UCD Impact Case Study

Research that Directly Addresses the Climate Crisis

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SUMMARY

Climate change is arguably the greatest single existential challenge ever to confront mankind. Largely through the use of technology, man has created the problem in less than two centuries. Now technological advances in the capture, management and distribution of renewable energy are key to the solution. With a long track record in electronic and electrical engineering, UCD is playing a leading role in developing these new approaches. In particular, it is bringing expertise in managing power grids to the challenge of integrating renewable energy, such as offshore wind power, within electricity networks. Professor Andrew Keane, Director of the UCD Energy Institute and of the SFI Energy Systems Integration Partnership Programme (ESIPP), is co-ordinating the efforts of a large multidisciplinary team of experts from UCD and other Irish universities to research and develop solutions that will have global as well as national impact in the race to become carbon neutral.

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Finding Optimum ways to Integrate Energy Systems

At its broadest, UCD's Energy Institute and the associated Science Foundation Ireland-funded Energy Systems Integration Partnership Programme (ESIPP) examines how Ireland's energy infrastructure interact as the country seeks to become carbon neutral by 2040, or by 2050 at the very latest.

"Our task is to define credible pathways towards that objective. But there are so many technologies that still have to be developed and others that have yet to mature," says Professor Andrew Keane. "There are uncertainties around the costs involved and there is a huge societal dimension to the whole energy transition. This climate crisis will have an impact on every sector of our society, which is why we're using a multidisciplinary approach."

ESIPP, coordinated by UCD's Energy Institute, is a major research programme delivered in partnership with industry and a multidisciplinary team of researchers from UCD, Trinity College Dublin, NUI Galway, the Economic and Social Research Institute and Dublin City University.

The programme has three stands addressing operational and technical aspects of the network, identifying energy solutions for people in their homes and businesses and informing energy policy and infrastructure investment to enable energy decarbonisation.

The research disciplines involved range from economics, finance and behavioural science to applied mathematics and engineering in its many forms.

An electrical engineer by background, Prof Keane's particular focus is on technical modelling and optimisation of the power system to integrate more renewable energy – especially wind power in Ireland – and to accommodate new technologies such as electric vehicles, solar panels and heat pumps.

"There's inherent efficiency with electrification, which is why it is one of the fundamental pillars of strategies across the world to decarbonise energy. But this in turn puts ever more stress on existing electrical structures, which is why we need to develop an ever smarter grid," he says.

Mathematical Models to Create Better Information

One practical example illustrates the type of work involved. For years the distribution network – the lower voltage end of the electricity network closest to the end consumer – has been largely seen as little more than a set of wires through which energy flows as required.

But as Prof Keane explains: "There's a growing need for us to know, closer to real time, what's actually happening on that network, in the substations as well as along the wires. There are two ways to address this. You can invest in a massive deployment of sensors – potentially both difficult and costly – or you can use sophisticated mathematical modelling to try to infer or generate more real time data from the limited set of measurements that are available.

"Using data from a single house, for example, along with knowledge of the number of houses on the street, what we know about the network structure and a few additional measurements we have been able to employ a mathematical technique (for those interested in statistics: non-linear regression) to generate a simple equation to provide insights into demand patterns elsewhere in the broader network. We've tested that theoretical model and it performs well.

"So now we're building on that work and data analytics – commonly referred to as Big Data – is coming to the fore. There's actually a massive amount of new data being generated from the grid and we're looking at how we can generate even more of it, and crucially more information, from quite limited data sets. So we're deliberately setting ourselves a hard challenge in the quest to avoid the complexity and expense involved in installing multiple sensors."

This is one element in a much broader vision for the future of a system in which there is a strong and continuing shift away from a "control centre" approach to a more decentralised or distributed system – a kind of "blockchain for energy". "We want to ensure ahead of time that we have sufficient energy to meet whatever the expected demand will be – to avoid outages – but with as little as possible surplus capacity engaged. That requires better techniques to forecast, for example, what wind power output will be available an hour ahead, or even a day ahead. That way we can reduce the uncertainty which has to be managed and that's really vital. We're trying to create new methods that can actually tell us, in real time, what's going on and then use that information to identify what can be done to improve or optimise the system as a whole."

Multidisciplinary Approach Provides Holistic Vision

Supported by the vision of philanthropist David O'Reilly, which led directly to the establishment of UCD's Energy Institute a decade ago, this work is highly practical. The broadening out from excellence in electrical engineering to the emergence of a truly multidisciplinary effort in ESIPP has been the result of close partnership with Ireland's electricity generating and distribution industry alongside international academic partners.

"It's taken years to develop what we have," says Prof Keane. "People can be inclined to focus exclusively on their discipline-specific work – and there's a value in that, of course. But there's also a huge need for knowledge to be generated and shared across those various disciplines and that is an increasingly important piece.

"A lot of the work we're doing is around modelling these systems to gain insights into where the vulnerabilities lie and how we can prevent them undermining the system. So the large scale managing of the grid is another of our focuses, identifying potential bottlenecks and adequate infrastructures. We're always going to have unforeseen events and equipment failures, so we need to have robustness built into the enlarged system."

Significant Real and Potential Impacts

The availability of an efficient, reliable and cost effective electricity supply has long been a key ingredient in Ireland's package of attractions for Foreign Direct Investment (FDI) and the job opportunities it brings. Stability in the voltage as well as avoidance of outages is of paramount importance to virtually all of the high tech companies that have located in in Ireland over the past three decades. But this guaranteed supply comes at a cost, requiring considerable investment and provision of surplus generating capacity. Here, too, the research activities of the School of Electrical & Electronic Engineering have played a vital role.

For many years industry partners such as ESB, ESB Networks, EirGrid and Gas Networks Ireland have directly funded elements of this work. "Our research is informed by the data they provide and also by the insight that they can provide us in terms of the future challenges they see coming down the line," Prof Keane says.

So as well as being published in leading peer-reviewed international journals, this research informs the development of the industry's own internal processes and that of the grid as a whole. By helping the main industry providers improve the efficiency of their systems and hone their capital investment strategies, the School's research continues to play

an important role in containing both capital and operational costs, ultimately ensuring reliability of supply at the lowest possible price to consumers.

Prof Keane also highlights the valuable role this research activity plays in ensuring the availability of highly skilled and talented graduates with a good understanding of current themes in a rapidly evolving sector. “It would be wrong to think of us as just providing consulting. Far from it, we’re here to generate deep new knowledge. While our work might often not have an impact for several years it can still be seen as centrally important to the future.”

The Energy Institute is also an active participant in the European Energy Research Alliance and engages in many EU-funded projects, such as the Horizon 2020 Programme, that are often also directly related to research being undertaken at a national level.

The UCD research also feeds directly into Irish government policy on energy. The Energy Institute is contracted by Department of the Environment, Climate and Communications to advise on the evolution of the national Climate Action Plan, and in particular on electricity grids, providing quantification and an evidence base for energy policy formation.

As well as working in an advisory capacity, Prof Keane and his team of researchers have been job creators in their own right through an award-winning UCD spin-out company, NovoGrid. This provider of patented software, which helps wind farms improve the efficiency of their energy transmission and their integration into national grids, is gaining market particular traction in the UK.

This area of expertise will be particularly relevant if Ireland is to make the most of the exciting longer-term future Prof Keane sees ahead for it as an energy exporter, generating both income and employment. Renewable energy currently provides about 40% of the country’s electricity but that proportion is expected to rise to around 70% by 2030 as floating offshore wind turbine technology matures.

“The development of floating offshore wind turbine technology will unlock deeper water areas where we can harvest a huge amount of energy, with reduced impacts on people and communities,” Prof Keane says. “Wind is such a huge resource. In Ireland’s case floating turbines will enable production of energy far in excess of what we need – perhaps 30 to 40 GW of resource available against a max electricity demand at the moment of around 7 to 8 GW. We will also need increased interconnection with other countries, such as France, to ensure our energy security and that will help to open up opportunities for us as an energy exporter.”

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Funding Acknowledgements

This research is supported through the ESIPP project which is funded (in part) by Science Foundation Ireland (SFI) under the SFI Strategic Partnership Programme Grant Number SFI/15/SPP/E3125, along with a philanthropic donation from Mr. David O'Reilly and funding from our industry partners, as well as through SFI individual award 16/IA/4496