates should be able to work in all engineering positions, with due training and experience, given that the building blocks are similar, an approach to problem solving, the elements of design, etc. Can environmental engineers work as electrical engineers and vice versa? Is 'engineering' the only discipline, and are civil, electrical and mechanical engineering just topic areas?

5. CONCLUSIUN

This paper attempts to demonstrate that energy engineering is certainly more than a pick and mix of existing disciplines, in that it adds new elements and topics within engineering in addition to drawing on existing elements that are relevant too energy engineering.

Whether or not it represents a new engineering 'discipline' depends on how discipline is defined.

Whatever the answers to these questions, energy engineering is growing apace as a sector that requires specifically trained graduates and the evidence shows that it's an appealing choice for students. To conclude, the external reviewer to the BE Programme (who hails from MIT) closed his review with 'I wish my institute would launch the same initiative and produce an energy engineering program as well!'

6. REFERENCES

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