Scotland's Energy Future:

A submission to the Energy Inquiry of the Royal Society of Edinburgh

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1. Energy Landscape: What are the most significant challenges to, and influences on, the energy landscape that any future energy strategy needs to take in to account.

Our greatest challenge is to transition to a sustainable energy supply, whilst meeting societal expectations for demand and continuity of supply. Specifically, within Scotland we must:

- Reduce waste in our consumption of energy, particularly for heating
- Mitigate an increasing demand for energy for transportation
- Avoid 'offshoring' emissions through either a) obtaining raw fuels from non-sustainable sources; or b) offshoring the manufacturing of goods which we produce and consume
- Address our energy security and sustainability with the rest of the UK
- Apply new technology to meet these challenges, but with suitable due diligence

Demand Context: Energy is essential to our survival, but the continuous availability of low cost energy has become critical to the way our society functions. In particular, our ability to exploit high energy density, portable hydrocarbon fuels over the past 100 years has enabled boundless increases in mobility, technology and the integration of global supply chains.

In the UK, the continuous availability of energy (specifically in the forms of electricity, petrol/diesel, and gas) has become so essential that supply disruptions of more than a few hours' duration would be considered a national emergency [1]. Even short interruptions in energy supply can be expected to cause significant disruption and are considered to be politically unacceptable.

In Scotland, 50% of our energy consumption is for heating (74% of our domestic energy). Whilst the efficiency of Scotland's housing stock has improved in recent years, this is now showing signs of a plateau with only 39% of Scotland's housing stock in EPC Band C and above in 2016. Even with oil price near to 15 year lows, 27% of Scotland's homes remain in fuel poverty [2].

Around 25% of our current energy use is for transportation. Whilst energy consumption for road travel has been broadly flat since 2005 [3], air travel will increase by 1-3% per annum for the foreseeable future [4] [5], and air travel has a 2-3x multiplier effect in terms of radiative forcing [6]. Scotland is currently considering a reduction in air passenger duty, which could raise passenger numbers by an additional 3% [7].

Sources of Supply: In 2017 the Scottish government estimated that 91% of the primary energy generated in Scotland was from hydrocarbon resources (53% crude oil, 31% gas) [8]. Scotland produces 35% of its electricity from nuclear, with the remainder primarily from gas and renewable wind power (though the latter is highly dependent on export capability to be useful [9]).

The UK is now highly dependent on imported energy, reflecting 40% of UK total energy consumption [10]. Manufactured goods reflect another source of imported energy, with emissions created during manufacturing frequently displaced to a third country. For example, although electric vehicles are expected to produce only 50% of the lifecycle emissions of a conventionally fuelled vehicle [11], most of these emissions are related to initial manufacture, with batteries contributing up to 40% of total manufacturing emissions.

Integrated Approach: Scotland exports a large proportion of its energy from renewable sources to the remainder of the UK, and also receives gas from the EU. It's approach to energy targets and climate change need to be integrated with the wider UK economy.

Technology: Scotland should focus on the adoption and development of proven world leading technology. Major opportunities exist to reduce waste in our existing supply chain by refining and deploying technologies that are already available. However, caution should be exercised when looking to develop bespoke solutions which can take many years to commercialise and can prove to be expensive for the taxpayer [12].

2. What will energy demand in Scotland look like in 2030, 2040, 2050?

A variety of scenarios are possible, from a 20% increase to a 30% decrease. A UK Department of Energy calculator provides useful insight [13]. In the base case, energy consumption increases by 20% to 2050, driven by expanded industrial consumption. However, a 30% reduction in consumption could be achieved with ambitious regulation and no further growth in industrial activity. A reasonable expectation is therefore that we will see more or less flat demand in the coming decades, but that this outcome relies on a number of regulatory interventions to reduce demand.

Although UK consumption has fallen by 10% since 2002 [14], this has been driven by reductions in industrial consumption (particularly heavy industry), with some contribution from domestic energy savings. Demand is now beginning to plateau, with transportation accounting for an increasing share. Further reductions in energy consumption are likely to require government intervention or an increase in wholesale prices. Energy demand for aviation is likely to increase. Estimates vary widely, but the UK Aviation Forecasts suggest passenger numbers will double by 2050 vs 2010 [5].

3. What are the biggest barriers faced to meeting the demand we will have for energy by 2030, 2040, 2050?

In 2017 the Scottish government estimated that 91% of the primary energy generated in Scotland was from hydrocarbon resources (53% crude oil, 31% gas) [8]. This creates key challenges for 2050:

- **Sustainability:** It is now widely acknowledged that the use of fossil fuels is unsustainable, with CO2 levels now at least 30% higher than they were in 1950 and 33% higher than they have been for the last 400,000 years [15]. The speed of change is widely understood to pose major threats to the short and long term survivability of virtually every species.
- **Awareness:** Due to the remote nature of current energy production, most people are unaware of how energy is produced. There also appears to be a lack of research into public awareness in this area. This makes it difficult to engage the public in discussions regarding the potential cost of changing the energy landscape.
- **Capacity:** The UK imports between 35-40% of its total energy supply [10], and has been a net importer since 2004. Production of north sea oil and gas has declined significantly. Although crude oil production capacity has recovered slightly in recent years, it remains near an all time low of 850,000 bbl/d (vs a peak of 2.5M bbl/d in 1999) [16], whilst gas production has also fallen to one third of its peak.
- **Infrastructure:** Our infrastructure is heavily biased towards the production and consumption of hydrocarbon fuels, whereas more sustainable energy sources require the ability to store, trade and recover electrical energy and heat. By example, although Scotland has experienced a boom in the availability of wind energy, it still needs to generate its own power by conventional means because there is insufficient storage [17]. Scotland's housing and industrial building stock also remains in a state of poor energy efficiency.
- **Cost:** With up to 27% of households already experiencing fuel poverty, there is a reduced priority on managing the demand profile and reducing long term cost, whilst there is political pressure to source fuel at the lowest possible cost [2].

4. Given the international nature of the energy market, how should acceptable quantities and origins of energy imports, and their associated energy security risks, be assessed?

Energy security should take into account:

- Supply constraints for producing nations
- Potential for technical / other failure of energy imports
- Political risk (for example, dispute or disagreement)
- Offshoring of emissions to other countries
- Environmental impact of chosen strategy

With the UK now importing up to 40% of its total energy supply [10], this is an important question. Energy security is now considered a matter of national security [1] but the increasing need to import energy also raises economic concerns. A recent closure of the UK Forties' pipeline coupled with an incident at one EU pipeline terminal resulted in a 20% jump in UK gas prices [18].

As of 2016, Scotland imports gas from the United States via the new terminal at Grangemouth. Each vessel imports 27,500 m3 (~15,000 tonnes) of ethane. Two vessels are expected each week, suggesting that the imported gas could represent up to 15% of Scotland's gross energy consumption. In England, there has been controversy over gas imported from the Peruvian rainforest, raising further questions regarding the social and environmental impact of imported fuels [19].

In 2015 only 45% of UK gas production was domestic, with the remainder from European imports (38%) and tankers (17%) [20]. EU imports were from a variety of sources, including 35% from Russia and 21% from Norway. A Russia-EU dispute could leave the continent unable to fulfil deliveries to the UK at short notice.

5. What overall role should be played by various elements of the energy landscape?

Renewable energy should be at the heart of any future landscape, but its development should be sustainable. Scotland has set a target of producing the equivalent of 100% of its consumption from Renewable sources by 2020 [21]. Current trends suggest that two thirds of this target will be met by wind power [22], which cannot provide sufficiently stable generation on its own. It has been convincingly argued that almost all of Scotland's wind energy is actually exported, and a good proportion of available capacity cannot be used at all [9].

Investment in Scotland's wind sector from the UK government provides Scotland with a unique opportunity to lead in the application of energy storage, and we should consider this a strategic priority. By setting a target to provide energy storage for 50% of installed wind power capacity by 2023 (5 years), Scotland would increase its energy security and be able to increase the utilisation of available wind power.

Offshore oil and gas continues to offer a significant revenue stream to the Scottish economy, as well as reducing the cost of energy to UK homes and businesses. This source of low cost energy offers the opportunity to provide the means for energy transition, and its premature exclusion from the energy mix could reinforce requirements on energy imports, reducing energy security and having the potential to 'offshore' emissions.

Overall, the proposed Scottish government target of reducing CO_2 emissions to 66% below 1990's levels by 2032 will provide the framework needed to reduce the contribution of fossil fuels to the energy mix. Minimising the contribution of offshore oil and gas should remain a priority, but not at the expense of using higher emission sources of fuel from elsewhere.

Unconventional oil and gas is already part of our energy mix through imports from the United States, Peru and other countries [19], and its development over recent years has drastically lowered energy prices globally. There is evidence that onshore unconventional gas could further lower energy prices in the UK and enable a more immediate transition to gas as a lower emission fuel than coal or oil.

However, the development of onshore unconventional oil and gas is highly unpopular with the public, primarily because of the risk of pollution to water supplies. There have been several cases of contamination in the United States, with regulators and industry leaders being slow to acknowledge the effects [23].

With sufficient oil and gas already in production to enable a transition to lower carbon supply chain and to provide low cost energy in the near term, the development of unconventional oil and gas would be likely to be a distraction from our long term goal of decarbonising the economy and also delay implementation of effective demand reduction measures. However, emissions associated with the production of imported energy should be included in the cost of consumption as discussed below in Question 9.

Nuclear power is already part of the UK's energy mix and is regularly imported from France. Within Scotland, existing stations at Hunterston and Torness contribute 35% of our domestic electricity consumption. Nuclear power provides a baseload of low carbon electricity, providing 35% of Scotland's electricity and significantly contributing to grid stability [24] at with only 5-25% lifetime CO_2 emissions of a comparable natural gas facility [25]. The Scottish government has ruled out replacement of existing nuclear facilities. This would appear to be in line with current public opinion, though a credible plan for replacement with long term, stable power generation methods is now sorely needed.

District Heating should play a key role in the supply of energy to Scotland, where heating accounts for 50% of our primary energy consumption. Community generation and storage should also feature widely. Both of these techniques offer credible potential to have a major impact on carbon emissions, whilst securing energy supply. We should aim to generate 25% of our heating requirements from district heating by 2030.

6. What action needs to be taken to ensure that Scotland fulfils its climate change obligations while also meeting demand, and what are the main obstacles to achieving this?

Scotland is currently considering a target of 66% emissions by 2032 vs 1990 levels [26]. This is an ambitious target and should be retained, but not at the expense of offshoring these same emissions.

Scotland should focus its energy on reducing waste throughout the supply chain and at the point of consumption. With its primary energy consumption dominated by transport and heating, Scotland should consider methods of reducing these losses at all stages. Critical activities will include:

- Infrastructure – providing the infrastructure to allow electricity and heat to be effectively stored and traded, so that energy losses can be minimised throughout the supply chain. For example, allowing excess industrial heat to be transferred into a centralised system for use elsewhere.
- Demand management – in particular reducing transport emissions through the deployment of electric vehicles and better provision of pool vehicles in cities, as well as reducing heat losses through the poor quality housing stock and industrial facilities.
- Heating Efficiency – Scotland should aim to be a pioneer in the deployment of efficient heating systems on brownfield sites, redeploying a skilled technical population towards the use of proven technology which will deliver tangible benefits for the future and allowing heat to become a tradeable resource.
- Improving connectivity with the UK grid to ensure maximum use of installed wind capacity.
- Carefully evaluating the full environmental impact of aviation emissions and credible fuel use scenarios when considering a reduction in aircraft passenger duty.

There is an urgent need to pursue improvement in energy consumption for the 61% of housing in EPC Bands D/E, but also for homes at Bands B & C. An EPC Band A property uses between 30-50% of the energy of a Band C property and only 18-25% of the energy of a Band D/E property [27].

Obstacles: Scotland has a mature market which is heavily biased towards the use of hydrocarbon fuels and large scale energy generation. It's building stock remains in poor condition and requires major investment to reduce excessive heat losses. Demand for air transport will continue to outstrip expectations and is likely to mitigate other efforts to reduce climate change.

7. What are the factors and risks which may impact upon the Scottish Government meeting the targets it has proposed on sustainable and renewable energy?

The Scottish Government 2017 Draft Climate Change Action Plan proposes a number of ambitious initiatives to move to a more sustainable energy production and consumption, with the goal of reducing CO2 emissions to 66% below 1990 levels by 2032 [26]. However, many of its measures are not fully detailed and rely to a large extent on improvements in efficiency which are yet to be technologically demonstrated. The most difficult challenges to be faced will include:

- **Housing stock:** The cost of transforming 80% of residential buildings to low carbon heating over 15 years is a major challenge and will be expensive. The average cost of energy efficiency measures applied through the current HEEPS scheme for vulnerable home-owners is around £4000 [28], suggesting a cost of up to £10bn for the entire housing stock. Though a sound objective, the average age of a domestic heating system is around 10-15 years, so the proposed reductions in domestic heating requirements will require a major government intervention to become achievable.
- **Transport emissions:** Transport emissions – particularly from aviation – will be difficult to reduce. The Scottish Government should be encouraged to use internationally recognised figures for radiative forcing potential (typically 2-4x) when calculating global warming emissions from aviation emissions [29].
- **Infrastructure:** It is widely expected that transition to an electrified economy will provide the potential for more efficient transfer of energy from one mode to another, and hence more efficient use overall. However, infrastructure for electricity supply has been designed on the assumption that there are several large producers and many small consumers.

- **Energy Storage:** Scotland is a world leader in the application of onshore wind power, but there is limited capacity to store the energy for use locally. Much of this power is exported, though a good proportion remains unused at source [9]. Transition to a sustainable low carbon economy will require efficient ways of storing this energy.

8. What are the environmental impacts of individual elements of a future energy mix, to what extent can these be mitigated, and how can any remaining waste products be dealt with?

The efficiency of most conventional fuel sources is shockingly poor, particularly when used for transportation or electricity generation. Even the most efficient combined cycle gas powered generating stations will convert only 54% of the available energy into electricity, whilst 30-40% is more typical. Efficiencies are lower for coal or oil fired facilities. A typical vehicle will use only 30% of the available thermal energy for motion, with the remainder lost to the environment. Heat is by far the greatest waste byproduct from energy generation, and methods of collecting and using this heat offer a significant potential benefit to the UK economy.

9. What account should be taken of environmental and social impacts on those living elsewhere in the world, of the international energy supply chains on which we may choose to rely?

The Scottish Government and UK Governments should agree a framework for social and environmental impact of imported fuels and energy. A carbon penalty should be applied to imported fuels at the current European ETS rate, providing a level playing field for fuel use. This could help remove some of the distortions that are sometimes caused by market intervention in favour of low carbon sources. Policy should include a transparent methodology for assessing (i) energy intensity of fuel production, (ii) energy intensity of transportation, (iii) local social and environmental impact at origin. Policy should ensure it is never possible to import a fuel with a higher overall social and environmental impact than that produced and consumed domestically.

Low carbon electric vehicles present a similar challenge, though to a lesser extent. Batteries for these vehicles require energy intensive manufacturing processes, which can contribute an additional 30-70% to the energy required [11]. These emissions typically remain offshore, though it is currently thought that the vehicles might reduce the overall impact by 50% over a full lifecycle analysis.

Particular areas of concern for policymakers should be emissions caused by unconventional oil and gas production, which may account for a near doubling of US methane emissions since 2002 [30]. Methane is a highly potent greenhouse gas. Imported gas from unconventional sources is likely to have a <u>much</u> higher embodied global warming potential than domestic production.

10. What actions can be taken, and by whom, to ensure that energy is accessible to all at an affordable cost for those on low incomes; and that any changes in energy provisions and associated tariffs are understandable and acceptable?

District heating schemes and insulation measures should be planned for all urban areas where fuel poverty affects more than 20% of the local population. Criteria for the current HEEPS scheme are restricted to those with disabilities or over age 75. For rural areas, policy should be developed to enable all properties to become EPC C rating or better by 2025, with an additional focus on unblocking planning constraints for community power schemes.

11. what are the particular advantages enjoyed, and challenges faced, regarding energy; and what lessons can be learned on a national scale from community energy schemes undertaken by:

Rural: A key benefit of community schemes is that they bring ownership of the energy cycle closer to the individual consumers, encouraging a greater understanding of their energy needs and their dependence on energy resources. Several successful schemes have been documented by Friends of the Earth [31].

Urban: District heating schemes and CHP offer enormous potential for carbon reduction in Scotland. A recent review by the UNEP estimated that district heating offers countries up to 30-50% reduction in primary energy consumption [32]. Denmark has been estimated to have seen a 20% national reduction in CO_2 emissions since 1990 because of district heating.

Efforts should be made to learn from Scandanavian district heating systems such as those in Norway, Sweden and Iceland, where CO2 emissions for heat delivered are below 5g/MJ_{th}, which is radically lower than might be expected from natural gas at 50-70g/MJ_{th} [33].

12. To ensure that energy is successfully sourced for, and delivered to, the people living in Scotland, how can different levels of government best cooperate with one another and existing stakeholders?

There is a significant role for Government in changing the status quo of the energy supply chain, and helping local authorities to find and prioritise solutions that work locally. For example, incentives or low cost loans could be provided for the adoption of proven technology for carbon mitigation. Government should also lead local authorities in the identification of low carbon solutions and provide incentives for regional stakeholders to engage. The government should prioritise decarbonisation of the economy and communicate its rationale and strategy for doing this both within Scotland and to the international audience. Finally, government should work with existing energy suppliers, industry stakeholders and academia to develop a credible plan for meeting the carbon mitigation goals outlined in its climate change action plan [26].

13 How can we best encourage objective, evidence -informed debate around energy whilst also acknowledging the differing perpsectives and priorities held by business, civil society and government?

Focused campaigns are needed to educate the public about how energy is generated, and the inefficiencies which are inherent in today's energy system. Most people are entirely unaware of how energy is produced and delivered and feel they have limited opportunity to influence how energy is generated and provided to them.

Wherever possible, organisations like the RSE should provide unbiased assessments of the factors affecting our energy market and provide a platform to communicate these to a wider audience. In particular, effort should be made to engage communities who do not normally participate in scientific debate. Emphasis on scientific rigour should be encouraged at all ages of schooling.

14. How can Scotland ensure that it retains, and develops, the necessary workforce of skilled professionals needed to meet its energy needs?

Scotland has world leading capability in its energy sector and has the ability to take a leading role on specific technologies which are aligned to existing skills sets. Examples include the installation of intelligent energy systems, installation of district heating systems and offshore wind power. Scotland should lean on this expertise and encourage domestic trials of this technology.

15. What issues arise regarding innovation for Scotland's energy future; how might this interact with an industrial strategy for Scotland?

New technology brings significant challenges and requires rigorous assessment by those who have experience in launching new technologies to market. Investment can be easily misplaced with good faith, as happened with the Pelamis and Aquamarine wave machines, which were poorly designed and ill equipped to operate on the surface of the sea [12], at a cost the Scottish taxpayer around £35m.

Whilst we should always promote domestic technology, this should be against a background of credible technology assessment. A target price for energy delivered by the technology should be agreed and a stage gated approach to funding deployed. Scotland should develop rigorous validation of technology for government funding using the Technology Readiness Level (TRL) scale, developed by NASA [34]. A staged approach to funding should be developed, and it should be clearly communicated that only a proportion of technologies are expected to reach final commercial application.

Finally, we should recognise the benefit of becoming leaders in the deployment of technology developed elsewhere. Many of the technologies needed to achieve our ambitious climate and energy goals already exist but are deployed in relatively few countries. In particular, Scotland has the potential to become world leaders in the deployment of low carbon heating systems.

End of Submission. References are attached for the readers' convenience.

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Useful Figures

Figure 1 estimates CO2 emissions from district heating systems in different countries. For comparison, typical emissions from natural gas, as would be used in a UK domestic boiler, are included. The boiler is assumed to have approximately 30% heat recovery and an overall efficiency of 98%, which is typically a maximum for best available technology today.

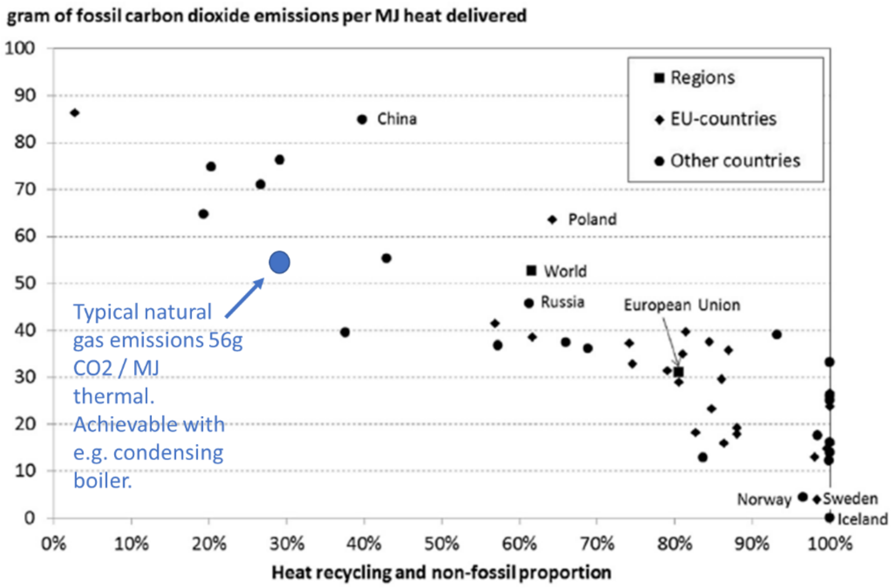

Figure 1 – Estimated specific carbon dioxide emissions 2014 from district heating systems, adapted from Werner [33]

Figure 2 shows how gas is imported to the UK. These imports contribute towards a total of 40% of the UK's primary energy currently being from imported sources.

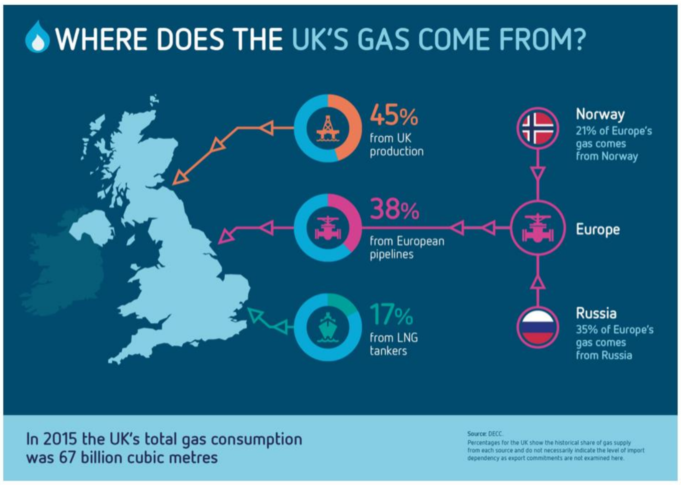

Figure 2 - Energy Security in the UK - Imported Gas [20]

Figure 3 shows an assessment of primary energy supply and consumption from the Scottish Government. Exports largely include gas from Scotland to the rest of the UK. There is also an interdependency between production and consumption, created by the intermittent loading of wind power generation, which is not shown here.

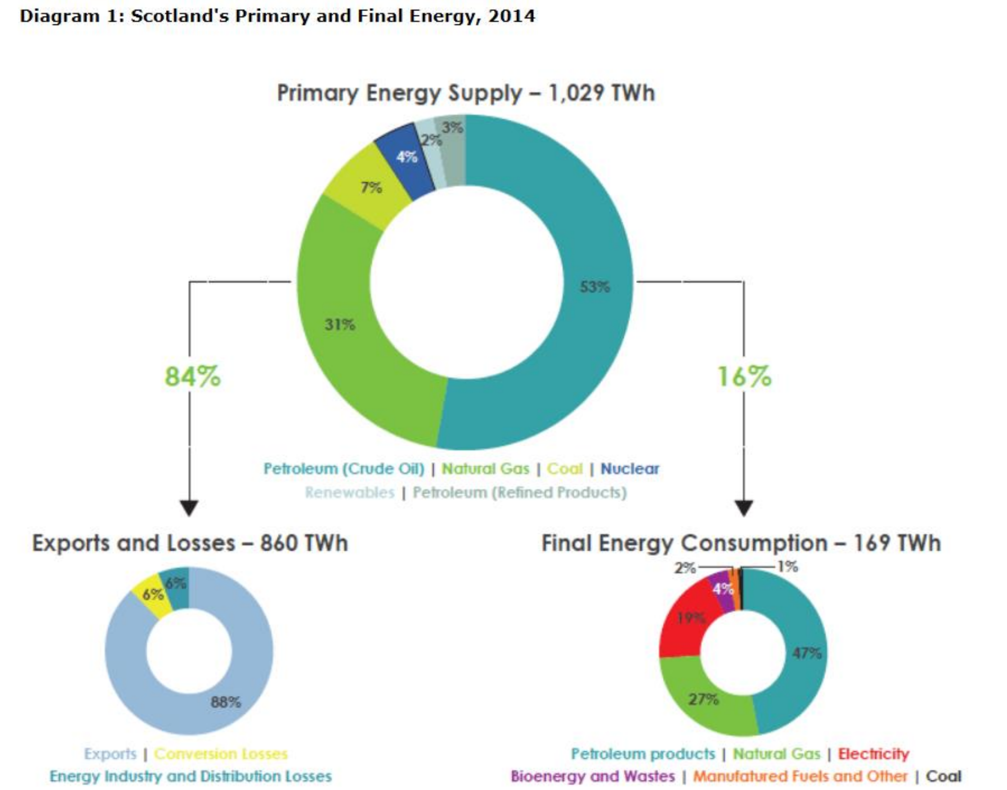

Figure 3 - Primary energy supply and consumption in Scotland [8]