UKERC

UKERC ENERGY RESEARCH LANDSCAPE: Electric Power Conversion

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1. Overview

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Characterisation of the Field

The purpose of the energy conversion research landscape is to capture important strands of research activity not covered within the other "hardware" landscapes.

This is necessarily a disparate category whose definitions are open to challenge and modification, as well as slower evolution with time as topics change. There is potential for overlap with other areas and there will be some consideration / iteration of boundaries required when revising this and other landscapes. Some topics which might feature in other landscapes have therefore been included for completeness, albeit at some risk of double-counting. The utility of the landscape should be: 1) to highlight new concentrations of research in areas which could potentially fall outside (or are superset extensions of) core areas of other topics / represent distinct areas of energy conversion unrelated to the non-traditional or non-mainstream areas; 2) to demonstrate the broader bench-strength of the research groups cited.

The scope of the landscape covers subject area definitions agreed by the IEA. An initial list of topics was discussed with UKERC and then cross referenced with the Research Atlas database (2005 to present), ie those programmes which demonstrated a reasonable mapping onto the overall title. This has led to three principal groupings and a number of disparate "other" areas, as follows:

- Energy Conversion research related to conventional thermal generation:
    - Balance of Plant (where this is taken to mean ancillary equipment "outside" the core of gas turbine or coal powered steam turbines, eg special governing or thermodynamic approaches, or boiler research not covered elsewhere); dry cooling towers
    - CHP (combined heat and power) not covered elsewhere;
    - Air pollution and thermal pollution from power plants - not covered elsewhere
- Generator and transformer research, components and materials not covered elsewhere including Superconducting generation machines
- Novel solid-state energy conversion devices; novel combinations and integrations of energy conversion technologies – potentially cross-cutting and serving more than one sector (eg Transport, Renewables)

Other IEA topics outside these groupings (not well represented in accessible projects databases) are also considered to be in-scope:

- magneto hydrodynamic conversion;
- other distributed generation

From the above list of topics, it will be seen that a very broad range of disciplines are involved and hence draw on the skills of University departments on the Engineering / Applied side (Electrical / Chemical / Mechanical Engineering) to their confreres in Physics and Chemistry departments. It will be seen from sections 3 and 4 (providers of Basic and Applied research) that many universities have set up multi-disciplinary "Energy Conversion" groups, perhaps responding to the evolving prioritisation and funding environment represented by the

RCUK "Grand Challenges" of which Energy is a prominent example. Universities with multi-disciplinary groups with names such as Energy / Power Conversion include Cranfield, Cambridge, Cardiff, Manchester and Southampton.

Basic research covers characterisation studies, including the development of analytical techniques and modelling approaches. The applied research programmes by their nature require more in the nature of test beds and practical implementation.

Due to the nature of this topic (somewhat of a "catch-all"), there are no high-level national or international programmes dedicated to "Power Conversion" unlike other landscape topics, and no dedicated hardware facilities.

Research Challenges

Research challenges are disparate and fall into several categories.

In research related to conventional generation infrastructure – broadly thermal generation via coal or gas and standard electromagnetic generators there is a worldwide network of manufacturers ("Original Equipment Manufacturers" – OEMs), trade and research organisations and academic institutions, conferences, publications etc. However, the pace of innovation is extremely measured given the high capital value (and often large size) of the elements of the entire system. The industry is over 100 years old and has developed a high level of practical caution, backed up by an experience-based (and long-winded) innovation processes, sometimes formalised and sometimes ad-hoc. "Field Trials" from an Energy Utility point of view (ie by a big national provider eg E.ON) only occur when the technology has been "completely de-risked" by the OEM, often after a decade of pre-development (source – interview with RWE NPower). Owing to this leisurely pace, resourcing for the consideration of speculative or unadopted technologies tends to be very much underpowered and understaffed. New propositions must be extremely compelling to be selected for project resourcing. As a consequence, productive research relationships between universities and manufacturers who might adopt their technologies tend to be of long-standing and are sustained also by indirect research benefits such as the employment flow from universities to companies.

Most technology innovation proceeds from standard commercial considerations. Lower plant down-time and cost of maintenance are the most important factors, followed at some distance by higher efficiencies and operational flexibility. There is extreme reluctance to adopt new efficiency / flexibility technology if there is any risk to "up-time", except after protracted adoption programmes. Changes in regulatory standards can however force the pace of change a little faster and shorten the adoption time for new technology and new suppliers, but not by much.

A consequent problem from the extremely long gestation time for new technology is the difficulty in justifying the R&D spend on an a priori basis. For the OEMs, a broad based R&D portfolio carried on over many years will, on an ensemble basis, produce a technology flow matching corporate strategic goals for competitiveness and cost / benefit. As technologies mature under the company's in-house Innovation process (by attaining progressively higher Technology Readiness Levels – TRLs) - with consequently higher project costs, they will be subject to ever more rigorous economic hurdles, eg Internal Rate of Return (IRR). A small number of early stage projects can be tolerated on a "look-see" basis amidst a large development portfolio, but the attrition rate will be high. When viewed in isolation (eg by an outside company or university hoping to introduce new research aimed at future application and deployment) it will be extremely difficult to demonstrate anything like an acceptable IRR when the many selection hurdles are still to be crossed and a long and uncertain adoption process remains ahead. For this reason, new technology for energy is often seen as being held back due to "market failure", ie the inability to make an economic justification for an otherwise promising technology due to the time and uncertainty elements in the IRR calculation. Outside an OEM's carefully balanced R&D portfolio, grant funding is the only feasible way (as opposed to Private Venture commercial funding) to mature technologies through the TRL levels. Indeed, the OEMs look to public grant funding as the first and frequently determing port of call in their selection process for early stage projects (ie will not select a project if grant funding is not already assured). While public funding for "fresh ideas", ie very early stage projects TRL 1-4, is frequently available for 3-4 years, grant funding is usually hard to obtain for demonstrator projects at later stage without a consortium of significant standing. Even then, funding ratios normally preclude participation by companies without significant financial resources except as subcontractors with smaller absolute subventions. While "market failure" is often a positive selection criterion for public grant awarding bodies, they are normally ill-equiped to fund a new technology until the point of realistic private venture backing due to selection criteria which envisage a cessation of support after 3-4 years (since the expectation is that in "normal" industry, a product is "close to market" after such a period of public support, rarely true in the energy industry.

Due to the potential for economic discontinuity inherent in the journey of a technology from university to OEM (excepting those that are substantially developed by the OEM from an early stage), certain technological discontinuities and inefficiencies can also occur, Early stages (TRL 1-4) naturally attempt to demonstrate proof-of-concept at low levels of funding without necessarily having a realistic environmental specification to design to (this almost certainly does not exist – specifications tend to evolve at the same pace as the underlying technology). This is no different qualitatively from any other product development but the late involvement of product reliability and manufacturing expertise in an already protracted development only compounds the economic problem and often leads to the often quoted phenomenon of "develop it once, develop it again" – often considerably extending the development time. Best practice in this case is always for the early stage research to seek the closest involvemenmt with the end user and the most detailed specification at every stage, and to seek to perform equipment trials at every opportunity with feedback on environmental performance as well as performance to specification (numeric) targets.

As is common to all the related to existing high capital value assets representative of, or more often belonging to, the existing productive infrastructure, access to experiments using realistic equipment is of primary importance. Such access is normally highly restricted and /or expensive due to the risk of malfunction or damage and also restricted in time: full size equipment is either used continuously for production or intermittently in "campaigns". Again, a consortium approach where several technologies are trialled at the same time on a large asset (eg gas or steam turbine) is often the most efficient, favouring well networked technology providers.

Beyond these challenges generic to the structure of the energy industry, specific challenges related to individual technologies exist (materials science, fabrication, advanced modelling) and multidisciplinary expertise which militate in favour of better endowed and larger institutions. The statistics of institutional involvement in Energy Conversion projects bear this out, with considerable weighting to the larger universities.

2. Capabilities Assessment

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The UK as a well developed G8 economy with a leading position in international research inidices and university rankings should be well positioned to occupy a leading place in Energy Conversion research as in other areas. However, other factors are less favourable. These relate to public policy and funding structures, institutional tramework, and relative industrial landscape / strength.

Public Policy vis a vis energy research in the UK has been in a state of flux for many years and research has suffered from periods of strong neglect. The break up of the CEGB and the privatisation and "atomisation" of the generation capacity had a profoundly negative effect on directed energy research in the UK (source: interviews). The smaller absolute scale of individual providers (even National Power and Powergen, now the UK arms of RWE and E.ON) made the less able to support generalised research activities. The 1992 closure of CEGB research laboratory at Leatherhead was such an example. The successor companies to CEGB were also left with relatively more diverse generation assets - ie each inheritor company had a "basket" of assets from different OEMs – making their engineering teams more thinly spread. This had the consequence of requiring relatively more resource for sustaining engineering and less for innovative R&D.

Economic changes and regulation have also played a role. Increased regulation on acid emissions and a generally falling price of gas in the 1990's led to the "dash for gas" (now possibly entering a second phase due to CO2 emissions caps and uncertainty over nuclear). This had the tendency of pushing more of the R&D burden on the OEM suppliers of new "low NOx" gas turbines and support for their introduction and management. Consumer price regulation in the 1990's also provided downward cost pressure on engineering and R&D organisation which fell disproportionally on the "futures" side.

While government policy was not in denial of global warming issues, neither was it strongly in favour of low carbon introduction to the extent of, say, continental European policies towards Wind and Solar. It is no accident that industries supporting wind and solar sprang up preferentially in Germany and Spain vs the UK, together with their supporting R&D infrastructure. The long anticipated draft UK Energy Bill published by the Coalition Governmment in November 2012 has announced an increase to £7.6bn p.a. of the "Green Levy" spending by 2020 to support "decarbonsation". However, no carbon targets have yet been included and so choices between which green energy technologies will received support are likely to be made on pragmatic grounds rather than a "grand scheme" approach. While much remains unclear about the policy it seems likely that an incremental "business as usual" approach will be adopted to R&D, albeit with perhaps more money available as scale-up is required.

In the United States, energy policy has been more consistently driven by government policy, this time by "Energy Security" imperatives in the wake of Sept 11th 2001. Policy is agreed via a national framework and is implemented by the National Laboratories (eg Oak Ridge, Argonne) who are involved in administering the various funding mechanisms such as ARPA-E and SBIR. Until recently, coal gasification was a major recipient; more recently the emphasis has shifted to shale gas recovery and "fracking".

In the UK, bottom-up efforts (lacking any overall national framework) have been funded by EPSRC and the TSB (fully funded and co-funded, respectively). Generation of ideas is normally led by universities but the role of their long term relationships and familiarity with the power industry is important here. Even given the relative decline of the UK in heavy industry (eg GEC turbine and transformer business passing to foreign ownership and the research intensiveness being consequently diluted), long standing relationships between UK universities and the operating divisions of energy companies present in the UK maintain a moderate-to-good capabilities here.

In the more novel technologies such as solid state and superconducting technologies, the UK maintains excellent basic research capabilities but lacks to some degree the large electrotechnical industrial companies with UK-based research intensity (vs US, Germany, Japan).

Table 2.1 Capability Assessment

UK Capability	Area	Market potential
High	Generator / Transformer research	Worldwide: 5+ years for materials dependent
High	Novel solid-state energy conversion devices	Worldwide: 5+ years
High	Novel combinations (eg including PV)	Worldwide: 5+ years
Medium	Thermal generation – balance of plant	Some plant specificity, so restricted: Now
Medium	Thermal generation boiler / thermodynamics NCE	Worldwide but via OEM: 5+ years
Medium	Superconducting generator research	Worldwide: 10+ years
Low	Combined Heat / Power NCE	Continental EU has higher capability: Now
Low	Thermal / Air pollution	Cont. EU and US higher capability: Now

NCE = "not covered elsewhere" ie in other landscapes

3. Basic and strategic research

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In view of the reliance of industry on "ideas flow" from universities (very little comes from SME's in view of the timescales incompatible with risk-capital return), the standard method of funding is the Engineering and Physical Sciences Research Council (EPSRC).

It is possible that private venture "Energy Conversion" projects have been successful in attracting funding but these are harder to identify,

The UKERC database contains details of EPSRC funded projects going back several years. Nine programmes were identified in the database covering the period 2005 to present; some programs have been completed but are included in the analysis to ensure that research groups with direct relevance were identified.

Projects included in the analysis are associated with the following subject areas (see Section 1).

Conventional generation:

- Balance of Plant : 1 project

Generator and transformer research:

- High efficiency power converters: 1 project
- Superconductivity: 1 project

Novel generation:

- Solid state generation 5 projects (Giant electrocalorific effect, silicon nanowires, nano-crystalline water splitting photodiodes etc)

Other:

- 1 project (Novel thermo-molecular effects at nanoscale interfaces)

Table 3.1: Research Funding

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
Responsive Mode http://www.epsrc.ac.uk	EPSRC	EPSRC "Research Base Funding" – researchers can apply any time, in any area of EPSRC's remit and for any amount and length of funding	Variable	Ongoing	Average (annual) programme award is £140K for analysed projects giving a representative spend of £600k for around four active projects at any one time
Encouraging Physical Sciences Research to meet Energy Needs See also: RCUK Energy Programme	EPSRC	Specific 2012 call for speculative research ideas to be submitted as a standard research grant applications in areas that offer promise to tackle some of the issues identified by the RCUK Energy Programme. Technologies highlighted for invitation include Materials for Energy Applications, Catalysis, Chemical reaction dynamics and mechanisms, Computational and theoretical chemistry, Electrochemical sciences, Photonic materials and metamaterials, Superconductivity, Synthetic coordination chemistry and Synthetic supramolecular chemistry.	None specified	2013 onwards	N/A
http://www.innovateuk.org/ see also:	TSB	The Technology Strategy Board funding for Research,	Variable	Ongoing	No individual TSB funded project which

http://www.innovateuk.org/content/competition-announcements/power-electronics-enabling-a-resilient-energy-syst.ashx		Development and Demonstration projects ranges from small proof -of-concept grants and feasibility studies through to large multi-partner collaborative R&D and demonstration projects. The projects must be business led from early stage micro businesses, to large multi-nationals. There are different models depending on the specific needs of companies, sectors and technologies. Apart from the smaller awards, funding is usually associated with themed competitions. One recently announced competition of some relevance to Energy Conversion is for Power Electronics.			is identifiable as specifically Energy Conversion
Defence Science & Technology Laboratory https://www.dstl.gov.uk/	DSTL	Direct contracts for military related energy technologies. Recent example: 6 month contract with Ilika plc for screening of thermoelectric materials	Variable	Unknown	N/A

Table 3.2: Key Research Providers

Name	Description	Sub-topics Covered	No of staff	Field
Cranfield School of Applied Science www.cranfield.ac.uk/sas	School of Applied Sciences includes Energy and Resource Technology	• Automotive and motorsport • Design • Energy and offshore • Manufacturing and materials	21 Faculty in Energy and Resource group	Mechanical, Aeronautical and Manufacturing Engineering
University of Cambridge Engineering Department http://www-g.eng.cam.ac.uk/epec/people.php	The Electronics, Power and Energy Conversion group within the Engineering Department focuses on power electronic devices and integrated circuits, and their uses in various applications. Other major research strands include solar cells and their integration in power systems, integrated design of electrical machines and drives, electromagnetic modelling, radio frequency and microwave power for industrial applications, and electrical power applications of superconductivity.	• Nanoscale materials and device design for electronics and energy conversion. • Integrated and discrete semiconductor devices for power switching and control • Electrical Machines & Electromagnetic Modelling • Engineering Applications of Superconductivity • MEMS	6 faculty, 7 researchers, 21 PhD students	Electrical and Electronic Engineering
University of Cambridge Materials Science Department http://www.msm.cam.ac.uk/research/clean-energy/clean-production.php	The Department's work supports many other landscape fields and includes non-fossil-fuel power generation (solar cells), high-temperature materials for more efficient power generation (fossil-fuel and fusion), materials (superconductors and, potentially, CNTs) for lower-loss electricity distribution, and energy-storage technologies for transport (batteries, hydrogen and methanol fuel cells).	• Enhancement of superconductors • Carbon nanotubes for reduced energy loss	N/A as subfraction	Metallurgy and Materials Electrical and Electronic Engineering
Department of Aeronautical and	Combustion and Energy Conversion Research Group in the Department of	• Combustion research • Exhaust energy recovery	15 faculty, 48 researchers,	Mechanical, Aeronautical and

Name	Description	Sub-topics Covered	No of staff	Field
Automotive Engineering Faculty of Engineering and Faculty of Science, Loughborough University http://www.lboro.ac.uk/departments/aae/ Department of Chemistry http://www.lboro.ac.uk/departments/chemistry/research/groups/energy/	Aeronautical and Automotive Engineering. Energy Research Group in the Department of Chemistry, Faculty of Science.	• Free piston energy converter • Fuel cells	70 PhD students (5 researchers in Low Carbon group)	Manufacturing Engineering
University of Manchester Power Conversion group http://www.eee.manchester.ac.uk/research/groups/pc/	Power Conversion group within the Department of Electrical and Electronic Engineering. Annual funding reported as EPSRC ~£0.9M, Industry / others £2.9M. The Group's research activities are broad, embracing power electronic converters, electrical machine design, electrical motor drives and the integration and control of power electronics in energy conversion systems. The research is both fundamental and applied, and usually has a strong practical dimension, supported by extensive well equipped laboratories including a 100 kW aircraft electrical systems demonstrator.	• Electrical system integration • Power electronics • Electrical machine design • Superconducting applications • Condition monitoring	8 faculty, 9 researchers, 24 PhD students	Electrical and Electronic Engineering
University of Cardiff Engineering	The Institute of Energy within the Engineering department has	• Thermoelectric Materials • Transient Overvoltages	21 faculty, 28researchers,	Electrical and Electronic

Name	Description	Sub-topics Covered	No of staff	Field
Department Institute of Energy http://www.engin.cf.ac.uk/research/resInstitute.asp?InstNo=9	expertise in energy supply, conventional and renewable generation systems, electricity transmission and distribution, as well as the demand-side and efficient utilisation of energy.	• Complex Fluid and Thermal Systems • Low Carbon Heat & Power • Assessment & Modelling • Smart Grids • Power Magnetics and Wolfson Centre	PhD students	Engineering
Imperial College Department of Electrical Engineering Control and Power group http://www3.imperial.ac.uk/controlandpower	We do research in several areas of system and control theory, a range of control systems applications, and the analysis and design of power systems and power converters .	• the control of induction machines power converter design	8 faculty, 9 researchers, 24 PhD students	Electrical and Electronic Engineering
Imperial College Department of Chemistry http://www3.imperial.ac.uk/chemistry/research/sections/nanostructuredmaterialsgroup See also: http://www3.imperial.ac.uk/energyfutureslab/research	Energy Conversion technologies, including low cost photovoltaics (organic, dye sensitized and hybrid solar cells), and electrical energy storage (batteries and supercapacitors)	• solar driven fuel synthesis • artificial leaf	N/A distributed	Electrical and Electronic Engineering Chemical Engineering

4. Applied research

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EPSRC again provides the best data for projects in the "Applied" category. It is likely that all of these originate from the classic "Response Mode" funding route; however, EPSRC is now moving to a more thematic basis and has recently put out a call for projects on "Power Electronics". No separate budget has been ring-fenced but the topic will have its own prioritisation / merit ranking vs the standard response mode input.

Ten EPSRC funded projects were identified from the database over the period of study (2005 – present), many already completed but included here to ensure that relevant university research groups with particular focus on Energy Conversion are included in the analysis. Average annual award was £200k and thus representative annual spend around £700-800K.

Projects included in the analysis are associated with the following subject areas (see Section 1).

Conventional generation:

- Balance of Plant: 2 projects
- Boiler R&D, not covered elsewhere: 3 projects
- Atmospheric Pollution: 1 project

Generator and transformer research:

- High efficiency power converters: 2 project
- Superconductivity: 1 project

Others: 1 project "Enhancement of Electrochemical Energy Efficiency via Process Intensification"

The Technology Strategy Board is the most important funding body for commercially directed applied research in the UK. It is the "inheritor" body for the R&D portfolio previously managed by the Department for Trade and Industry and, in the transformation of one body to another, its funding strategy has gone through consdiderable evolution. One large scale project originally funded by DTI is included in the Research Atlas for the period 2005-present. This was "Innovative High-Power Direct Drive Superconducting Generator for offshore wind" which ran from December 2005 to November 2008. The project lead was Alstom: other partners included the University of Cambridge Engineering Department which has received funding for other superconducting related projects (included in the analysis of Basic Research programmes above - energy loss study for AC excited superconducting tape coils). Hence the project included in this analysis is clearly an example of an energy conversion project including (or led by) industry with Applied research as intent. The total award size was £3.5M over 35 months hence about £1.2M per year. While little inference can be drawn from a single programme the overall size of the award indicates a larger effort appropriate for experiments involving more sophisticated test beds and multiple organisations.

The funding policy of TSB in its first few years of operation has been more, but not exclusively, towards smaller projects with "commercialisation" in 3-5 years and somewhat away from large consortia in Energy (perhaps leaving this field to EPSRC and the Energy Technology Institute). TSB funding implicitly requires private venture part funding and hence a business case which militates against long payback projects. A full list of over 2000 TSB funded projects has been analysed in over 30 topics related to energy conversion, nominally covering 150 projects. While many of these fit well into other landscapes none at all appear to fit into the "early stage" or "large plant" nature of this present landscape. More recent directed calls (eg for Power Electronics) may produce projects better related to electric power conversion.

Table 4.1: Research Funding

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
Responsive Mode http://www.epsrc.ac.uk	EPSRC	EPSRC "Research Base Funding" – researchers can apply any time, in any area of EPSRC's remit and for any amount and length of funding	Variable	Ongoing	Average (annual) programme award is £140K for analysed projects giving a representative spend of £600k for around four active projects at any one time
Encouraging Physical Sciences Research to meet Energy Needs See also: RCUK Energy Programme	EPSRC	Specific 2012 call for speculative research ideas to be submitted as a standard research grant applications in areas that offer promise to tackle some of the issues identified by the RCUK Energy Programme. Technologies highlighted for invitation include Materials for Energy Applications, Catalysis, Chemical reaction dynamics and mechanisms, Computational and theoretical chemistry, Electrochemical sciences, Photonic materials and metamaterials, Superconductivity, Synthetic coordination chemistry and Synthetic supramolecular chemistry.	None specified	2013 onwards	N/A
SUPERGEN2 Conventional Power Plant Lifetime Extension Consortium	EPSRC	SUPERGEN2 is EPSRC's follow on to SUPERGEN, the flagship initiative in Sustainable Power Generation and Supply. SUPERGEN2, is managed and led by EPSRC in partnership with BBSRC, EPSRC, NERC and the Carbon Trust. The initiative aims to help the UK meet its environmental emissions targets through a radical improvement in the sustainability of power	£4.2m	2008 to Dec 2012	All major areas are well covered by other landscapes – not possible to identify specific spending on Energy Conversion aspects

		generation and supply. The programme is supporting the development of new and improved products for efficient and sustainable power generation and supply. Of the focus areas the ones relevant to this Landscape are: - advanced steam systems - advanced cycles (including biomass co-firing, oxy-firing)			
http://www.innovateuk.org/ see also: http://www.innovateuk.org/content/competition-announcements/power-electronics-enabling-a-resilient-energy-syst.ashx	TSB	The Technology Strategy Board funding for Research, Development and Demonstration projects ranges from small proof -of-concept grants and feasibility studies through to large multi-partner collaborative R&D and demonstration projects. The projects must be business led from early stage micro businesses, to large multi-nationals. There are different models depending on the specific needs of companies, sectors and technologies. Apart from the smaller awards, funding is usually associated with themed competitions. One recently announced competition of some relevance to Energy Conversion is for Power Electronics.	Variable	Ongoing	Only a single applied research programme was identified during the period of £1.2m per annum over 3 years.

Table 4.2: Key Research Providers

Name	Description	Sub-topics Covered	No of Staff	Sector
University of Edinburgh Institute for Energy Studies http://www.see.ed.ac.uk/research/IES/ http://www.see.ed.ac.uk/research/IES/research/machines.html	The Institute for Energy Systems (IES) is one of five multi-disciplinary research institutes within the School of Engineering at the University of Edinburgh	• Novel Generator Designs for Renewable Power Generation • Thermal and Mechanical Analysis for Electrical Machines • Power Conversion and Control for Renewable Energy Converters	IES total 14 faculty, 26 researchers, 50 PhD The current research grant portfolio is around £10 million	R&D science and engineering
Cranfield School of Applied Sceince www.cranfield.ac.uk/sas	School of Applied Sciences includes Energy and Resource Technology	• Automotive and motorsport • Design • Energy and offshore • Manufacturing and materials	21 Faculty in Energy and Resource group	Transport Electricity and gas Manufacturing
University of Warwick School of Engineering http://www2.warwick.ac.uk/fac/sci/eng/research/power/pcsr/	The Power and Control Systems Research Laboratory is led by Professor Jihong Wang and the research areas cover: energy efficiency, power system modelling, simulation, control and monitoring, nonlinear control system theory and its industrial applications	• supercritical coal fired power plant dynamic Responses • thermal power plant modelling and simulation	IES total 6 faculty, 5 researchers	R&D science and engineering
University of Southampton School of Engineering Science http://www.southampton.ac.uk/engineering/research/groups/energy_technology.page	The Energy Technology Research (ETR) Group is the focal point for energy research in Engineering and the Environment. We are engaged in cutting-edge fundamental and applied research underpinning sustainable energy technologies	• thermal energy • electrochemical engineering • solar energy • maritime energy • electromechanical energy • materials for energy • energy management and control	25 faculty, 8 researchers, 7 PhD	R&D science and engineering

Name	Description	Sub-topics Covered	No of Staff	Sector
University of Newcastle School of Mechanical and Systems Engineering http://www.ncl.ac.uk/mech/research/mfts/	The Multiphase Flow and Thermal Systems group is engaged in a wide range of research work. This covers analytical, computational and experimental investigations of both fundamental and industrial problems of heat, mass and momentum transport.	• Free-piston engine technologies • Thermodynamic cycle analysis of power and process plants	10 faculty, 1 researchers, 10 PhD	R&D science and engineering

5. Development and Demonstration Funding

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No specific demonstration is currently dedicated to Energy Conversion projects. Such projects tend to be subsumed into the larger themes in the later stages (eg Coal / Gas / Wind generation)

6. Research Facilities and other Assets

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No specific facilities are dedicated to Energy Conversion projects. Such projects tend to be subsumed into the larger themes in the later stages (eg Coal / Gas / Wind generation)

7. Networks

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The sector is too disparate to identify any Networks which are not better covered in other landscapes.

8. UK Participation in EU Framework Programmes

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The sector is too disparate to identify any EU Framework Programmes which are not better covered in other landscapes.

9. International Initiatives

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The sector is too disparate to identify any international initiatives which are not better covered in other landscapes.