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Think Piece

Energy

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Executive Summary

Ninety per cent of Scotland's territorial greenhouse gas (GHG) emissions stem from energy production and consumption; ending the unabated use of fossil fuels is therefore critical to achieving the potential for net zero emissions. Since the RSE's 2011 report *Facing Up to Climate Change: Addressing the Barriers to a Low-Carbon Scotland*, there have been some significant achievements in transition to clean energy, but there are two major sectors – heat and transport - where little has changed.

The majority of GHG reductions have resulted from rapid development of renewable power, and closures of coal power stations; renewable electricity almost tripled between 2008 and 2018, while unabated fossil fuel generation decreased by 70%. Renewable electricity supply fluctuates, leading to new challenges in balancing supply and demand across the grid. More active and flexible management of distribution networks is required and could result in socio-economic benefits to local communities.

Despite the increase in renewable production, most energy consumed continues to be from fossil fuels. Heat and transport are heavily dependent on oil and gas, and account for around 75% of energy use. Meeting Scottish emissions reduction targets in the next decade requires a major shift to clean energy in these sectors.

For heat, Scotland can progress rapidly with upgrades to the whole building stock to reduce the need for, and costs of, space heating. This is in line with Scottish Government plans in the draft Heat in Buildings Strategy 2021.The Strategy also aims for rapid conversion to clean heating for buildings not connected to the gas grid, and new district heating networks using available 'waste' or residual heat.

District heating is an effective solution for reducing demand in areas of high density and diversity of heat demand, such as urban centres. However, significant heat requirements will remain. To eliminate methane gas-fired heating in Scotland requires governmental collaboration, as decisions about the future of the gas grid lie with the UK Government. Questions remain about the alternatives to methane gas: electrification of heat will require a significant rise in electricity production and could significantly increase the cost of heating; using hydrogen gas as an alternative heat source would require production of hydrogen at large scale. Hydrogen gas production from methane also requires large scale carbon storage, which will increase cost to the consumer and is as-yet unproven at a sufficiently large scale. Production of green hydrogen from water is also expensive and would significantly increase electricity production requirements. Ultimately, a mix of these solutions may be required, accompanied by district heating infrastructure and retrofit to significantly reduce demand.

In the transport sector, clean energy and low carbon technology options and policy commitments are emerging, but clear policy priorities and technology plans need to be finalised and implemented rapidly. Research has concluded that a 2030 phase-out of all combustion engine vehicles, combined with reduced travel and car ownership, is needed for an emissions pathway compliant with the Paris Agreement. Scottish policy is formally committed to a sustainable transport hierarchy, which prioritises walking and cycling as most beneficial to the environment and to public health; public transport is the second priority, with use of private vehicles ranked least sustainable. Phase 2 of the Strategic Transport Projects Review, which will govern transport investment in Scotland over the next 20 years, reports in Autumn 2021. The outcomes of this Review will be critical to implementing the sustainable travel hierarchy as a means to a clean energy, active travel and socially inclusive transport sector.

In conclusion, this is a critical moment for rapid change in the next decade. UK central and devolved governments need to collaborate in: planning clean heat in buildings and industry; managing the necessary major increase in low carbon electricity generation; securing a shift to active and shared modes of transport and mobility, as well as use of low/zero emission vehicles; and ensuring that all infrastructure investments are prioritised against their contribution to net zero GHG emissions. The focus thus far has been on technology innovation; people, society and ways of life are (often) in the shadows. The UK Climate Change Committee Sixth Carbon Budget comments that three fifths of the changes needed now are in how we behave. In the short term, 'reshaping demand' for energy is key to making best use of resources. This will require central, devolved and local governments and businesses at all levels to engage fully with citizens and customers about sustainable consumption, a socially just transition and zero waste of energy and resources. Such engagement needs to be backed by a clear, comprehensive programme of action, including regulatory and tax reforms. CoP26 is an opportunity for UK central and devolved governments to demonstrate that they are serious and trustworthy.

1. Introduction

Scotland's energy system: change in the last decade, and changes ahead

When the RSE report *Facing Up to Climate Change: Addressing the Barriers to a Low-Carbon Scotland* was published in 2011, Scotland's Parliament had already set ambitious targets to reduce greenhouse gas (GHG) emissions by 42% by 2020 and 80% by 2050, against a 1990 baseline. The report concluded that these targets were achievable, but required major commitment and investment. In fact, the original 2020 target was met in 2014, and Scotland's legislated emissions' reduction targets are now higher, with a goal of net zero by 2045, and interim reduction targets of 75% by 2030, and 90% by 2040.

Ninety per cent of Scotland's territorial GHG emissions stem from energy production and consumption; ending the unabated use of fossil fuels is therefore critical to potential for net zero emissions.

2. Rapid Progress in Renewable Electricity

The majority of GHG reductions over the past decade have resulted from rapid development of renewable power, and closures of coal power stations. Between 2008 and 2018, renewable electricity almost tripled, while unabated fossil fuel generation decreased by 70% (UK Climate Change Committee (CCC) 2020a). The last coal-fired power plant in Scotland closed in 2016. Out of the four UK countries, Scotland has led in development of onshore wind power, and continues to lead in the overall proportion of electricity generated from renewable sources (Figure One).

Rapid development has been achieved without formal powers over energy markets and regulation. Instead, successive Scottish Governments have positioned energy as central to economic strategy, 'making full and assertive use of the powers conferred … by devolution' (Cowell et al., 2017a, p. 177). Powers over economic development and land use planning have been used to facilitate on-shore

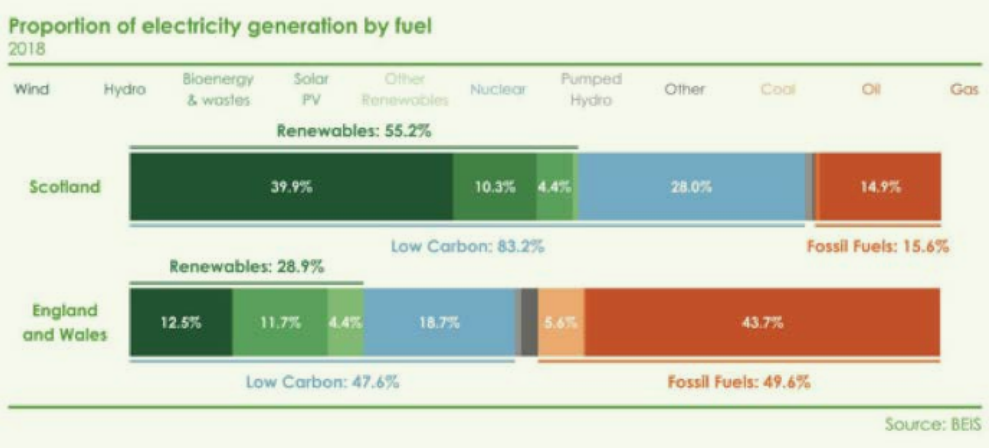

Figure One, Annual Compendium of Scottish Energy Statistics (ACSES), 2020, p.28

wind investment, first by asking local planning authorities to identify preferred areas for development, and by negotiating with authorities inclined to restrict consent (Cowell et al, 2017b). Second, government has fostered a cross-sector policy community geared to best use of GB market support schemes for renewables, bringing energy utilities into the development process (Cowell et al, 2017a). The effectiveness of this strategy is indicated by the significant proportion of renewable generation (mainly onshore wind), equivalent to 90% of Scottish gross electricity consumption in 2019 (Figure Two), now in the mix of sources. In the last year or so, however, growth in renewable electricity capacity has slowed, increasing by only 0.1 GW between 2019 and 2020, and a further 0.2 GW by early 2021 (Energy Statistics for Scotland Q1, 2020 and 2021).

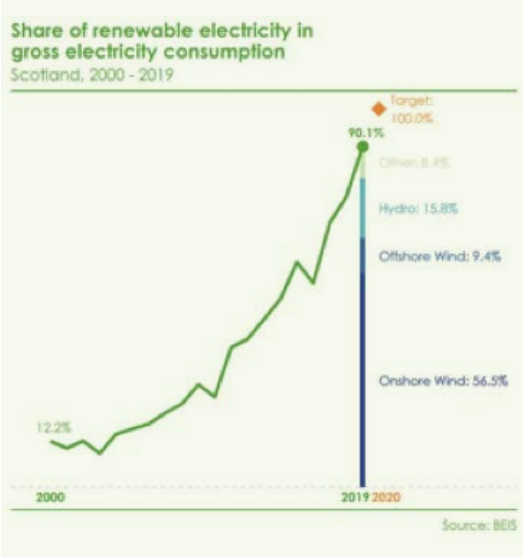

Figure Two, ACSES, 2020, p.25

3. New Needs for Flexibility in Electricity System Operation

The increasing volume of renewable power connected to transmission and distribution networks is raising new questions about resilience and security of electricity supply. Historically, grid operation has relied on controllable coal- and gas-fired power to balance supply and demand continuously, with circa 20% nuclear power base load. At present, grid balancing continues to rely on the flexibility of (carbon-emitting) gas-fired power stations. Continuing use of gas turbines would however need, as yet undeveloped, carbon capture and storage (CCS), and assumes that the full cycle of methane gas exploitation and combustion could operate with a net zero emissions standard. The future of nuclear power is uncertain, with unresolved questions about economics, technical performance, safety and hazardous waste. A recent systematic review, comparing nuclear power, renewable energy and 'do everything' pathways to decarbonise electricity, concluded that the most cost-effective, fastest route is to prioritise renewables (Sovacool et al, 2020).[1]

Regardless of the particular mix of generation sources, managing a grid with high levels of intermittent and variable renewable power, from wind and solar sources, as well as more decentralised generation, requires new forms of flexibility. Decarbonising heat and transport is also envisaged as increasing the use of electricity. Across supply, distribution and use, therefore, further rapid, and radical, change is needed in the next decade to meet net zero carbon targets, while maintaining a reliable, safe and affordable system.

[1] see also: https://www.worldnuclearreport.org/

Attention is increasingly focused on devising new types of flexibility, including integrating heat, power, transport and storage at locality scale, to facilitate transformation and manage network costs[2]. Digital technologies are also expected to improve visibility of energy flows and enable proactive management of demand to match supply. New forms of flexibility are as yet under-developed but could encompass diverse changes in the interactions of supply and use. Examples range from changes in societal routines, such as more home working and reduced travel during 'peak hours', to socio-technical innovations such as inter-seasonal storage of low carbon heat, or time shifting of energy use through remote operation of appliances, to business innovations in 'time of use' tariffs, local energy trading, and a shift to energy services rather than bills for KWs consumed. The eventual mix of these and other changes is uncertain, and will depend on interactions between political, technical-economic and social dynamics.

4. Flexibility and Co-Benefits from Integrated Local Energy Systems?

One potential dimension of flexibility is the development of more localised energy systems, taking advantage of renewable power connected to low voltage distribution (rather than high voltage transmission) networks. This could potentially be combined with district heating systems and storage. Such localised systems may resolve technical-economic 'problems' created by renewable generation connected to distribution networks, which were designed for passive one-way operation, as well as realising new opportunities. In Scotland, the majority of onshore wind is connected to distribution networks at 33kV, usually because of physical distance from high voltage transmission grids[3]. In addition, around 1.2GW of power is from small scale generation of less than 5 MW[4] (ACSES, 2020). These resources could be a foundation for more integrated local energy systems which would, in theory, provide whole system 'balancing' services, reducing, or at least spreading over a longer period, the costs of grid reinforcement associated with expected electrification of transport and some heat.

Technology change is only part of the picture however; there are also societal expectations of more regional and local decision making on energy, grounded in concerns over climate disruption as well as social justice, fair work and citizenship. These expectations are placing new demands on governance arrangements to manage trade-offs between local, regional and national priorities, including greater devolution of regulatory powers. Localised systems are for example promoted in Scottish Energy Strategy (2017). The Strategy, which is due to be renewed in 2022, again positions energy as critical to economic development, recognising that localised systems may be a sphere of socio-economic innovation amenable to devolved powers.

[2] https://www.ofgem.gov.uk/electricity/retail-market/market-review-and-reform/electricity-system-flexibility

[3] Information from Dr Graeme Hawker, University of Strathclyde.

[4] 442 MW of onshore wind, 338 MW of solar PV, 314 MW of hydro and 133 MW of bioenergy and waste (ACSES, 2020).

British liberalised energy markets, and regulations, however, remain geared to established top-down large-scale generation and supply. As a consequence, there are no straightforward governance, planning and investment routes to assessing costs and benefits of local systems, or their realisation under a mix of ownership structures. A key test of potential is the UK Industrial Strategy Challenge: Prospering from the Energy Revolution[5]. The Challenge received £102.5 million from UK Treasury to assess whether smart local energy systems can provide clean and affordable energy, as well as attracting commercial investment and creating jobs in local economies. One of the main demonstrator projects is ReFLEX Orkney, which aims to build an integrated energy system, coordinating and combining energy assets across electricity, heat and transport[6].

5. Most Energy Consumed Continues to be from Fossil Fuels

Electricity is only one part of the energy system; a far bigger share of consumption is for heat and transport, and both of these sectors remain heavily dependent on oil and gas (Figure Three).

The share of renewable energy, as a percentage of Scotland's total energy consumption, is relatively small, at just over one fifth (Figure Four).

In the RSE Report 2011, we concluded that slow progress was being made on emissions' reductions which were, in principle, more amenable to change through powers devolved to Scottish Government, notably in transport and heat in buildings (p7). This pattern has not changed; emissions from energy use in buildings remain much the same as those ten years ago and transport emissions have increased slightly.

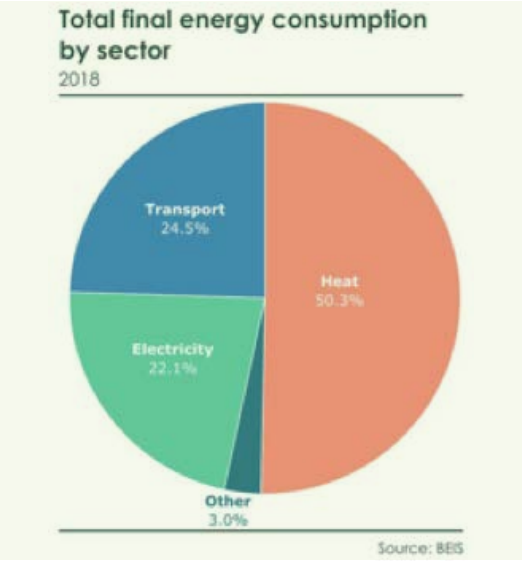

Figure Three, ACSES, 2020, p.14

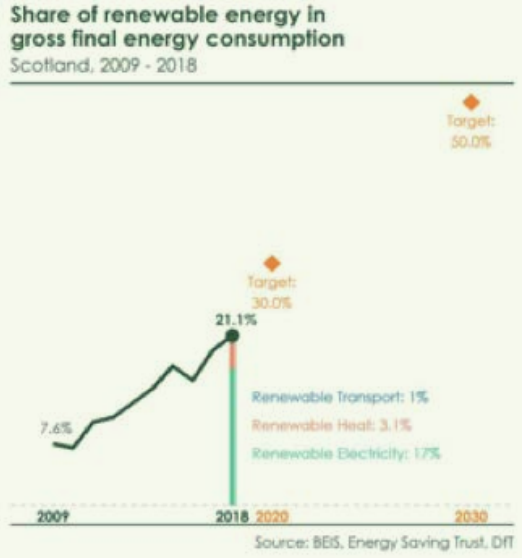

Figure Four, ACSES, 2020, p.16

[5] https://www.ukri.org/our-work/our-main-funds/industrial-strategy-challenge-fund/clean-growth/prospering-from-the-energy-revolution-challenge/

[6] https://www.reflexorkney.co.uk/

Meeting Scottish emission targets in the next decade hence requires a major shift to clean energy for heat and transport. These are both sectors of energy use and in the following sections questions about use are considered alongside those about supply.

6. Heat Supply and Use

As shown in Figure Three above, heat comprises half of all energy use in Scotland. The share of heat from renewable sources has increased slightly over the last decade, but remains very small scale, at approximately 6.5% of demand, and is predominantly from biomass combustion. This is considerably below the 2020 target of 11%.

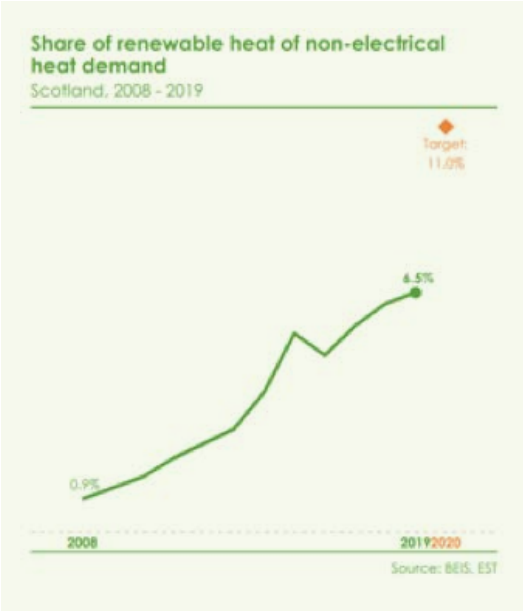

Figure Five ACSES, 2020, p.36.

The majority of Scottish buildings are connected to the extensive GB methane gas grid, and building owners continue to use gas-fired boilers for heating and hot water. Around 80% of homes, and 30% of non-domestic buildings, use gas as the primary source of heating. Regulatory powers over gas grids and gas supply are reserved to the Westminster Parliament. But 'heat', as an end use category, is 'devolved by default', because it is not specifically regulated or referenced in UK legislated devolution frameworks. Scottish Government can set standards for energy performance of buildings; regulate technical aspects of district heating, and introduce measures to decarbonise heat in buildings, particularly those not connected to mains gas. From 2024, new houses granted planning consent will, for example, be required to use renewable or low carbon heating. New housing is however a very small part of housing stock: around 20,000 new homes are built per year, compared to around 2 million existing homes which require change to their heating systems (Infrastructure Commission for Scotland, 2020).

In its draft Heat in Buildings Strategy (2021)[7], Scottish Government proposed new targets for around 50% of homes, or over a million households, to convert to a zero or low emissions heating system by 2030. This means that buildings not connected to the gas grid (circa 167,000 homes using high emissions oil, LPG, and solid fuels, as well as non-domestic buildings) will need to convert to zero emission sources of heat.

[7] https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings-consultation/

In addition, around one million homes, and an estimated 50,000 non-domestic properties, currently using mains gas, will need to convert to zero emission heating to meet the target. Meeting the proposed 2030 target will hence require rapid, large scale installation of new heating systems, using available technologies.

The main options in discussion are: electrification of heat using air or ground source heat pumps and/or storage heaters, which could include solar PV, storage and solar thermal systems; conversion of (at least some sections of) the methane gas grid to hydrogen. Development of district heating networks is also a constant 'low regrets' feature in current Scottish Government policy. Heat networks are agnostic with respect to heat sources, using residual or waste heat from nearby industry, waste water or waste incineration, and hence adding flexibility and thermal storage for locally-integrated systems.

Given the lack of devolved powers over the gas industry and grid, the major question about the future of gas has to be addressed through collaboration between UK and Scottish Governments. At the time of writing, in late summer 2021, the expected UK Heat and Buildings Strategy had not been published.

All options for clean heat have advantages and disadvantages, as well as uncertainties over costs, performance, finance and means to rapid change in privately owned properties. Different options may also be more suitable in different places. District heating, for example, is suited to areas where heat demand is high and diverse, such as in urban centres, and where waste or residual heat is available; stand-alone electrical heating is likely to be needed in dispersed, well-insulated buildings off the gas grid. The gas industry is promoting development of hydrogen for heat, and Scottish Government has announced ambitious plans[8], but significant technical-economic, environmental and societal questions are unanswered. Initially, production of 'blue' hydrogen would rely on steam methane reforming, with new large-scale carbon capture and storage; new pipes would also be required for hydrogen gas transmission, to minimise risks of steel corrosion. Green hydrogen, from electrolysis using renewable electricity, is currently used at very small scales for some industry and transport. Current technologies have a high cost and a significant electricity demand, placing an additional burden on low carbon electricity generation. There is a hydrogen for heat demonstration project at Levenmouth, Fife, led by SGN, the gas network operator. The H100 Fife[9] initiative was awarded (up to) £18 million from the Ofgem Network Innovation Competition 2020, and £6.9 million from Scottish Government. Feasibility of large scale development of hydrogen systems is as yet untested, with high costs entailed in production, network infrastructure and carbon capture and storage. The UK Climate Change Committee (2020) concludes that hydrogen needs to be part of the UK's strategy for net zero, but in the next decade any development should focus on uses in shipping and areas of industry less suited to electrification.

[8] https://www.gov.scot/publications/scottish-government-hydrogen-policy-statement/

[9] https://www.sgn.co.uk/H100Fife

Converting all heating systems to electricity is also a difficult, and costly, proposition. It would entail significant investment in new appliances, and energy efficiency improvements in buildings, with some disruption in domestic, and many commercial and public premises. It would also require major investment in reinforcing networks to supply electricity at much larger scales, as well as stand-by power generation to meet peak demands (see Figure Six below).

While winter peaks in heating demand could be reduced to some extent by upgrading the fabric of existing buildings to minimise heat loss, this would provide only part of the solution. The daily, as well as seasonal, variability in heat demand has been used to suggest the value of district heating networks (DHNs) to store heat and to manage density and diversity of demand. Such networks would use locally available sources of heat, as well as renewable power, in combination with thermal storage. In the RSE 2011 Report we argued that there were opportunities for 'combining heat networks with flexible sources of heat and high standards of building insulation, to increase local, sustainable employment and affordable heating' (p6).

Policy development has since taken place, with the 2015 Scottish Heat Policy Statement setting two goals:

- To achieve 1.5 TWh of heat from district or communal heating by 2020
- To have 40,000 homes connected by 2020.

Available statistics on district heating are estimates, but Figure Seven suggests slow progress in a very small sector, with around 30,000 homes connected and 1.1 TWh of heat supplied.

Figure Seven ACSES 2020, p.43.

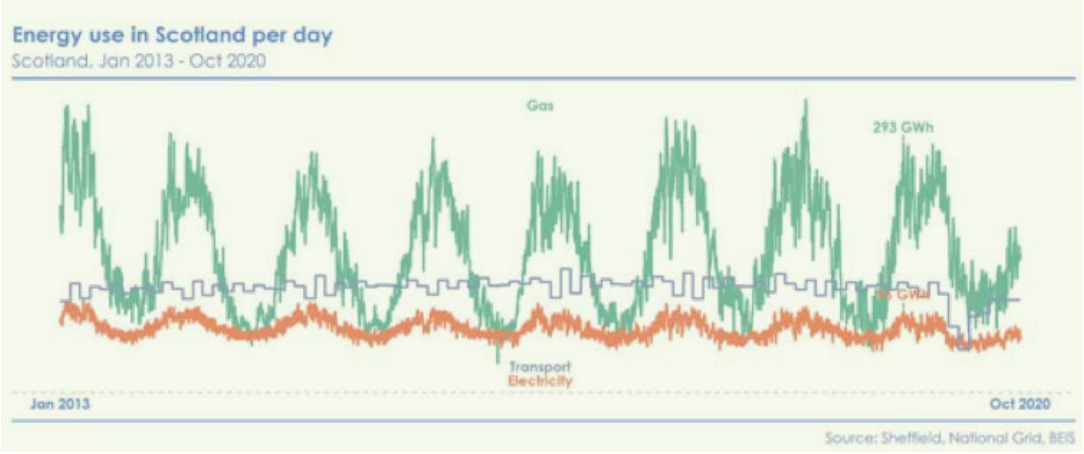

Figure Six ACSES 2020, p.67.

District heating is also newly subject to regulation and licensing: the Heat Networks (Scotland) Act became law in March 2021, with the objective of developing the sector more effectively, including identifying priority zones for new networks. The impacts are as yet uncertain; the high capital costs of infrastructure (insulated pipes and pumps) are usually recovered from long term heat purchase agreements between supplier and customers. The Act does not however include an obligation on building owners to connect to a heat network, and in most areas suitable for district heating, buildings are already using gas. In the absence of some form of obligation to connect, district heating development is likely to be inter-dependent with decisions on the future of the gas grid.

Creating the means to decarbonise heat is now an urgent policy matter, with rapid change needed over the next few years.

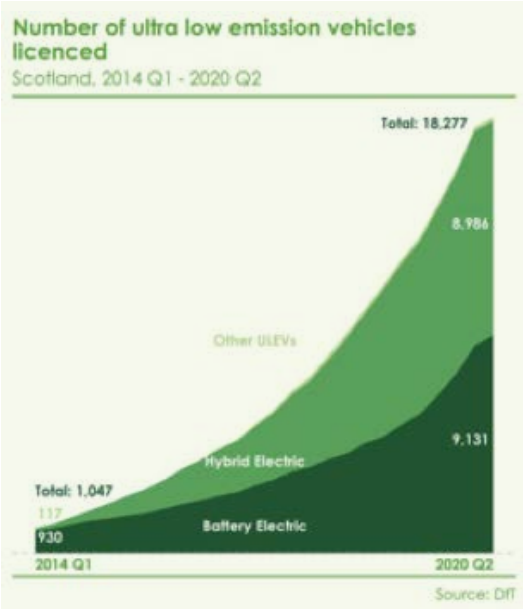

Figure Eight AACSES 2020, p.37.

7. Transport

In the transport sector, clean energy and low carbon technology options, and policy, are emerging, but clear priorities and technology plans need to be finalised and implemented. During the last decade in Scotland, energy consumption for transport has increased overall (see Figure 9): fuel use for freight increased by 15.6%, while personal transport fuel use decreased by 6.2%.

In terms of modal share of journeys, private cars and vans are dominant, comprising around 65% of all journeys, followed by walking (21%), bus (8%), rail (3%), cycling (2%), and other (2%) (Scottish Transport Statistics, 2020). Scottish Government aims to phase out sale of new petrol and diesel cars and vans by 2030, but older petrol and diesel cars will remain. Ultra-low emission vehicles (ULEVs - mainly electric, plug-in hybrid and hydrogen fuel-cell vehicles) comprise less than 1% of all vehicles currently licenced in Scotland, although the rate of increase is rapid (Figure 8).

Increased use of ULEVs is expected to reduce greenhouse gas emissions, but simply substituting combustion engine vehicles for ULEVS is insufficient to meet targets, including the early reductions needed to meet the net-zero goal for cars and vans (Brand et al, 2020). Among other factors, the significant rise in sales (now 21%) of larger cars, particularly Sports Utility Vehicles (SUVs), which use more fuel and emit 25% more CO2 than a medium sized car, is increasing current emissions; the life cycle carbon footprint of large private vehicles is also a significant factor in carbon accounting. Brand et al (2020) conclude that a 2030 phase-out of all

combustion engine vehicles, combined with reduced travel and car ownership, would enable an emissions pathway compliant with the Paris Agreement. Scottish policy is formally committed to a sustainable transport hierarchy, exemplified in the second Strategic Transport Projects Review (STPR2)[10] . The hierarchy prioritises active travel - walking and cycling - as most beneficial, both to the environment and to public health. Public transport is the second priority, with use of private vehicles ranked least sustainable. Phase 2 of the STPR2 is due to report in Autumn 2021 and will govern transport investment in Scotland over the next 20 years. It will be critical to implementing the sustainable travel hierarchy, and is the key means to a clean energy, active travel and socially inclusive transport sector.

The unprecedented restrictions on mobility and international travel during the corona virus pandemic have demonstrated both the potential for rapid reduction in transport energy use, as well as the difficulty of maintaining such reductions. Home working and video conferencing have reduced daily car commuting and international business travel. Between March and September 2020, car traffic declined to around 25 per cent of 2019 levels. It returned however to 91 per cent of 2019 levels by the end of the period (Transport Scotland, 2020). Public transport use has remained lower, with government messages to avoid public transport due to suspected infection risks, damaging confidence. In addition, the rise in internet shopping has increased van traffic substantially, and illustrated the impact of a deregulated system, with competing delivery services, on GHG emissions (Docherty et al, 2020).

Conversely, the Scottish Government's 'Spaces for People' fund for active travel has demonstrated that improved walking and cycling facilities can be created rapidly by changing road layouts with paint, signs and some physical barriers. Technical guidance however continues to prioritise vehicles, indicating the political sensitivities over restricting car access. There is also a risk that economic recovery investments may prioritise all 'shovel ready' projects, regardless of clean energy and active travel policies. The desire to avoid political controversy, especially over reducing car use, may result in 'more of everything' (Docherty et al, 2020), while bracketing questions about energy use in aviation and shipping. This approach would make carbon targets unattainable. In 2021 it is, therefore, essential that Scotland's sustainable transport hierarchy is made integral to all related spending on economic recovery and infrastructure.

8. Efficiency in Energy Use in Scotland and the Carbon Footprint

As argued in the RSE 2011 Report, using less energy makes all GHG targets easier to meet. Policies to reduce energy use have typically been less developed than those concerned with supply (Eyre and Killip, 2019). Supply side policies align more straightforwardly with dominant policies for economic growth, while policies to reduce consumption target societal practices, such as car driving,

[10] https://www.transport.gov.scot/our-approach/strategy/strategic-transport-projects-review-2/

air travel, and how we use heating and hot water. This is more politically contentious, with disagreement about effective policies, and a stop-start pattern in policy initiatives.

In 2010, Scotland had a target to reduce final energy consumption by 12% by 2020. Against a 2005-07 baseline, this was in fact first met in 2013, but the contribution of policy to that achievement is debatable; Figure Eight below suggests the particular impact of the financial crisis and recession.

Main reductions (Figure Nine) have been in industrial energy use; much of this is likely to stem from industrial restructuring and recession[11]. The shift to services is also implied by the 11.9% increase in commercial sector energy use. The impact of reduced economic activity is evident in decreased electricity demand during the 2020 covid-19 lockdown, when average daily demand in Scotland declined by 10% compared with the equivalent period in 2019. Despite many people working from home, the increase in domestic consumption was more than offset by inactivity in commercial and industrial premises.

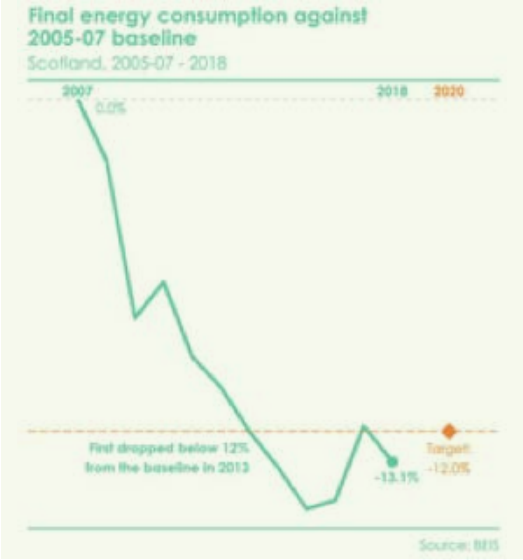

Figure Eight, ACSES, 2020, p.46.

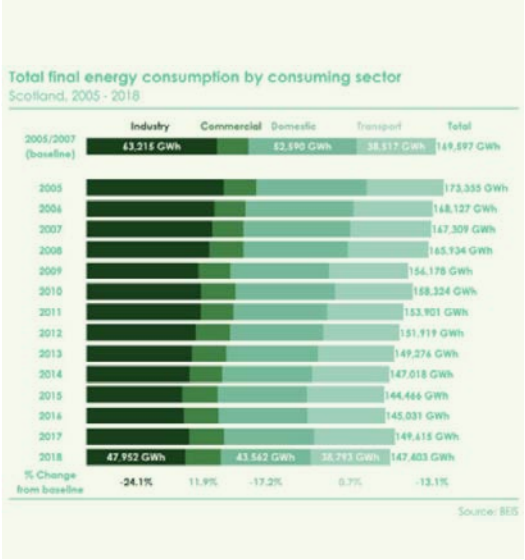

Figure Nine, ACSES, 2020, p.47.

[11] Loss of manufacturing industry is also associated with 'off shoring' energy use and associated emissions, when imported products, with embedded carbon plus shipping emissions, substitute for on-shore production. Such consumption-based emissions, described as the 'carbon footprint', were estimated to increase in Scotland between 1999 and 2007, and then decline sharply following the financial crisis. Decline has continued more gradually until at least 2015 (most recent data https://www.gov.scot/publications/scotlands-carbon-footprint-2015/), with an overall reduction between 2007 and 2015 estimated as 21.8 per cent.

In the domestic sector, energy savings are associated with incremental improvements in energy efficiency, including more efficient condensing boilers for gas central heating[12]. Gas consumption for example has declined by around one fifth between 2005-07 and 2018[13], despite a 9% increase in the number of households. Although (non-electrical) heat demand decreased by 17% overall between 2005 and 2018, it has fluctuated, increasing by 4.8% since 2015[14].

Overall these data suggest that policy has worked to reduce energy use in the domestic sector, although global socio-economic events - the financial crisis in 2007 and the corona virus pandemic in 2020-21, account for considerable shifts in economy-wide demand.

9. Policy Developments in Energy Efficiency in Buildings

Over the last decade, Scottish energy efficiency policy has diverged from that set by UK government, providing consistent support for improvements to existing homes, particularly in social housing and for low income households (Webb and Van der Horst, 2021). Fifty-six per cent of social housing is now rated as EPC C or higher, compared with 38% of owner-occupied homes.

The energy efficiency of buildings was also designated a national infrastructure priority in 2015, leading to development of the Energy Efficient Scotland programme.[15] Local Authorities and public bodies have received funding to test the potential for area-based improvement programmes, and Local Heat and Energy Efficiency Strategies (LHEES). The latter are proposed as the statutory basis for planning, costing and prioritising the refurbishment of the whole building stock, and identifying options for decarbonised heat, over 15 to 20 years.

Overall progress is slow relative to ambitious targets; the draft Scottish Heat in Buildings Strategy 2021[16], published for consultation, indicates the challenges. These include agreement between central and local government over shares of responsibilities and resources; protection of vulnerable groups; heat planning and implementation; increased standards to accelerate retrofit of buildings; financing, and development of high quality retrofit supply, with consumer protections and guarantees.

The benefits in improved building stock, more resilient to climate change, combined with reduced energy costs, better welfare, reduced emissions and skilled jobs in local economies, are considerable (Rosenow et al 2018). However, making the policy work will need sustained political leadership, public commitment and cross-sector investment.

[12] Average energy savings from installation of condensing boilers in Scottish homes are estimated as 7.4% of consumption.

[13] 23.3% decrease in the non-domestic sector and 18.3% in the domestic sector.

[14] Non-domestic sector 6.7% increase; domestic sector 2.3%.

[15] https://www.gov.scot/policies/energy-efficiency/energy-efficient-scotland/

[16] https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings-consultation/

10. Conclusion

The RSE Climate Change Inquiry began in an atmosphere of optimism in autumn 2009, with expectations of progress in global commitments at the UN Conference of the Parties (CoP) in Copenhagen at the end of the year. Disappointment followed, but expectations were raised again after the 2015 (CoP 21) Paris Agreement to limit global temperature rise to well below 2, preferably to 1.5, degrees Celsius, compared to pre-industrial levels. Much now rests on the postponed CoP26, hosted by UK Government in Glasgow in November 2021. Alok Sharma, CoP 26 President, has thus far focused on agreements around ending coal exploitation. This is essential, but Scotland and the UK must go much further, potentially setting the trajectory for socially just transition in the North Sea oil and gas sector, and contributing more to climate adaptation funding for poorer countries.

The RSE Report 2011 concluded that

- The central question for 21st Century societies is whether we can turn our considerable scientific, cultural and technological knowledge and resources to the prevention of climate-related disasters, and to adaptation to the uncertainties of a complex and changing climate system.
- Actions could drive a new industrial revolution, based on Scotland's wealth of renewable resources and skills to develop them.

In 2021, the same points remain at the fore. Achievements in the renewable electricity sector, as well as rapid societal changes in response to the corona virus pandemic, show what can be done. This is, for many reasons, a critical moment. The Scottish target for reducing greenhouse gas emissions was again missed in 2019. Figures for 2019 show emissions fell 51.5% against the baseline, as compared to a 55% target. Although some of the shortfall is attributable to revised accounting, the data serve to emphasise the necessity for rapid change in the major sectors of heat and transport, and for flexibility services, both to reduce energy use and to decarbonise supply. To secure the necessary radical changes, UK central and devolved governments need to collaborate in: planning the future of the gas grid and heat in buildings and industry; securing a shift to active and shared modes of transport and mobility; rapidly increasing the use of electric vehicles; and ensuring that all infrastructure investments are prioritised against their contribution to net zero GHG emissions.

The main focus thus far has been on technology innovation; people, society and ways of life are (often) in the shadows. The UK CCC Sixth Carbon Budget comments that three fifths of the changes needed now are in how we live. Public concern about climate change has increased, alongside direct experiences of more extreme weather. Understanding of more sustainable ways of living, and links with better health and better places, however remains limited.

Most importantly, the production, trade, transport and building infrastructures of modern societies are geared to perpetually increasing exploitation of natural resources, particularly fossil fuels, as a means to economic growth. Climate disruption is one of the high risk consequences. In the short term, reducing the need to use energy, and developing a renewables-based system, are critical to future societal prosperity and inter-generational justice. Getting there will require leadership by central, devolved and local governments, and businesses at all levels, to prioritise investment in low carbon infrastructures, and to engage citizens and customers in sustainable consumption, and zero waste of energy and resources. Such engagement needs to be backed by clear, comprehensive programmes of action across sectors, including regulatory and tax reforms to ensure that active travel, public transport, whole building retrofit and energy efficient appliances are accessible to all, and the default options in private and public spending decisions. These themes are further developed in the related essay on climate change and participatory politics.

CoP26 is an opportunity for UK central and devolved governments to demonstrate that they are serious and trustworthy. Among other things, focusing on home renovation, zero waste of energy and greener places to live are essential to involving all citizens in climate action. Beyond that, a circular economy for zero waste of energy and materials, restoration of eco-systems, societal welfare and fair work is challenging, but attainable.

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