

**The Royal Society of Edinburgh  
Inquiry for Scotland's Energy Supply**

**SUBMISSION  
FROM THE  
ENERGY ACADEMY  
AT HERIOT-WATT UNIVERSITY**

**A vision for how Scotland could be satisfying its energy requirements in 2050 –  
through local energy responsibility, source diversity and energy education**

The Energy Academy was established in Heriot-Watt in 2004 as an energy-interest group and includes activities in Edinburgh, the Borders and Orkney, where Heriot-Watt has its campuses. Whilst written as a submission for the Royal Society from a user's perspective, this document also sets out some of the routes The Energy Academy perceived for Scotland's Energy Supply in the respective communities in 2050. There are a number of ways in which such a submission may be made; academics more usually quote data and forecasts and impediments to the development of certain technologies which are favoured by them. Instead we present a holistic vision of what we believe is likely to be the situation in 2050. It is an optimistic vision, but one which when read by others has forced a measured consideration of the actual potential and possibilities for change.

**Domestic**

In the Edinburgh, the Borders and Orkney, we will be increasingly reliant on a mix of Energy Sources. Domestic users can import or export electricity. Micro-generation and rooftop wind devices provide substantial proportions of the requirements, and will be supplemented by green electricity from wind farms (offshore/onshore), hydroelectric, tide and wave power systems. Network management and peak-shaving will be enabled by energy storage and demand management technologies (including hydrogen and hydrate) applied at industrial and domestic scales. Some space and water-heating requirements provided by shallow boreholes, heat exchangers or ground source heat pumps, already economic for new-build properties in 2010. Deeper storage of "winter-cold" has proved less popular due to Scotland's relatively low requirement for summer cooling. By 2050, low-cost electrolysis and photolysis provides hydrogen at local level for heating as well as a transport fuel. Low cost solar photovoltaic panels have become effective alternative to conventional roofing materials for new-build properties. The PV arrays use a new hybrid wide- and narrow- band-gap semiconductor technologies to extract nearly 60% of the irradiation incident on the panel. Per capita electricity demand in homes has reduced through energy-saving devices (smart LED devices, smart insulating wallpaper, smart lights, smart standby technology, new materials for energy conversion and storage, more efficient heat-pumps and air conditioning systems). More properties are being built with local wood with higher standards of insulation and triple glazing encouraging longer-term sequestration of carbon in biomass (and reducing the use of cement). Biomass generators are being used in the Borders for local small scale domestic/industrial supply and export to the grid.

## **Services**

Electricity supplies for services will come from local wind energy (Heriot-Watt Edinburgh campus even has its 3 distinctive wind devices) and also supplied through the grid at competitive prices from the green sources mentioned above. Orkney has become a major supplier of energy from wind and tide (the Scapa Flow Marine Energy Centre) to the mainland via the offshore Stromness-Inverness interconnector. After a period of intense fundamental research and industrial-led development several wave and tidal devices have gone through the development and prototype stages and are now making significant contribution to energy generation. The excellent wave resource and the high degree of understanding brought about by many years of wave climate study and modelling has made Orkney, along with the west coast of Scotland a prime site for developers. The growth of this sector in Orkney has been supported by the activity at the European Marine Energy Centre which has worked closely with Scottish Universities and has had a key role in the development of performance evaluation and testing standards within the marine energy industry.

Public concerns about the environmental damage by transmission lines (w.r.t. people's health and visual impact) has been mitigated by the investment in buried and offshore cabling and novel hydrogen transportation technologies.. The increasing frequency of winter storms means that the buried transmission system is also more robust. Clean coal power stations (using coal with biomass fuel and carbon capture) around the Firth of Forth supplement the energy supply. Import of low sulphur coal provides secure supply as this can be stockpiled. These power stations are also powered by 'town' gas generated by in-situ gasification of the coal measures under the Firth of Forth. Enhanced coal-bed methane recovery has also been recently tested. Excess CO<sub>2</sub> is being stored in a subsurface CO<sub>2</sub> storage facility in the outer Firth of Forth. Collected CO<sub>2</sub> is also being piped to St Fergus and from there into some of the remaining oil producing fields. The North Sea oil story has confounded all the pessimists of the early 2000's. New discoveries (many in subtle traps) and new technologies (hoover-rig-boats, 60% recovery factors, intelligent fields, downhole steam factories, and in-situ gasification to produce low carbon fuel and hydrogen) have sustained the industry passed its original end date (which is now projected to be 2075). This oil is increasingly reserved for use as a precious feedstock for the petrochemical industry and is only used in transport by the airline industry. Recently a new hydrogen generating plant with CO<sub>2</sub> capture and storage was commissioned to supply the growing demand for hydrogen for transport in urban areas (taxis and buses). Following a variety of successful demonstration projects and schemes, hydrogen is becoming much more widely available in rural areas.

## **Industry**

By 2050, the Grangemouth refinery site is also using gas from the Firth of Forth for its operations. There is now also an LNG import location in the Firth of Forth. There is a gas-powered station on the site taking fuel from the Firth of Forth subsurface gasification project and imported LNG. The LNG is being used in the UK gas - transmission pipeline system. Gas is the preferred source for industrial energy supplies. Some hydrogen (using the technology developed in Scotland) is imported from the south (via enhanced interconnectors with French-built nuclear plant) and from the north (a geothermal plant in Iceland). Favourable experience with the

world's first commercial fusion plant, commissioned in 2045, has led to the search for suitable sites in Scotland.

A critical phase of national grid investment occurred between 2008 – 2020. The original passive network was upgraded to a real-time, actively managed grid with coordinated flow of power and voltage control. The network was then in a position to support increased generation from remote renewable sites, and to exploit embedded generation at domestic and industrial scales. The distribution network now operates with two supply qualities: premium (high) quality contracts are offered to sensitive industrial and commercial enterprises, and; standard (reduced) quality for domestic and insensitive operations. The two-tier system increased the distribution network capacity, reducing the need for network reinforcement. When required in the domestic setting, standard power quality is supplemented and improved by a locally-installed mix of energy storage, power generation, and power electronic conversion – this concept evolved from the power systems developed for the all- and more-electric developments in transportation in the early 2000s. The introduction of wide band-gap semiconductor technology in 2010 produced an order of magnitude improvement in power conversion efficiency and size. There is now no need to use low-frequency transformers; these have been replaced by high-frequency devices 1/10 of the size. Like-wise with circuit breaker and fault current protection equipment. As a result, the average substation footprint has been reduced by a factor of five.

Interestingly, the hydrogen fuel developments that we see today were partly inspired in the region by a pilot plant in Shetland in the early part of the century, which produced H<sub>2</sub> from wind and fuelled a car (fuel cell), with some industrial and domestic heating.

### **Transport**

Hydrogen-fuelled vehicles have become popular since the introduction of low-cost fuel cells in the 2020's. Electric scooters are common in cities (such as Edinburgh) using the new urban two-wheel network. Electric and Hybrid commercial vehicles have become more commonplace, their performance enhanced by developments in electrical drive technology (specifically the use of high-temperature superconducting motors using ultra-high energy density magnets). Biodiesel has been a transport fuel since its introduction in the early-2000's – where the island of Westray had a car running on used chip shop oil - with oil seed rape being widely grown for biodiesel. Biodiesel vehicles have become very popular in South America. Park and ride schemes are well established on the edges of towns – where one can also charge up vehicles from the national grid. Road charging schemes introduced in the 2010's stopped the ever increasing growth in traffic. Vehicles emitting greater than 250gm/km CO<sub>2</sub> have become very unpopular for social use since the introducing of swinging road tax in 2007. Cities are now much more pleasant environments. The electric trams running to Galashiels and Peebles have had a significant effect on those communities – now thriving dormitory towns. The Borders is a major biking centre – with many travelling out at weekends to Galashiels using the electric tramway. The Edinburgh and Borders Festival of the Outdoors in June attracts as many people to the region as the arts festival in August.

Nearly 15% of students and staff now cycle to the Riccarton campus – helped by the investment in cycle networks in the early part of the Century. Biking is a big part of

Heriot-Watt's sports science programme, taking advantage of the international Mountain Biking centres in the Borders.

In 2050, air travel continues to grow but at slower rates. The use of the Internet has slowed the growth in the market for business travel. The growth of leisure parks – controlled environments in local communities - and the fears about skin cancer have slowed the growth of sun-seeking holidaymakers. Global citizenship tours have now become big business. Fuel tax has slowed worldwide transport of cheap goods enabling more sustainable markets to grow locally.

### **Agriculture**

In 2050, agriculture in Scotland has seen a switch to biomass production for energy. Environmental management of the new landscape dominated by rapidly growing plants (e.g. coppiced trees and rape seed) has been a contentious issue during the last 20 years, but is becoming less of an issue as more attention is being paid to the sustainability of bird and insect populations. Agricultural machinery – now 50% hybrid – has seen an increase in the use of bio-diesel. Agriculture in the Borders has also become increasingly recreationally based. Cycling and horse riding are significant spinout industries for former agricultural businesses. The establishment of the South of Scotland Countryside Trails in the 2000's laid the foundation for a thriving tourist industry. The path networks have helped encouraged children to walk and ride to school saving fuel wastage. This has had the knock-on effect of improving their health. The wind farms built at that time are now seen to be a necessary addition to the countryside rather than an unwelcome invasion (which was felt by many at the time). They have helped sustain local communities through their low- CO<sub>2</sub> premium energy supplies. Their development was well managed so that their impact on key beauty spots was not too large. There are still valued locations in the Borders where as far as the eye can see there are no wind farms. Several offshore wind farms have sprung up – some around former oil producing platforms reusing much of the infrastructure – in the last 20 years.

### **Education**

The Energy and Sustainability programme introduced in 2009 is now commonplace in UK schools through the Scholar programme. The Energy Academy at Heriot-Watt, in its climate-controlled dome - is now teaching its Sustainable Energy programme in 16 centres across the world. Heriot-Watt Alumni helped by the Energy Foundation, are having a real impact on energy policy and usage in many parts of the world. The Energy for Island Communities Centre in Stromness (Orkney) attracts students from all over the world. Sea levels are still rising – although this seems to be slowing and island communities have the most to gain from an understanding of global climate change.

In 2005, the Joint Research Institute in Energy was launched as part of the Edinburgh Research Partnership bringing together groups of researchers at Edinburgh and Heriot-Watt University. By 2010, the research partnership had evolved to involve UHI, Robert Gordon's and Aberdeen to become a pan-Scotland Energy grouping. Scottish Universities (following the lead of the Edinburgh Research Partnership at Edinburgh and Heriot-Watt) have expertise in characterising and engineering the subsurface linking with experts in Europe, China, Russia, India and USA to facilitate and promote the underground storage of CO<sub>2</sub> and Energy. Critically for CO<sub>2</sub> the

Universities have been influential in those countries of most need for clean coal - e.g. in India and China. This has created many new opportunities for the Scottish Knowledge Economy as well as helping the planet. Underground storage of energy (gas storage) provides the UK with capacity and security, buffering variable supply.

### **Energy consultation**

In preparing this vision, The Energy Academy has invited many individuals and organisations to provide comment. We have undertaken to use all the feedback constructively to evolve our vision at timely intervals. However, the vision in the initial document remains the vision for the Energy Academy and we believe that it will help drive the research agenda forward in Scotland, particularly in the communities in which HWU is active. It is intended that the document be updated as new technologies come along. It is intended that The Energy Academy will help generate some of those new technologies.

### **Energy Academy members at Heriot-Watt University**

Colin Bullen	International Centre for Island Technology	Marine Renewables
Patrick Corbett	Institute of Petroleum Engineering	Petroleum Resources and Reserves, Geostorage, Geoenergy
David Davies	Institute of Petroleum Engineering	Oilfield and Geothermal well completions
John Fletcher	School of Engineering and Physical Sciences	Power Systems
Fhatollah Gozalpour	Institute of Petroleum Engineering	Carbon Storage
Bahman Tohidi	Institute of Petroleum Engineering	Hydrates
Paul Jowitt	Scottish Institute for Sustainable Technology	Sustainability
Sandy Kerr	International Centre for Island Technology	Renewable Energy Policy
Marcus Newborough	School of Engineering and Physical Sciences	Power Systems and Hydrogen
Jon Side	International Centre for Island Technology	Marine Environment, Decommissioning
Brian Smart	Institute of Petroleum Engineering	Coal, In-situ Gasification
George Smith	School of Life Sciences	Marine Renewables Engineering
Bahman Tohidi	Institute of Petroleum Engineering	Hydrates