SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Energy Research in Ireland 2004 – 2010

People, Funding and Technologies

This publication, compiled by the Sustainable Energy Authority of Ireland (SEAI), presents an overview of the current state of energy research and development in Ireland.

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Preface

Ireland, and the rest of the world, face great challenges in ensuring access to secure sources of low cost energy that can be produced and used with minimal environmental impact.

Over the past decade, this fact has moved from a subject of debate to generally accepted conventional wisdom. The response has been a significant policy shift towards a sustainable energy agenda. In Ireland, the response has included increased funding for energy research and development, and the application of expertise from outside the energy sector to the development of low carbon technologies. These factors have deepened our existing research capacity and brought new talents and fresh perspectives to an area of increasing importance and complexity.

This report and the associated website represent a continuation of SEAI's effort to bring improved coherence to the energy research landscape in Ireland. They report the result of a data collection exercise that has identified and categorised over 700 energy related research and development projects on the island of Ireland, led by over 200 Principal Investigators across twenty-one academic institutions in the period 2004–2010. These projects represent €174 million in research and development (R&D) funding from various sources including Government, industry and the EU. We expect the result to be a useful resource for stakeholders in Government, the academic institutions and industry.

The process of building the Irish Energy Research Map has required the deepening of relationships across the academic institutions and with the energy research funding agencies. Maintaining the database will require continuing cooperation with these key stakeholders. We would like to acknowledge the commitment and enthusiasm of all those who participated in the exercise, particularly the university research offices, and the energy specialists in Science Foundation Ireland. We look forward to continuing the engagement into the future.

Professor J. Owen Lewis

Chief Executive,

Sustainable Energy Authority of Ireland

1.0 Introduction

"As a nation, we are at a crucial moment in time, where the right actions will determine our future wellbeing and that of generations to come. We must act now to address issues such as security of energy supply as a consequence of rapidly declining fossil fuel resources, and of course, the real and present threat of irreversible climate change."

Sustainable Energy Authority of Ireland, "Strategic Plan 2010–2015"

1.1 Overview

This publication, compiled by the Sustainable Energy Authority of Ireland (SEAI), presents an overview of the current state of academic energy research and development on the island of Ireland.

SEAI is the statutory Authority responsible for promoting and assisting the development of sustainable energy in Ireland. Since 2004, SEAI has had responsibility for reporting on Energy Research, Development and Demonstration (RD&D). Each year, SEAI gathers data, and presents overall statistics on research based on an aggregated analysis of survey data, matched to International Energy Agency (IEA) categories. Though useful for reporting purposes, it was felt that a more detailed analysis might provide a greater understanding of the activities of energy research. In 2010, SEAI began a more detailed information gathering exercise on the current state of academic-led energy R&D in Ireland.

All academic institutions in Ireland were asked to supply information on energy-related research projects for the period 2004–2010. This special report, therefore, contains a subset of the overall data by concentrating on research and development in the academic sector. It does not capture demonstration or non-academic research.

Overall data on research, development and demonstration projects (both academic and non-academic) continues to be collected and reported and is covered in a separate report.

1.2 The purpose of the exercise

The main aim of the exercise is to create a comprehensive overview of energy R&D activities in Ireland within academic institutions, and build a detailed online Energy Research Map in order to:

- Highlight the main **categories** of current research activity within more than a dozen technology areas
- Identify how this research is **clustered** amongst the institutions, centres, groups, Principle Investigators (PIs) and funding agencies involved
- Identify the current **energy research strengths** in Ireland, giving an overall picture of the capabilities and capacities of researchers and academic institutions
- Place energy research in Ireland within the **wider context** of European and International energy technology research objectives with reference to research roadmaps

- Understand the relationship between today's **priority research areas** (in terms of technologies and the activity, funding and other resources being devoted to them) and those that are likely to be priorities in the future
- Provide up-to-date **resources and links** to energy research opportunities such as the Seventh Framework Programme, FP7

An online portal to Irish energy research was developed by SEAI. The data contained in the portal is based on projects reported to SEAI by 21 Irish academic institutions. Seven hundred energy projects have been identified across different research departments within these institutions. A total of €174 million was awarded to energy research and development projects in academic institutions between 2004 and 2010.

A limited number of energy technology categories were chosen for their relevance to European and International energy research and development goals. Additional categories were selected based on Ireland's specific energy challenges. Each project was categorised both by energy technology and by source of funding. The benefit of this categorisation lies in the capability to view energy research and development from a number of different angles, giving new perspectives on Irish energy research.

The process of building up the Irish Energy Research Map continues. The survey relied on the goodwill and co-operation of institutes carrying out energy R&D. The challenge of identifying what research projects were energy related was daunting, as energy is not a category typically found in the databases kept by university research offices. Although considerable efforts were made to obtain comprehensive data, we are aware that some projects may have been missed.

1.3 SEAI's five-year strategy

SEAI's Strategic Plan for 2010–2015 identifies a key role for the Authority in "improving the coherence of Irish energy research and development". The importance of this role is evident from the increased focus on energy R&D in Ireland, in the EU, and internationally.

The Irish energy sector is in a period of rapid change; energy R&D takes place within the context of:

- Supporting the wider sustainable development agenda, and national and EU policies of enhancing energy security in a more environmentally sustainable manner
- Ireland's regulatory and policy regime as it applies to energy, and important European Directives
- Playing catch-up in the adoption and deployment of certain technologies such as biomass-based heat and power systems
- Opportunities arising from basic research where application to energy may be possible

Investing in energy RD&D and bringing new technologies to market will support Ireland's industrial competitiveness, strengthen innovation, and develop key expertise and competences. This will provide a motor for economic development, with the establishment of indigenous businesses with high export potential, and the creation of an attractive location for foreign direct investment in the sector.

1.4 The Irish Energy Research Council's Energy Research Strategy

With representation from academia, business, Government and its agencies, the Irish Energy Research Council (IERC) was convened to coordinate and deliver an integrated approach to energy research activities. The IERC's Energy Research Strategy 2008–2013 sets out a vision for energy research in the medium term, and the strategic actions for each of the following major areas of research activity:

- Energy systems modelling and analysis
- Fundamental frontier and multi-disciplinary research
- Energy RD&D in five sector-specific fields:
  - *Ocean energy*
  - *Grid / infrastructure / smart grids*
  - *Energy in buildings*
  - *Energy in transport*
  - *Sustainable bioenergy*
- Research support in identifying and mapping Ireland's energy resources
- Maintain a "watching brief" for technologies of potential application in Ireland

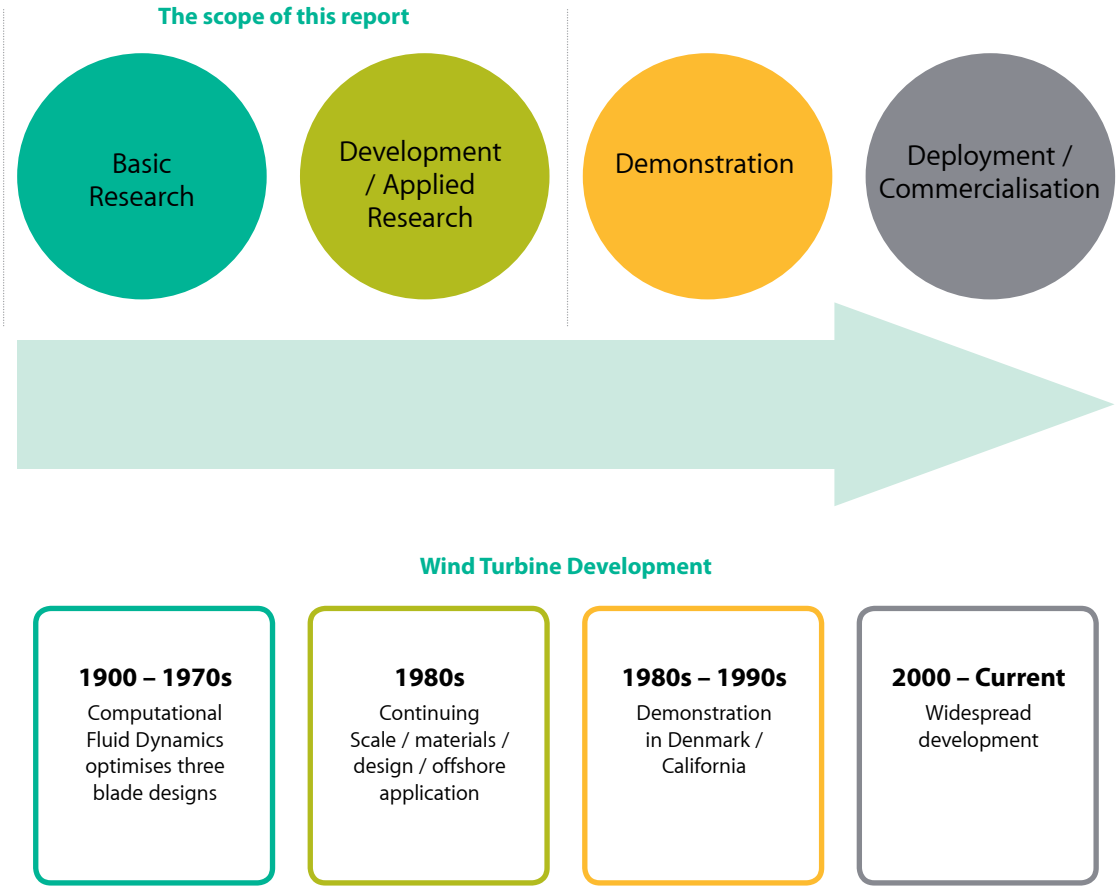
This strategy was published in 2008 and has provided a framework for the development of energy research programmes for a number of funding bodies that are active in Ireland.

2.0 The Energy Research, Development, Demonstration and Deployment Process

2.1 Research and technology development

Government energy policies seek to move specific technologies through a spectrum of interventions based on the maturity of the technology; from technology R&D through to prototype and demonstration and finally to deployment support (see diagram Figure 1). The example shown relates to the development stages of the modern wind turbine.

Figure 1: Overview of the R&D Intervention Spectrum, From Basic Research to Deployment



This report focuses on the basic research, applied research, and development parts of the spectrum within academic institutions.

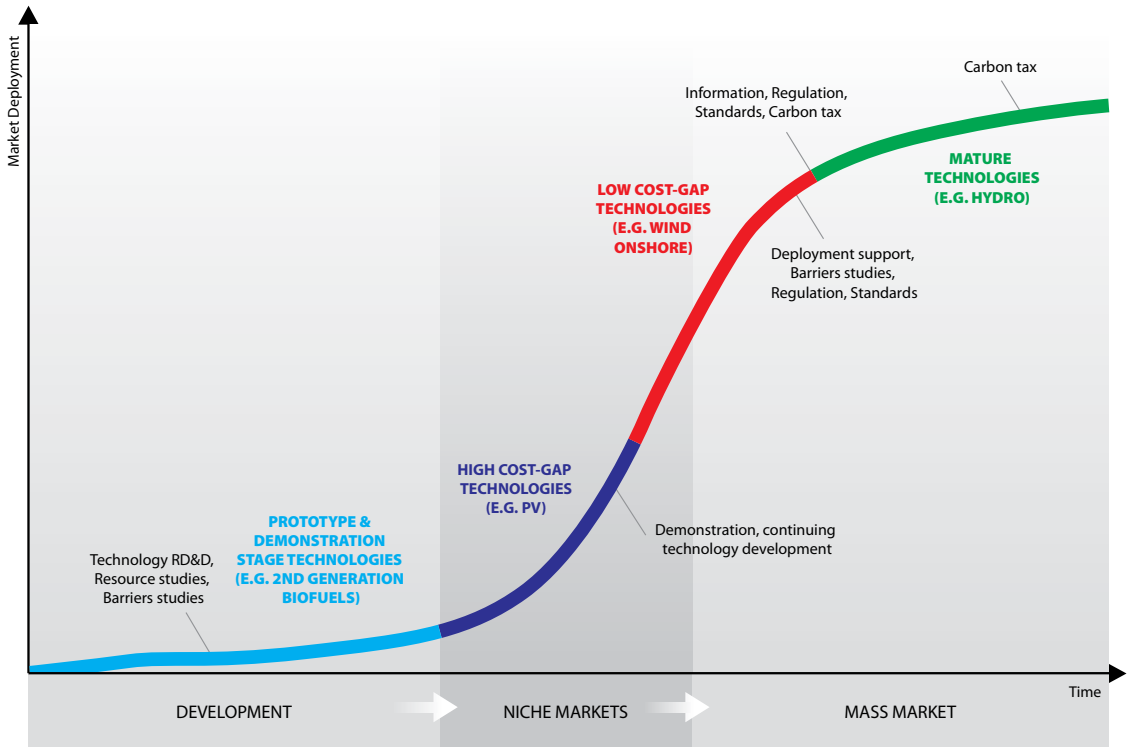
The diagram in Figure 2 provides examples of technologies at different phases along the spectrum and the types of interventions appropriate for each phase.

While basic research tends to be carried out in academia, a significant amount of development and applied research is carried out by business. Business also tends to dominate the demonstration and deployment / commercialisation phases of the chain, particularly for mature technologies where market penetration is the goal.

Although this report is focused on the research and development elements, many of the energy research centres and clusters identified in this report have formal collaborations with industry. In the European context, industry-led roadmaps are driving energy research priorities.

The Irish Energy Research Council also highlighted the need for close contact between the energy research community and the energy related business sector, with a continuous and effective dialogue between them and the agencies involved in promoting and supporting research and innovation.

Figure 2: Energy RD&D in the Stages from Initial Development to Deployment



Adapted from: "Deploying Renewables: Principles for Effective Policies", International Energy Agency, (2008)

Over the period 2004–2010, the amount devoted to energy RD&D has tended to grow year on year, with a higher proportion of funding allocated to demonstration projects. This reflects a decade where the application of sustainable energy expanded significantly in Ireland. In 2002, SEAI began a programme of trialling and demonstrating technologies that had been used successfully in other countries. By 2006 some of these technologies were the subject of deployment support programmes.

2.2 SEAI's role in energy research

SEAI's objective is to support and carry out energy policy research, and to improve the coherence of Irish energy research and development. To ensure that low carbon technologies which can be adopted in Ireland are well understood, informed policy decisions must be taken. Examples of successful SEAI deployment schemes building on earlier demonstrations include the Greener Homes Scheme and Home Energy Saving scheme, both of which were based on the House of Tomorrow demonstration programme and other demonstration projects supported under the Renewable Energy RD&D Programme.

Energy efficiency, particularly in industry and business, has been extensively demonstrated and implemented and a sound set of solutions are understood. However, research needs are still being defined, particularly around moving to zero carbon buildings and exploiting efficiencies made possible by advanced real-time energy monitoring systems. These research topics are on SEAI's current research agenda.

Many low carbon technologies remain in the research and development phase. SEAI has a specific focus on supporting technology research in ocean, wave and tidal energy, and aspects of bioenergy. Low carbon technologies at demonstration phase of particular interest to Ireland include bioenergy heat from miscanthus, biogas for electricity generation, electric vehicles, and micro- and small-scale electricity generation. At deployment stage, SEAI supports renewable heat technologies.

Across all of these technology areas, and other priority deployment areas like wind energy, SEAI is also conducting policy research to identify and map Ireland's resource, and to understand and address barriers to the application of that resource.

A number of other technologies, including solar photovoltaic (PV) and geothermal energy are supported by SEAI research programmes, but are not given a priority focus at this time.

SEAI's 2010–2015 Strategic Plan identifies our priorities and objectives as:

- Strengthen national expertise and capacity in energy modelling and analysis activities
- Establish and develop a sound programme of applied RD&D that focuses on Ireland-specific priorities in collaboration with other State agencies
- Co-ordinate the implementation of the National Ocean Energy Strategy
- Encourage participation by Irish energy researchers in EU and other energy research programmes
- Support green enterprise growth in all aspects of sustainable energy
- Work with the International Energy Agency to support new technologies and policies for achieving our energy goals

3.0 Overview of Energy R&D in Ireland and Major Trends

Our Vision: "A rigorous energy research programme with a reputation for excellence and success, with Ireland branded as a world centre for research, demonstration and innovation. This will be achieved through strong support for energy research within a coherent, overarching research system and promotion of Ireland as a location for research and testing."

Sustainable Energy Authority of Ireland, "Strategic Plan 2010–2015"

3.1 Academic research: findings from 2004–2010 activities

The information gathering exercise identified a total of 500 energy R&D projects undertaken by the university sector in Ireland during 2004–2010, and these accounted for €156 million of research funding. A further 200 projects totalling €18 million were carried out in Ireland's Institutes of Technology.

3.2 Main areas of focus

The two most active areas of R&D activity in the Universities and Institutes of Technology are Energy Efficiency and Bioenergy. These two sectors accounted for 21% and 18% respectively of total funding during 2004–2010 (see Figure 1). Other areas of significant activity are Solar Energy (13%), Marine Energy (10%), Energy Policy / Modelling & Analysis (10%), and Electrical Grid (9%).

The analysis gives an interesting insight to where these technologies sit on the spectrum of intervention. Those that are already commercialised (e.g. Wind Energy) show little R&D activity. In the specific case of wind, the research needs are electricity grid integration and policy and many projects relevant to wind are captured in these categories. Offshore Wind technology is relatively new and shares challenges with ocean energy devices; therefore relevant research is captured under the Marine Energy category.

Solar Energy R&D funding is high relative to its role in current Irish energy policy because solar photovoltaic remains an R&D technology, despite significant international demonstration and deployment activity in recent years. Researchers with expertise in related disciplines are now applying their research to PV development. While rapid technology development in PV has contributed to significant efficiency gains and cost reduction, widespread cost effective commercialisation has not yet been realised. However, current research and development on both the technology and manufacturing processes promises to achieve greater conversion efficiency, increased product life, and reduced manufacturing cost. Many of these advances are driven by the transfer of knowledge from related disciplines, such as chemistry, nanotechnology, and materials science.

Research and development for energy in the built environment is included as energy efficiency. This is such a wide area that there will be many overlaps with other technology areas. Information and communication technologies fit here also, but these also have relevance to the electrical grid, or "smart grid".

A breakdown of the total funding received under each of the energy technology areas is shown in Figure 3.

Figure 3: R&D Funding by Energy Technology Category 2004–2010

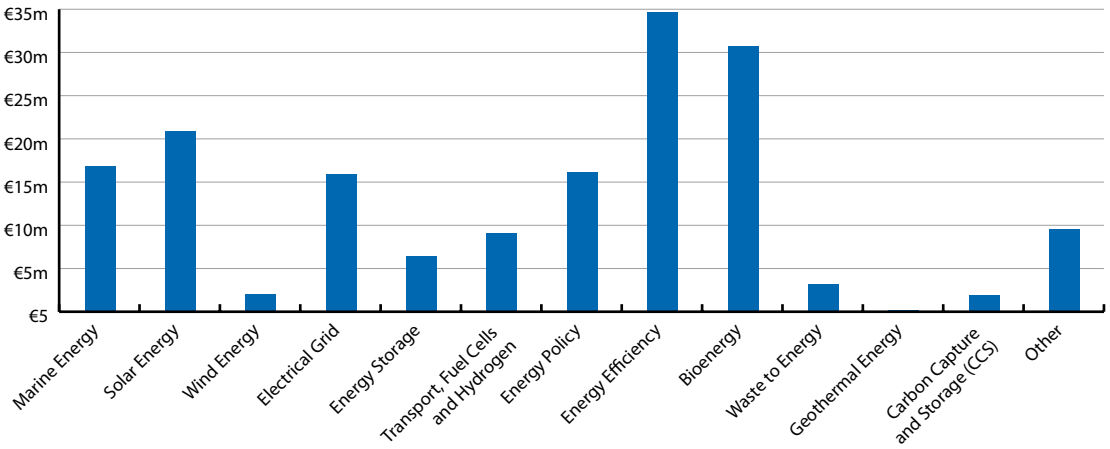
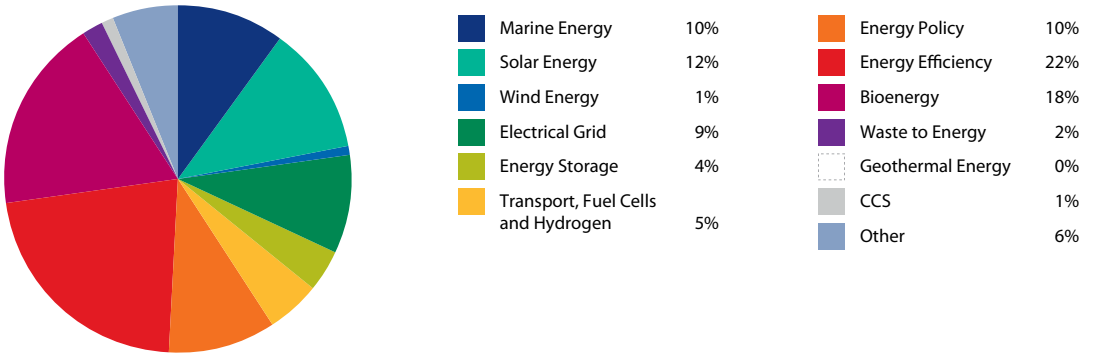


Figure 4: Percentage R&D Funding by Energy Technology Category 2004–2010



3.3 Funding Trends

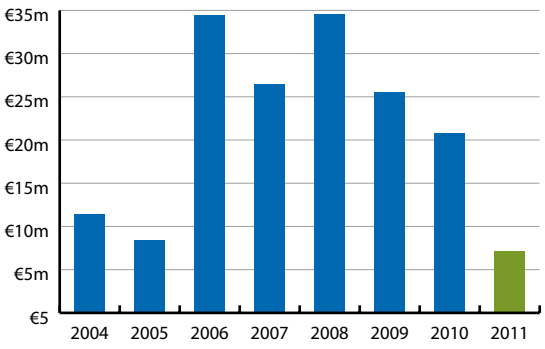
Research projects usually span a number of years. This database assigns a project's total funding to the year in which it was awarded to the project. No attempt has been made in this analysis to average the funding over the lifetime of any project. Most projects continue for 3 to 5 years after award.

Figure 5 shows a significant increase in the amount of funding awarded in 2006, This was due to the Department of Communications, Energy, and Natural Resources Charles Parsons awards, which established a number of energy research clusters. The awards are now managed by Science Foundation Ireland (SFI) and are therefore allocated to SFI in the analysis.

Funding awards peaked in 2008, the year the Ocean Energy Development Unit was established at SEAI and a large number of Stokes Lectureship awards were made.

Some projects from 2010 are not yet accounted for, and 2011 funding shown represents awards reported in the first two months of the year.

Figure 5: Academic Energy Research Funding by Year of Award



Note 1: 2011 partial
Note 2: €5,218,582 omitted – Year of award not reported
Note 3: Most projects last 3 to 5 years, so awarded funding will continue to have an impact after the year of the award.

4.0 Technology Overview

4.1 Classification of Energy Technologies

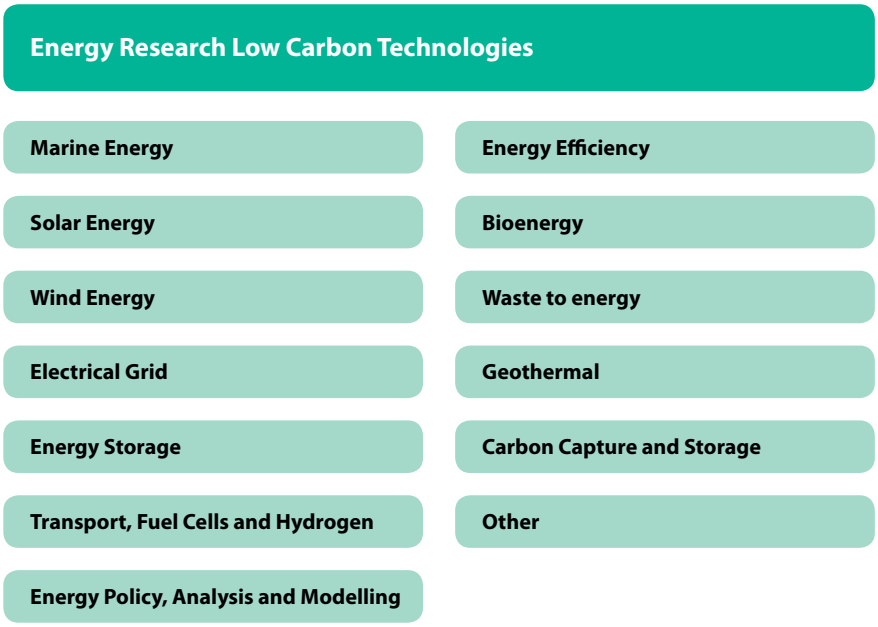
The technology categories used in this exercise were chosen on the basis of the current and future direction of EU and international research where appropriate. The EU Strategic Energy Technology (SET) Plan, for instance, identifies six strategic energy technologies (SET) for Europe: Wind, Solar, Biofuels, Carbon Capture and Storage, Nuclear, and Electrical Grid. The SET plan currently excludes Marine Energy and Energy Efficiency for example, and so a wider approach was needed.

The categorisation adopted is shown below with 13 main categories.

Research and development in "materials for energy" are usually included under the specific technology for which they were created – e.g. materials for wind turbine blades within the Wind Energy category or materials for solar panels within the Solar Energy category.

The category "Other" captures Nuclear, Materials not already counted, and a number of environment projects that are not directly energy related, but are interesting in the context of the study.

Figure 6: The Irish Energy Research Map's Main Categories



Main Category	Includes	EU Relevant Initiatives
Marine Energy	Wave / Tidal Devices Offshore Wind Prediction and Modelling	EU SET Plan – European Industrial Initiative (EII) Wind (Offshore wind)
Solar Energy	Solar Thermal Solar Photovoltaic Concentrated Solar Power	European Energy Research Alliance – Wind EU SET Plan – EII PV EU SET Plan – EII CSP
Wind Energy	Wind Turbines Wind Prediction / Modelling	EU SET Plan – EII Wind European Energy Research Alliance (EERA) – Wind
Electrical Grid	Generation, Transmission and Distribution of Electricity SmartGrid	EU SET Plan – EII Electrical Grid ICT
Energy Storage	Batteries, PHES, CAES, Flywheel, etc	(EU SET Plan – EII Storage – Planned) (European Energy Research Alliance – Planned)
Transport, Fuel Cells and Hydrogen	Fuel Cells, Hydrogen Generation, Transportation and Storage, Hydrogen for Transport Electric Vehicles / Infrastructure	Fuel Cells and Hydrogen Joint Technology Initiative (FCH JTI) (European Energy Research Alliance – Planned)
Energy Policy, Analysis and Modelling	Policy Studies & Analysis Modelling of Energy Systems and Financial Mechanisms	N/A
Energy Efficiency	Built Environment Information and Communications Technology Lighting Industry Wastewater Treatment	N/A
Bioenergy	Conversion Sustainability Feedstocks	EU SET Plan – EII Biofuels
Waste to Energy	Includes Gasification, Pyrolysis, Anaerobic Digestion	N/A
Geothermal	Deep Geothermal Resource Analysis	European Energy Research Alliance – Geothermal
Carbon Capture and Storage	Carbon Capture (including Clean Coal) Carbon Transport and Storage	EU SET Plan – EII CCS (European Energy Research Alliance – Planned)
Other	Nuclear Energy (Fusion & Fission) Environment Materials for Energy	EURATOM EU SET Plan

4.2 Analysis of Irish Energy Technology Research and Development

This section introduces some key research activities underway in Irish academic institutions in each of the technology categories.

1. Marine Energy

Fifty-five marine energy projects amounting to total funding of €18 million were awarded during the 2004–2010 period.

Ireland is among the world leaders in ocean energy R&D, with considerable third-level expertise in areas including sea current turbine design, wave tank model testing and wave energy modelling. Offshore wind, platforms, modelling, and ecosystems are other key areas of research.

The strategic development of Ireland's ocean energy resource requires research into areas such as:

- resource measurement
- prediction and informatics
- device design and development
- control optimisation,
- economics
- grid connectivity
- offshore wind structures
- environmental impact

A number of Irish academic institutions are engaged in this research, often with ties into industry.

The biggest marine energy research centre in Ireland is the Hydraulics and Maritime Research Centre (HMRC) at University College Cork (UCC). With its wave test tank, the centre can test scale models of wave energy converters. The main funding for this centre comes from Science Foundation Ireland and SEAI's Ocean Energy Development Unit. A number of successful EU-funded FP7 projects such as MARINA, EQUIMAR and ORECCA are also underway at HMRC.

A quarter-scale test facility now exists in Galway Bay, with a data gathering element through the Marine Institute's SmartBay project. A full-scale grid connected site is being developed at Belmullet, Co Mayo. For more information on these sites refer to SEAI's Ocean Energy Development Unit.

Examples of ocean condition data gathering include a sensing and informatics project at Dublin City University (DCU), ocean habitat mapping projects at University of Limerick (UL) and an Ocean Information System project at NUI Galway (NUIG).

Other research activities include control and economic optimisation of multiple wave energy devices at the same site and short-term forecasting projects at NUI Maynooth (NUIM). Offshore wind topics related to foundations and marine platform stability are also covered, notably in Trinity College Dublin (TCD) and University College Dublin (UCD).

2. Solar Energy

Seventy-five solar energy research projects totalling €24 million were undertaken by Irish universities during the 2004–2010 period.

Despite the relatively low priority given to solar in Ireland's energy policy, there are significant research strengths in this area.

Solar Thermal

The DIT Dublin Energy Lab and DCU have projects covering solar thermal testing and characterisation and heat transfer mechanisms. Other developments include integration of solar slates with heating systems.

Concentrated Solar Power (CSP)

In 2010 UL's Stokes Institute won a significant FP7 project, MOLESOL, in partnership with a local SME – R&R Mechanical – and other European partners for work on concentrating solar thermal electricity generating plants. This project fits very well with the EU SET plan initiatives on CSP.

Solar Photovoltaic (PV)

This area has attracted over €14 million in funding during the period. Significant funding through the SFI Strategic Research Cluster programme was given to the Biomimetics Cluster for Solar Energy Conversion (SEC), which includes industry and academics in UCD, UL and DCU. Its research seeks to develop new materials and to synthesize devices that mimic the steps involved in natural photosynthesis.

Researchers at the Dublin Energy Lab at Dublin Institute of Technology are researching concentrating solar PV methods as well as organic PV. Other institutes such as Dublin Institute of Technology (DIT), Waterford Institute of Technology (WIT), Tralee IT and Tyndall National Institute (TNI) have carried out a variety of projects in solar photovoltaic technology.

EU SET Plan: Solar Energy is one of the Strategic Energy Technologies identified by the EU Commission. A European Industry Initiative (EII) for Solar Energy was launched in 2010 and a set of technology roadmaps have been developed.

3. Wind Energy

Twenty-one wind energy research projects totalling €2 million were undertaken by Irish universities during the 2004–2010 period, at UCC, UL, UCD, Dundalk Institute of Technology (DkIT), Galway Mayo Institute of Technology (GMIT), DIT, Letterkenny Institute of Technology (LIT) and DCU.

A number of the funded research projects developed and improved methods for wind forecasting systems. Research also focused on improving turbine structures. Demonstration projects focused on new business models including on-site or auto-production of electricity from wind. Funding also supported increased human capacity with a Stokes lectureship in wind energy at UCC and Charles Parsons awards at UL.

EU SET Plan: Wind Energy is one of the Strategic Energy Technologies identified by the European Commission. A European Industry Initiative for Wind was launched in 2010 and a set of technology roadmaps have been developed.

4. Electrical Grid

Forty-three electrical grid research projects totalling €15.8 million were undertaken by Irish universities during the 2004–2010 period. Energy efficiency in buildings and ICT categories also overlap with this category.

While electrical power transmission has changed little in the last century, this is set to undergo profound changes with the impact of large amounts of variable renewable energy such as wind, and the creation of smart energy networks. Smart grids will enable widespread penetration of new technologies in metering, transmission, distribution, and electricity storage, as well as providing new information and flexibility to both consumers and providers. Ireland's ambitious renewable electricity targets and relative isolation from other electricity grids mean the research challenges require solutions in Ireland earlier than in other countries. This creates the opportunity to foster world leading research in this area.

Smart Grid research and development, as well as field trial activity is already under way in Ireland, with strong support from the electricity sector and the participation of SMEs. In the university sector, UCD is the largest hub of R&D activity in the area, with work also being carried out at the Tyndall National Institute and DCU.

At UCD, the Electricity Research Centre (ERC) is leading world class research into the integration of wind and other variable renewable energy sources in the electricity system.

EU SET Plan: Electrical Grid is one of the Strategic Energy Technologies identified by the EU Commission. Smart Grid and Smart Cities initiatives also exist.

5. Energy Storage

Twenty-one energy storage research projects totalling €6.2 million were undertaken by Irish universities during the 2004–2010 period.

Most energy storage research carried out within Irish universities concerns electrochemical solutions, i.e. batteries. Studies are underway at UL Department of Physics, the Centre for Renewable Energy at Dundalk IT (CREDIT), the Power Electronics Research Centre (PERC) at NUI Galway and the National Centre for Sensor Research (NCSR) at DCU, with funding from Enterprise Ireland (EI), SFI, IRCSET and industry.

The Centre for Sustainable Technologies (CST) at the University of Ulster maintains energy storage as one of its key research areas.

At UCC, the Sustainable Energy Research Group (SERG) is working on modelling pumped hydro energy storage within the Irish market, while the 4C computing group is looking at the economics of natural gas storage.

Major research in this sector includes a project on "Microstructure of Electrodeposited Metallization" at the University of Limerick, and energy storage systems at DkIT. Other projects include one on grapheme-based supercapacitors at the School of Chemistry/National Centre for Sensor Research at DCU.

The UCD ERC has studied energy storage operation within the Irish electricity grid. This work allows evaluation of technologies in economic terms in relation to the mechanisms of the Single Electricity Market (SEM).

6. Transport, Fuel Cells and Hydrogen

Forty-two research projects relating to transport, fuel cells and hydrogen totalling €10 million were undertaken by Irish universities during the 2004–2010 period.

Transport research is also covered in the area of Biofuels under the Bioenergy category.

Transport

Ireland is almost entirely dependent on imported fossil fuels for private and public transport. This drives the need for research into alternatives to fossil fuel technology, including biofuels and electric vehicles, and more efficient use of existing transport technology and infrastructure.

Research activities in this area include:

- Modelling the impact of electric vehicles on greenhouse gas (GHG) emissions at UCC
- Optical fibre sensor based intelligent systems monitoring emissions of road vehicles and engine optimisation for efficiency at UL
- Energy-sensitive design of road surfaces and green transport plans at UCD
- Various studies by DIT's Transport Research Group including road and air travel
- The School of Chemistry at DCU is currently involved in the design of new photocatalytic systems for the generation of hydrogen from water using solar energy

Fuel Cells

Fuel cell oxides research is being conducted at TCD, DCU and DIT. NUIG is also researching fuel cell control electronics.

Hydrogen

The realisation of a hydrogen economy would require the use of renewable energy sources to generate hydrogen with minimum environmental impact. Studies carried out by DCU, TCD and UL focus mainly on the use of solar energy for hydrogen generation.

Hydrogen and Fuel Cells research in Europe is co-ordinated by the Fuel Cells and Hydrogen Joint Technology Initiative (FCH-JTI). Annual calls in the order of €100 million offer research opportunities in many areas from the generation of hydrogen as an energy carrier, to the development of transport infrastructure.

7. Energy Policy, Analysis and Modelling

This has been a significant area of energy research in Ireland, and continues to be necessary to guide and inform energy-related policy decisions. A total of €15.8 million has been provided for 70 projects since 2004, accounting for 9% of total energy R&D investment during the period. The University of Limerick is a key player in the field, and other universities with major involvement include DCU, UCD, UCC and NUI Maynooth.

Sample Projects:

- The Irish TIMES project underway at UCC's Sustainable Energy Research Group (SERG) undertaking long term bottom-up energy systems modelling
- Environment and Climate Change: Impacts and Responses. ConSenSus: A Cross-Border Household Analysis of Consumption, Environment and Sustainability in Ireland at NUIG
- Policy research projects at the Charles Parsons Research Institute at UL
- UCD – Urban environment – decision support tools for managing the urban environment in Ireland. Various projects related to the EU Emissions Trading Scheme
- Energy policy and analysis studies at the Dublin Energy Lab, DIT

8. Energy Efficiency

With over 150 projects, totalling €34 million, energy efficiency is the most significant area of energy R&D. The main sub-categories are built environment, wastewater treatment, ICT, lighting, industry and consumer products, and combustion. Examples of projects in these sub-categories are listed below:

Built Environment

Research in this area overlaps with many other technology areas. Key research centres include:

1. UCD – development of energy performance of buildings standards and building energy labelling; sustainable design and retrofitting of Irish buildings
2. TCD TrinityHaus – post-occupancy evaluation of energy consumption of Dublin City Council, Wood Quay offices; embodied energy and lifecycle analysis for energy efficient retrofitting
3. University of Ulster, Centre for Sustainable Technology – sustainable building design and construction materials
4. UCC-4C / ITOBO – ICT for sustainable building operation; carbon-neutral buildings research
5. UCC, IRUSE – network embedded systems
6. GMIT, CiSET – infrared thermography and the development of sustainable energy design methodologies to guide the integration of renewable energy systems within the built environment
7. DIT, Dublin Energy Lab – design and optimisation of energy efficient buildings

Wastewater treatment

Research projects looking into new, less energy-intensive processes for the treatment of municipal wastewater have been carried out at UL and NUIG. This work has been supported by the EPA, Enterprise Ireland and IRCSET.

Key research centres are NUIG and UL.

Information and Communication Technologies (ICT)

With €11 million in research funding across 48 projects, this is a varied area of research covering the application of ICT to buildings and process design, energy management and the use of energy in ICT itself.

Areas covered to date in Ireland include:

1. The use of ICT for building design and building energy management at UCC / Tyndall / NUIG – 4C / ITOBO / IRUSE / NEMBES
2. The application of computer simulation to energy problems:
   a. *TCD – enhanced gas jet cooling, heat transfer, offshore wind structures*
   b. *UCD – advanced molecular simulation: Applications and Methodological Advances across Biology, ICT and Nano-Materials, and Energy and the Environment*
3. The design and optimisation of energy-using ICT equipment and data centres:
   a. *ICT cooling applications – UL Stokes Institute*
   b. *Datacentre optimisation*
      i. *TCD TrinityHaus*
      ii. *UCC 4C Computing Centre*
      iii. *GMIT*
   c. *IT Architecture optimisation for energy efficiency at DCU*
   d. *Tyndall – Zeropower FP7 Project – Towards Zero-power ICT*

Energy research relating to ICT technologies is set to be a major priority as the ICT industry seeks to achieve greater energy efficiency in its products. This was recognised by the EU when it designated the largest part of its R&D funds (€9.11 billion) to ICT through its Strategic Research Program. Part of these funds will be allocated to energy-specific research topics (e.g. EU FP7 ICT programme – Section 6 calls for ICT solutions for energy efficiency).

Lighting

Seven lighting research projects totalling €520k were undertaken by Irish universities during the 2004–2010 period.

Energy efficient lighting projects have been carried out by CIMMS at Tralee Institute of Technology, funded through the Enterprise Ireland Innovation voucher scheme. The School of Physics at DCU (RINCE) received funding for the development of prototype copper halide lighting. The Dublin Energy Lab at DIT has also worked with efficient lighting systems.

Energy Efficiency in Industry

There have been 25 projects totalling €2.7 million in the area of industrial energy. This includes research into efficient equipment and industrial energy efficiency.

1. The I2E2 competence centre has funded a number of studies at UCC and UL, covering topics such as waste heat and suitable working environments.
2. The DIT Dublin Energy Lab and the DIT FOCAS research institute also perform projects related to industrial energy efficiency.
3. UCD has worked on efficiency of steam systems, heat recovery, heat pumps, micro CHP and manufacturing efficiency through advanced performance prediction.
4. Heat pump expertise also exists in the University of Ulster through its SFI-funded Centre for Sustainable Technologies.
5. TCD based research looks into industrial processes identifying the potential for recycling energy in, for example, polymer processing and heat transfer mechanisms.
6. NUIG Power Electronics Research Centre (PERC) activities include developments in low-power electronics equipment for industry and health applications.
7. DCU has carried out a number of projects in the area of efficient products.
8. GMIT CiSET, with funding from Enterprise Ireland, has worked on the efficiency of transport refrigeration systems and embodied energy.

Combustion

The Chemistry Combustion Centre (C3) at NUIG, carries out world-leading fundamental research on the combustion of fossil and biofuels. More than €3.5 million in funding has come from various sources, including SFI, EPA, IRCSET, EU and international sources across 11 projects.

9. Bioenergy

Bioenergy is a significant area of activity with 120 research projects totalling over €30 million undertaken by Irish universities during the 2004–2010 period.

Bioenergy covers a diverse range of resources, supply chains, processes, and conversion technologies. Reflecting this, university-based bioenergy research in Ireland is both diverse and dispersed. A number of institutions cover a spectrum of bioenergy research categories, whilst others focus on just one aspect. Funding for bioenergy research in Ireland in the period 2004 – 2010 was second only to that for energy efficiency. This reflects European priorities – it is Europe's intention that by 2020 bioenergy will supply 14% of all European energy needs, and 61% of renewable energy in Europe.

The bioenergy research areas in Ireland mostly match stated European bioenergy research priorities, and also address a number of issues impacting on bioenergy development in Ireland. Funding is dominated by the Bioenergy and Biorefinery Competence Centre, which was established by Enterprise Ireland to be an industry-led facility focussed on the future direction of bioenergy. The majority of the remaining two-thirds of funding for bioenergy research in Ireland falls into the following fields:

- Conversion – both into energy, and into final energy carriers such as biofuels, in particular:
  - *First generation biofuels (UCD, DCU, and UL)*
  - *Second generation biofuels (UL, NUIG, DkIT, IT Carlow (ITC) and IT Sligo (ITS))*
  - *Digestion technologies (dominated by NUIG with 17 projects; also UCC)*
  - *Upgrading biogas (UCC)*
  - *Conversion efficiency (NUIG and UL)*
  - *Thermochemical conversion (UL, WIT, and UCD)*
- Sustainability – this covers carbon movement and capture; land use change affects; economic sustainability and social sustainability
  - *Life Cycle Analysis (UCD, NUIG, UL and UCC)*
  - *Land Use Change and Indirect Land Use Change (UCD, UL, and LIT)*
  - *Other sustainability areas (NUIG, UL, ITC and UCD)*
- Feedstocks – this includes resource cultivation, harvesting and pre-processing into denser energy forms, with research occurring at WIT, UCD, DCU and UL
- Other areas – such as co-production of high value products and long term R&D at NUIG, UCD and UL

Improved coordination and communication of RD&D activities in bioenergy in Ireland, and linking these with Europe, could lead to accelerated development.

The European Strategic Energy Technology (SET) Plan and the European Industrial Bioenergy Initiative aim to address technical and economic barriers to commercial deployment of bioenergy technologies.

10. Waste to Energy

Nine waste to energy research projects totalling €2.9 million were undertaken by Irish universities during the 2004–2010 period.

Waste-to-energy historically referred to the incineration of standard municipal solid waste. Increasingly, though, a number of new technologies capable of processing a variety of wastes are becoming commercially viable, with the benefits of reducing the quantity of waste sent to landfill and helping to reduce fossil fuel consumption.

There is significant overlap in this area with Bioenergy as a number of feedstocks for bioenergy processes would otherwise be considered waste. Examples include anaerobic digestion and landfill gas (methane capture from waste).

The main centre for R&D in Ireland into waste to energy is a Charles Parsons funded centre at NUI Galway, with some research also undertaken at UCC. No waste gasification plants or incinerators are currently operating in Ireland, though incinerator facilities are in the planning process in counties Dublin, Cork and Meath. Consequently, no significant research is being done in Ireland into waste gasification technology.

11. Geothermal Energy

There was a very low level of R&D activity in geothermal energy during the 2004–2010 period. An SEAI-funded report in 2006 ignited a revival of interest in geothermal energy, and recent SEAI supported research has indicated the potential for economically viable exploitation of deep geothermal energy at depths of 2,500m below the surface. Several Irish universities and institutes have conducted small research projects on shallow geothermal energy, while UCC (in Mallow/Glanworth) and UCD (on campus) have investigated exploitation of deeper resources.

In 2011, SFI awarded over €1 million funding to the Dublin Institute of Advanced Studies for a geothermal study project, IRETHERM: developing a strategic and holistic understanding of Ireland's geothermal energy potential through integrated modelling of new and existing geophysical and geological data.

12. Carbon Capture and Storage (CCS)

Nineteen carbon capture and storage or sequestration research projects totalling €3 million were undertaken by Irish universities during the 2004–2010 period.

Carbon Capture and Storage technology in development and demonstration will capture approximately 90% of the carbon dioxide (CO_2) produced when fossil fuels are burnt, preventing it from entering the atmosphere. CCS has the potential to help reduce emissions from electricity generation and in heavy industries where there may be few or no other emissions reduction options.

Due to the very large scale of research, development and demonstration required to prove the viability of this set of technologies, the international and European initiatives in the area, and the limited potential for application in Ireland (one coal fired power plant at Moneypoint), Ireland will most likely seek to utilise this CCS after it has been commercialised in other locations.

Capture technology projects in Ireland vary from research in power plant emissions at DCU, CO_2 capture membranes at UCD, techno-economic assessment and power plant modelling at University of Ulster, and the integration of capture technology into power plants at UL and DIT.

Storage projects include imaging of potential storage reservoirs at UCD and UL and understanding the fate of geologically stored CO_2 at DCU.

Examples include the DCU National Centre for Sensor Research (NCSR) project on "Development and testing of autonomous environmental sensor systems for specific emissions to air from IPCC sites (SmartPlant) and landfills (SmartLandfill)". This project was funded by the EPA and was completed in 2009.

SEAI has also co-ordinated a number of studies to date on the potential for application of CCS and the geological storage of CO_2 in Ireland in conjunction with the Geological Survey of Ireland, DCENR and the EPA.

EU SET Plan: CCS is one of the Strategic Energy Technologies identified by the EU Commission. A European Industry Initiative for CCS is ongoing.

13. Other

This category accounted for 6% of funding on energy RD&D during 2004–2010. The main fields of research include the following subcategories:

- Nuclear Fusion
- Materials for energy – Composites at UCD and UL
- GHG emissions / Environment – Centre for Sustainability at DkIT

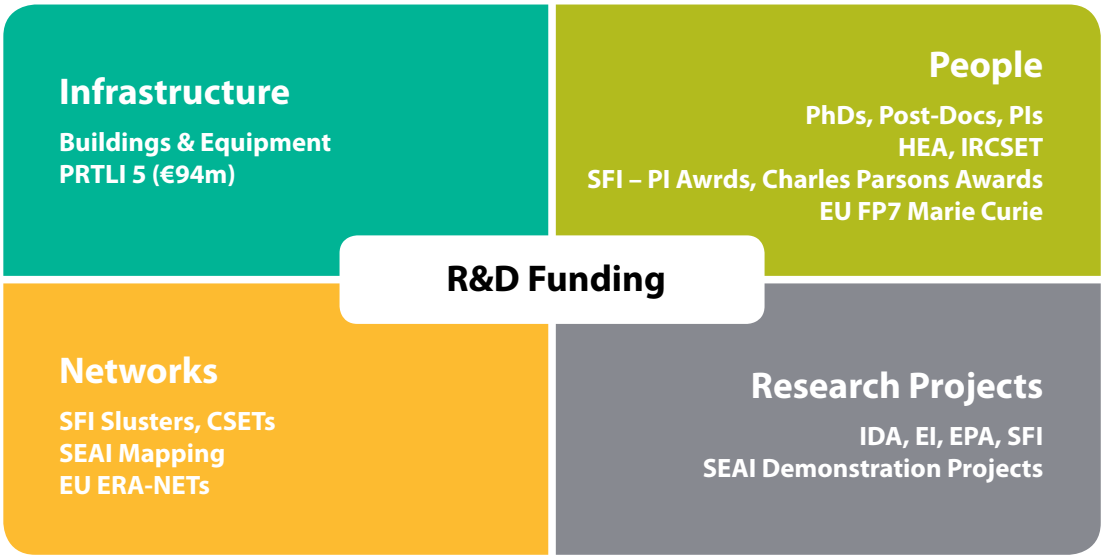
Research by Irish universities under this category during the period includes eight projects at UCD, and a €2.4 million project by the Plasma Data Analysis Group funded EURATOM at DCU.

5.0 Funding

5.1 Who the funders are

Funding for R&D comes from many different sources. Some government agencies focus on funding people, such as the Irish Research Council for Science, Engineering and Technology (IRCSET). Others also fund buildings, equipment and infrastructure, for example, the Higher Education Authority (HEA – PRTLI). Large scale technology clusters have been funded by SFI, and other agencies fund projects at various stages of maturity. Enterprise Ireland supports energy research by developing competence centres or by issuing innovation vouchers to entrepreneurs for use at universities. Figure 7 shows the key areas of funding and which funding bodies operate in each area.

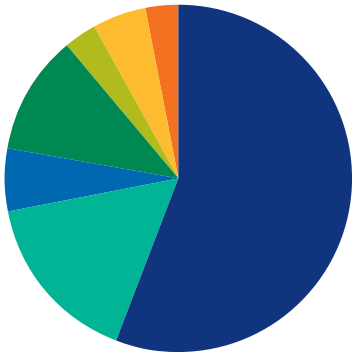
Figure 7: R&D Funding in Infrastruture, People, Networks and Research Projects



There has been significant year-on-year growth in energy R&D in Ireland during the past decade. More than 77% of funding for the University and Institute of Technology sectors comes from the Irish Government. A breakdown of funding by source includes:

- Irish Government (€128.2 million)
- The European Union (€18.3 million)
- Corporate bodies (€4 million)
- International funding (€1.9 million)
- Northern Ireland Government (€2.0 million – University of Ulster)

Figure 8: Irish Government funding to academic energy R&D 2004–2010



Science Foundation Ireland	€71,500,000	56%
Enterprise Ireland	€20,155,000	16%
EPA	€8,300,000	6%
HEA, IRCHSS, IRCSET	€14,240,000	11%
SEAI	€4,000,000	3%
DAFF, COFORD, COMHAR	€5,800,000	5%
Other	€4,300,000	3%
	€128,295,000	**100%**

Figure 9: Irish energy funding by Institutions 2004–2010

UCD	€37,300,000	20%
UL	€32,300,000	19%
NUIG	€23,500,000	14%
UCC	€22,900,000	13%
Institutes of Technology	€11,900,000	7%
TCD	€11,600,000	7%
University of Ulster	€10,500,000	6%
DCU	€9,800,000	6%
DIT	€7,500,000	4%
TNI	€6,100,000	4%
NUIM	€600,000	0%
	€174,000,000	**100%**

Institutes of Technology

Funding patterns for the Institutes of Technology are somewhat different to the University sector. ITs receive Government funding through:

- The Higher Education Authority (€2.5 million)
- Enterprise Ireland (€1.8 million)
- Department of Environment, Heritage and Local Government (€1 million)
- Department of Education and Science (€0.9 million)
- Environmental Protection Agency (€0.9 million)
- Irish Research Council for Science, Engineering & Technology (€220,000)
- Local councils (€40,000)
- Other sources (€1.3 million)

Science Foundation Ireland

Science Foundation Ireland plays a prominent role in funding energy R&D in Ireland. SFI operates by investing in academic research and research teams that are most likely to generate new knowledge, leading edge technologies and competitive enterprises. Formally SFI is mandated to fund basic research in the areas of highest strategic importance to Ireland's economy.

When SFI was established in 2000, these initial areas were Biotechnology and Information and Communications Technologies. SFI's remit was revised in 2008 to include Energy as a third key area.

SFI's 2009 report "Research for Ireland's Future: Energy" sets out the organisation's strategic approach to developing the research base that underpins sustainable energy and energy-efficient technologies. The report noted that energy-related research has some characteristics that differentiate it from research in the other two areas under its remit:

- Energy research straddles **many technological bases**. As a result, energy applications and awards will be administered within the two existing SFI Directorates (Information, Communications and Emergent Technologies, and Life Sciences)
- **Community building** is seen as central, in addition to capacity building. There are immediate national interest issues that need to be addressed, such as energy stocks/supplies, regulatory policy, and international regulatory agreements and their implementation

The report also noted: "SFI intends to integrate energy-related research into its existing portfolio of programmes, occasionally with targeted calls for proposals, while recognising and responding to these unique characteristics."

5.2 European Drivers for Energy Research and Development

Energy research also takes place within the wider context of the EU Innovation Union. This is one of seven flagship initiatives of the European Union's "Europe 2020" strategy for a smart, sustainable and inclusive economy, and it will be a key driver in turning research into innovation.

The EU Innovation Union plan aims to:

- Make Europe into a **world-class science performer**
- Remove **obstacles to innovation**, such as expensive patenting, market fragmentation, slow standard-setting and skills shortages – which currently prevent ideas getting quickly to market
- Revolutionise the way public and private sectors work together, notably through "**Innovation Partnerships**" between the European institutions, national and regional authorities and business

Innovation in energy technology is vital to meet our European energy and climate goals, to reduce the cost of decarbonisation and to put EU business on the right track to reap the benefits of growth and the creation of jobs from the exploitation of low-carbon technologies.

EU SET Plan

The main reference point in the EU roadmap for energy technologies is the EU SET Plan. The aim of the SET Plan is to strengthen the links between research and innovation (i.e. academia and industry) and develop low carbon technologies and to make them competitive. Industrial initiatives of the SET Plan were launched in 2010 in the areas of:

- Wind
- Solar
- Electricity Grids
- Carbon Capture and Storage
- Nuclear Energy
- Biofuels

Further priorities identified include research on promising renewable energy sources (such as environmental impact of ocean energy and microbial energy conversion), the testing of concepts and approaches regarding breakthrough orientated research (i.e. future and emerging technologies), and a cross-technology mapping of research topics in the area of Materials for Energy.

Within this overall context of the EU roadmap for energy technologies, the Irish Energy Research Map will play a central role in evaluating current activities, showcasing R&D capabilities and strengths, and identifying opportunities to access EU funding through FP7 and future EU research funding priorities.

5.3 European Framework Programme

The EU's Framework Programme for Research and Technological Development (FP7) is its chief instrument for funding scientific research and technological development over the period 2007–2013.

Thematic areas within the cooperation programme include Health, Food & Biotech, Nanotech, Materials & Production, ICT, Environment, Transport, Security, Space, and Energy. The annual energy calls target energy projects with typical values of between €2 million and €10 million over three to five years. The budget for the 2012 Energy Cooperation Call is €140 million.

Energy RD&D activities under FP7 aim to:

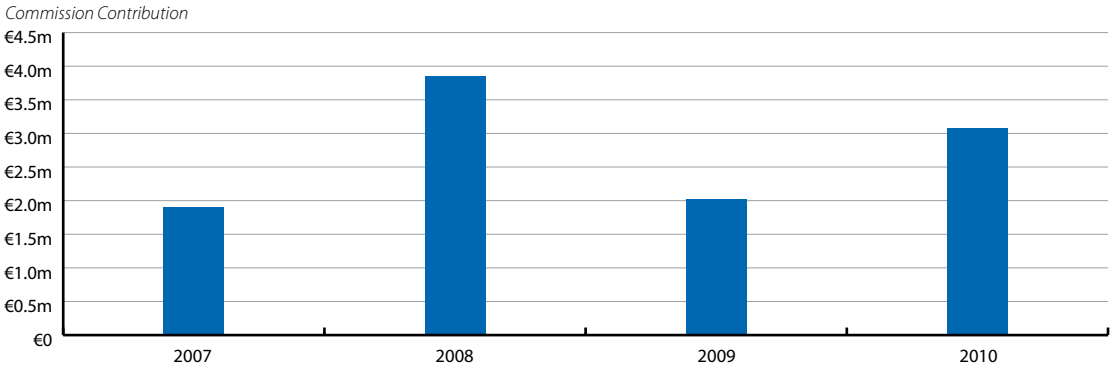
- Improve energy efficiency throughout the energy system taking into account the global environmental performance
- Accelerate the penetration of renewable energy sources
- Decarbonise power generation and, in the longer term, substantially decarbonise transport
- Reduce greenhouse gas emissions
- Diversify Europe's energy mix
- Enhance the competitiveness of European industry

The work programmes of FP7 align with the priorities of the EU SET Plan.

Ireland's success in FP7 to date includes participation in 18 funded projects totalling 25 Irish partners and a total EU Commission contribution to Ireland of €10.8 million since 2007.

Projects titles: MACCSOL, ORECCA, CGS EURROPE, MOLESOL, EFONET, EQUIMAR, TWENTIES, DIBANET, MARINA PLATFORM, STANDPOINT, CORES, SAFEWIND, GROUND-MED, C-ENERGY, EPHOCELL, MERGE, and AQUAFUELS. A breakdown of funding is shown in Figure 10 on the following page.

Figure 10: Ireland's Success in the FP7 Energy Programme



Information on all FP7 programmes can be found at www.fp7ireland.ie. The national network of contact points is coordinated by Enterprise Ireland. SEAI represents Ireland on the FP7 Energy Committee and is the National Contact Point (NCP) for Ireland.

FP7 Case study: Cooling solar power plants

R&R Mechanical and UL

Tullamore firm R&R Mechanical Ltd is part of a consortium led by Principal Investigator Ronan Grimes at the Stokes Institute, University of Limerick, which was successfully selected under an FP7 call in 2010. Other partners in the consortium include ebm-papst Ltd (Ireland), Torresol Energy Investments (Spain) and Friedrich-Alexander Universität (Germany).

The potential is for R&R Mechanical to receive EU funding up to €1,224,741, representing 29% of the total project budget, while University of Limerick and ebm-papst Ltd will receive up to 28% and 5% respectively. This project will bring EU funding of up to €2.62m to Ireland.

The UL Stokes Institute to date has worked on heat transfer applications, and the aim of this project is to develop and verify a novel modular air cooled condenser for enhanced concentrated solar power (CSP) generation. This technology will enable CSP plants to increase net power output, and reduce costs compared to existing dry cooled plants.

5.4 European Strategy Forum on Research Infrastructures (ESFRI)

Research infrastructures are defined as testing facilities that would be too large to be supported solely at a national level, and so need EU support in order to develop. Initial examples include nuclear fusion and fission infrastructures such as JHR: Jules Horowitz Reactor and HiPER: The European High Power Laser Energy Research facility and CCS infrastructures such as ECCSEL: European Carbon Dioxide Capture and Storage Laboratory Infrastructure.

In 2010, a report of the Energy Thematic Working Group of ESFRI recommended that three new research infrastructures be included in the ESFRI list:

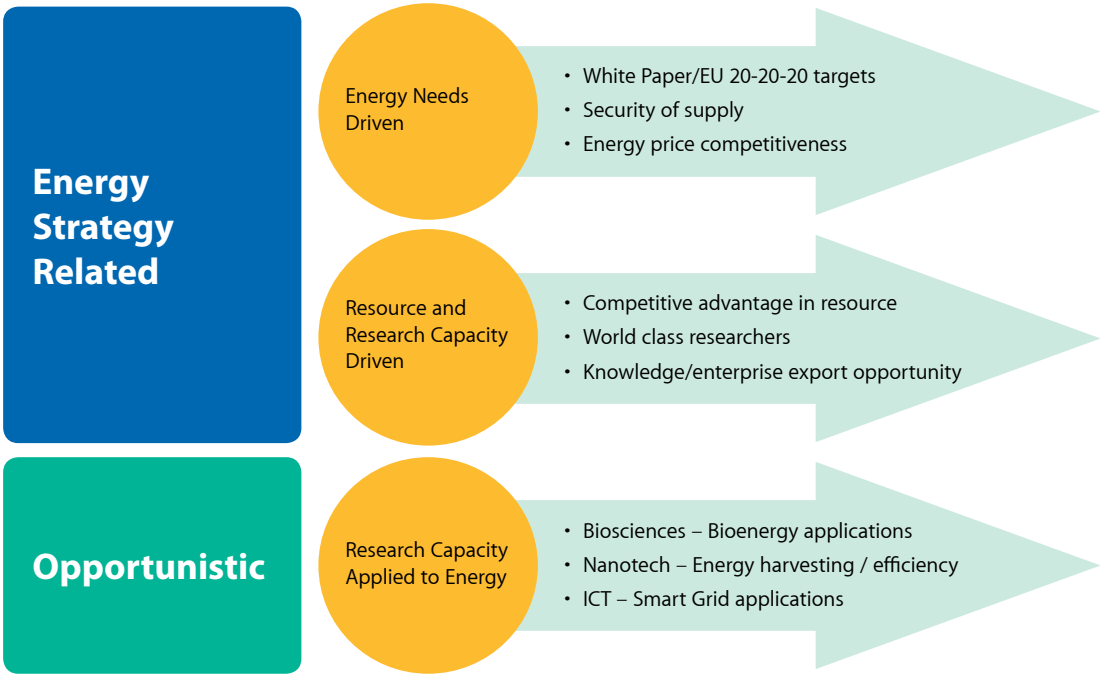
- Solar Energy – EU SOLARIS The European Solar Research Infrastructure for Concentrating Solar Power
- Wind Energy – WindScanner: European Centre for Wind Energy Research in Atmospheric Turbulent Flow and Nuclear Energy
- Nuclear Fission – MYRRHA: Multipurpose Hybrid Research Reactor for High-tech Applications

These research infrastructure projects will serve as open research spaces to stimulate technological breakthrough in these domains, and join the existing multidisciplinary research infrastructure already strongly contributing to energy innovation, through for example, the development of energy-related materials and methodologies.

5.5 Strategic Drivers for Irish Energy Research and Development

This research mapping exercise has revealed some insights into the strategic drivers of Irish energy research and development and how these influence the topic areas to which funding is allocated. The picture in Figure 11 describes energy research drivers as related to Ireland's energy strategy or opportunities.

Figure 11: Setting Irish Energy Research Priorities



The three drivers are:

- Strategic priorities driven by energy needs and the three pillars of sustainable energy; environmental impact, security of supply and price competitiveness. For example, Ireland's energy strategy sets renewable energy targets that require a high penetration of variable low carbon electricity generation. A firm understanding of the impacts of variable generation on the operation of the electrical grid is necessary if our targets are to be met without causing system instability. The Electricity Research Centre (ERC) at UCD does significant research on this topic.

- Ireland's energy strategy also includes a 4th pillar, enterprise development in the energy sector. This is reflected in policies that aim to turn Ireland's comparative advantage in resource, research capacity, or other areas of advantage, into export focused industries. For example, Ireland possesses one of the world's best ocean energy resources and a long established centre of research in ocean energy at the Hydraulics and Maritime Research Centre (HMRC). Further investment to strengthen the HMRC and support ocean energy research in other institutions followed the establishment of ocean energy strategy in 2006.

- During the last decade Ireland's funding infrastructure has awarded significant funding to basic research and has prioritised project funding to biotechnology and ICT. In many cases, basic research will yield findings that can be applied to the field of energy. The third strategic strand is funding projects that apply research capacity developed via basic research or findings from Biotech and ICT research application, to energy. In this strand, enterprise development is again the driver; however Ireland's energy strategy is not. The Advanced Biomimetic Cluster for Solar Energy Conversion (SEC) is an example of existing research capacity applied to energy.

This shows that the main strategic drivers are to create and apply solutions to our energy issues, create jobs and leverage our expertise and natural advantages.

6.0 Networks

Research networks take a number of forms. Networks within academic institutions bring together relevant in-house expertise to focus on a specific energy problem in a multi-disciplinary approach. These are termed "Research Centres" in this report. For those involving collaboration with other institutions and industry we have used the term "Research Clusters". This collaborative approach is seen as critical to successful commercialisation of research.

This section gives some examples of Research Clusters. It is followed by a list of all research clusters and research centres identified by the study.

6.1 Examples of Energy Research Clusters

There are fourteen clusters covering every energy topic and operating with a broad cross-section of industry involvement, ranging from large multi-nationals like Pfizer and Siemens to local start-ups like SolarPrint and Wirelite Sensors. Some examples are shown below.

Advanced Biomimetic Materials for Solar Energy Conversion (SEC)

The SEC is funded through the SFI Strategic Research Programme and industry partners SSE Renewables (formally Airtricity Holdings Ltd), Celtic Catalysts Ltd, and SolarPrint Ltd.

Its mission is to develop new materials and synthesise devices that mimic individually, and as a whole, the steps involved in natural photosynthesis. Harnessing the "free energy" of the sun, together with the application of engineering, chemistry, biochemistry, physics and computational modelling, it directs its research to the production of sustainable energy.

The cluster is led by Prof Don MacElroy (UCD), and the other Strand Leaders are Prof Edmond Magner (UL), Prof Han Vos (DCU) and Prof John T Sheridan (UCD). The project is managed by Dr Sharon Davin (UCD). In addition, the team comprises a number of academic funded researchers, collaborators, postdoctoral researchers, PhD and MSc research students.

The work-programme is subdivided into four Strands with tasks which parallel the sequence of steps observed in photosynthesis. Strands S1-S3 focus on the fabrication/characterisation of energy related materials in three major complementary areas. The objectives of Strand S4 will be the development of commercially viable solar energy modules. These Strands are:

- S1: Photo-responsive solar cell materials for power generation (Years 1–3)
  Dye Sensitised Solar Cells (DSSCs) – novel materials
  Novel materials for heterojunction Photovoltaic (PV) cells
- S2: Catalytic materials for hydrogen production via photolysis (Years 1–3)
  Development of a photoelectrochemical (PEC) cell for water splitting
- S3: Nanoporous and catalytic materials for CO_2 capture and fixation (Years 1–3)
  Catalytic and photocatalytic reduction of CO_2 for the production of chemical feedstocks
- S4: Energy conversion modules (Years 3–5)
  The translation of research into solar energy conversion devices and commercialisation of research

I2E2 (Innovation for Ireland's Energy Efficiency)

This Centre of Excellence in Ireland aims to be recognised as a European and global leader in directing energy RD&D for manufacturing industry in the areas of efficiency, management and sustainability. Its mission is the identification, development and implementation of world-leading research and innovation focused on assisting manufacturing companies operating in Ireland to reduce, on a sustainable basis, both the cost and the associated environmental impact of their energy usage.

I2E2 is an initiative of Enterprise Ireland and IDA Ireland, with industry partners Pfizer, Intel, HP, DePuy, Crowley Carbon, Ceramicx, Bombardier, Boston Scientific, Aughinish Alumina, Analog Devices, Xerox and Vistakon.

RD&D is conducted at TCD, UCC, NUI Galway and UL under the following headings:

- Compressed air systems – developing measurement capabilities and methods to identify efficiency improvements
- Appropriate working techniques in environments – dynamic monitoring HVAC systems for fault detection
- Energy from low grade heat – new techniques to assess heat recovery opportunities and emissions reduction
- Dynamic power use – methodologies to deliver dynamic control of key utilities
- Eco energy parks – supporting the development of sustainable industrial parks

UCD Electrical Research Centre

The ERC is one of Ireland's most innovative and progressive research groups, and is a unique collaboration between academia and major Irish and international electricity industry partners, including: UCD, TCD, Bord Gáis, ESB, Bord na Móna, Eirgrid, Viridian, EPRI, Goelectric, Cylon, SSE, Siemens, CER.

The group tackles the applied research questions underpinning the development of a sustainable electrical energy system, building human capacity in this crucial sector.

The ERC is based on a core group of engineering excellence in UCD and energy economics in TCD. The group collaborates with other research groups in Ireland and the UK, Europe and the US.

The main areas of research in the ERC are:

- Grid integration of renewables, in particular wind power
- Energy economics
- Microgeneration
- Demand-side management

The ERC is funded by industry, SFI Charles Parsons energy research award and other sources including SEAI, the European Commission EU FP6, IRCSET, IRCHSS, SFI Strategic Research Cluster (SRC) and Teagasc.

6.2 List of Research Clusters

Cluster	Technology	Partners	Institutes
PRECISION Plasma Technology for Nano Manufacturing	Nuclear	NCPST RINSE Surface Engineering Laboratory Intel Impedans Straatum Holfeld Plastics Proxy Biomedical EnBio Lexas Research	DCU DCU UCD
CLARITY Sensor Web – Adaptive Sensing and Information Discovery	Electrical Grid	Vodafone Ericsson IBM ChangingWorlds Oracle	DCU UCD TNI
SEC Advanced Biomimetric Materials for Solar Energy Conversion	Solar	UCD School of Chemical and Bioprocess Engineering Bioelectrochemistry & Biocatalysis Research Group School of Chemical Sciences SSE Renewables (Airtricity) Celtic Catalysts Solarprint Ltd.	UCD UL DCU
ITOBO Information and Communication Technology for Sustainable and Optimised Building Operation	Efficiency – Built Environment & ICT	IRUSE Cork Constraint Computation Centre Complex Systems Laboratory Microelectronics Applications Integration Group Centre for Wireless Adaptive Systems ARUP Cylon Controls Ltd. Spokesoft Ltd. HSG Technischer Service GmbH Intel	UCC NUIG UCC UCC TNI CIT
NEMBES NEMBES: Network Embedded Systems	Efficiency – ICT	CAWS KDEG Computer Science	CIT TCD TNI UCC

Cluster	Technology	Partners	Institutes
IRUSE Informatics Research Unit for Sustainable Engineering	Efficiency – Built Environment	Environmental Research Institute Dept of Civil Engineering	UCC NUIG
ERC Electricity Research Centre SFI Funded	Electrical Grid	Electrical Engineering Energy Economics Eirgrid EPRI Gaelectric SSE Renewables ESB Power Generation, ESB Networks, ESB International Bord Na Mona South Western Services Cylon Controls Commission for Energy Regulation Viridian Bord Gais Siemens	UCD TCD
CCBB The Competence Centre for BioREFINING AND BIOenergy Enterprise Ireland Funded	Bioenergy	Enterprise Ireland IDA	NUIG UCD UL
CRANN Centre for Research on Adaptive Nanostructures and Nanodevices	Energy Storage		TCD UCC
MERC3 Maritime & Energy Research Campus & Commercial Cluster	Marine Energy	Irish Naval Service Port of Cork Company Ltd Bord Gais Transas Ltd. Industrial Development Authority Enterprise Ireland Department of Communications, Energy & Natural Resources Sustainable Energy Authority of Ireland Marine Institute	UCC CIT National Maritime College of Ireland QUB UCD NUIM NUIG

Cluster	Technology	Partners	Institutes
I2E2 Energy Efficiency EI Funded	Energy Efficiency – Industry	Xerox Vistakon SEAI Pfizer Intel HP DePuy Crowley Carbon Ceramicx Boston Scientific Bombardier Aughinish Alumina	TCD UL NUIG UCC
BuildWise BUILDING a SUSTAINABLE FUTURE	Efficiency – Built Environment		TNI NUIG
IERC International Energy Research Centre	Various	In Development United Technologies Research Centre	TNI UCC UCD
Electrical Power & Energy Systems Research Cluster – power grids	Electrical Grid		QUB

Refer to SEAI energy research portal for links http://research.seai.ie

6.3 List of Research Centres

Research centres are structures established within universities for the purpose of bringing together multidisciplinary researchers to work on energy specific problems. The Irish Energy Research Map includes R&D activity by the following centres:

Centre	Acronym	Institute
National Centre for Plasma Science and Technology	NCPST	DCU
Networks and Communications Engineering: Researching innovation in engineering technologies	RINSE	DCU
Smart Power Management – EU Eniac JU – Nanotech	RINSE	DCU
National Centre for Sensor Research	NCSR	DCU
Dublin Energy Lab	DEL	DIT
Electical Power Research Group – Dub Energy Lab	EPRG	DIT
Fuel Cell Applications Research Group		DIT
The Transport Research Group		DIT
Antenna & High Frequency Research Group		DIT
Centre for Renewable Energy at Dundalk IT (CREDIT)	CREDIT	DkIT
Centre for Freshwater Studies	CFS	DkIT
Envirocore	EnviroCORE	ITC
Centre of Research and Enterprise in Green Energy Optimisation	GeoCORE	ITC
Centre for Sustainability		ITS
The Combustion Chemistry Centre	C3	NUIG
Environmental Change Institute – (Institute for Environment, Marine and Energy)	ECI	NUIG
Power Electronics Research Centre (PERC)	PERC	NUIG
Energy Research Centre	ERC	NUIG
Biomolecular Electronics Research Laboratory	BERL	NUIG
Microbial Ecology Laboratory	MEL	NUIG
The Ryan Institute	The Ryan Institute	NUIG
Electric Power and Energy Systems	EPES	QUB
UK-China Network of Clean Energy Research	UKChinaNet	QUB
TrinityHaus	TrinityHaus	TCD
Sustainable Energy Research Group	SERG	UCC
The Cork Constraint Computation Centre	4C	UCC
Hydraulics and Maritime Research Centre	HMRC	UCC
Bioresources Research Centre	BRC	UCD
The Earth Systems Institute	ESI	UCD
The Stokes Institute	Stokes	UL
Northern Ireland Centre for Energy Research and Technology	NICERT	UU
Eco-Innovation Research Centre	EIRC	WIT
Centre for the Integration of Sustainable Energy Technologies (CiSET)	CiSET	GMIT

Refer to SEAI energy research portal for links http://research.seai.ie

7.0 Online Energy Research Map

7.1 Objectives

Whilst the origin of this data gathering exercise was largely for SEAI's own use and to fulfill our commitment to publish an inventory of Research, Development and Demonstration, it has become a resource that will be useful to the whole energy community in Ireland. For this reason, the data is publicly available on the Irish Energy Research Map website http://research.seai.ie. The site presents an overall funding summary, information for each institution, and details within each technology category.

The site is intended to act as a **shop window** for all energy researchers on the island of Ireland. The data will be regularly updated by institutions through their research offices as they receive new funding awards, and SEAI will periodically survey the updates to ensure overall site content is maintained. The site will provide a continual and current status of energy research in Ireland. Institutions will also have specific news pages to allow their latest developments to be shared.

The portal will also point directly to EU funding opportunities such as FP7 calls and technology roadmaps from Joint Technology Initiatives and the EU SET plan. National funding opportunities will also be publicised through the site.

7.2 The Energy Research Portal

http://research.seai.ie

8.0 Next Steps

The research mapping exercise carried out with Irish academic institutions represents an enhancement of traditional reporting on energy research. The data allows energy research and development to be analysed from three different perspectives:

- Energy technology
- Institute
- Funding body

This allows for a much better understanding than before of where our strengths lie. Future developments might include input from industrial research, social networking, links with European research maps and the adoption of research performance indicators.

The Future: Research performance indicators

To date the energy research mapping exercise has concentrated on the most basic of measures – funding. This is a useful gauge of research success, but there are many more aspects that could be used for a more comprehensive evaluation. Some examples of such measures are outlined in the table below.

1st Order Indicators	Input Indicators	External Funding
		Recruitment of PhD students and academic staff
	Process Indicators	Seminar and conference activity
		Invited keynotes
		International visiting research appointments
	Structure Indicators	Staff active in research
		Number of PhD students
		Research collaborations and partnership
		Reputation and esteem
		Research Infrastructure and facilities
	Output Indicators	Publications
		Non-bibliographical outputs
		Number of PhD graduates and completion rates
		Public outreach
	Effect Indicators	Citations
		Number of awards and prizes
		Employability of PhD graduates
		Knowledge transfer and commercialisation of IP
		End-user esteem
2nd Order Indicators	Journal Impact Factor (JIF)	Average number of citations achieved by articles published in a given journal within a given period
	H Index	Number of articles a researcher has published which have a citation figure greater than H
3rd Order Indicators	Peer Review	Panels reviewing research groups

Source: OECD

9.0 Conclusions

As the profile of energy as an area of strategic national and international policy continues to rise, our efforts to understand energy and improve the ways we harvest and use it will become more important. Research and development are critical to increasing this understanding. Our objective in undertaking the development of this database of Irish energy research was to understand what our capacities in this increasingly important area are, in which institutions they are housed, and in whom they reside.

Significant investment has been made in recent years to increase Ireland's research capacity, which is by its nature largely human capital. This data collection exercise identified increasing capacity in energy research as reflected by levels of funding over the period 2004 to 2010. It also showed that the two areas attracting the largest proportion of funding were energy efficiency and bioenergy.

While funding is spread broadly across the institutions in Ireland, some universities are more active than others. UCD, UL, NUIG and UCC have gained a significant amount of funding, including a large proportion of the European funding won in Ireland in recent years.

While specific amounts of funding are not published according to specific researchers, this exercise has provided a resource to identify all of the key players in each technology area, in each institution and in the research clusters and centres.

Most importantly, the collection of what was dispersed and inconsistently reported information in to one database provides a first step towards looking at the capacity developed in context and with perspective. A number of next steps are already planned, including broadening the perspective to include comparisons to other EU member states and OECD countries, and adding indicators to measure output as well as input.

Given the challenges ahead nationally and internationally with energy security, greenhouse gas reduction, and the increasing cost of energy, the area is likely to continue to be a strategically important area for research in the coming decades. This database develops a more comprehensive picture of current energy research. It may play a key role in developing a strategic and coherent approach to energy research in Ireland in the future.

The Irish Energy Research Council's vision for energy research in Ireland:

"Ireland meeting its energy system requirements, in a manner that addresses the challenges of energy security and environmental sustainability, informed, underpinned and facilitated by highly motivated and strongly coordinated teams of energy researchers of world class standard operating in a stable, adequately resourced and continuous research environment."

The IERC's "Energy Research Strategy for Ireland 2008–2013"

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