RSE Inquiry

Scotland's Energy Future

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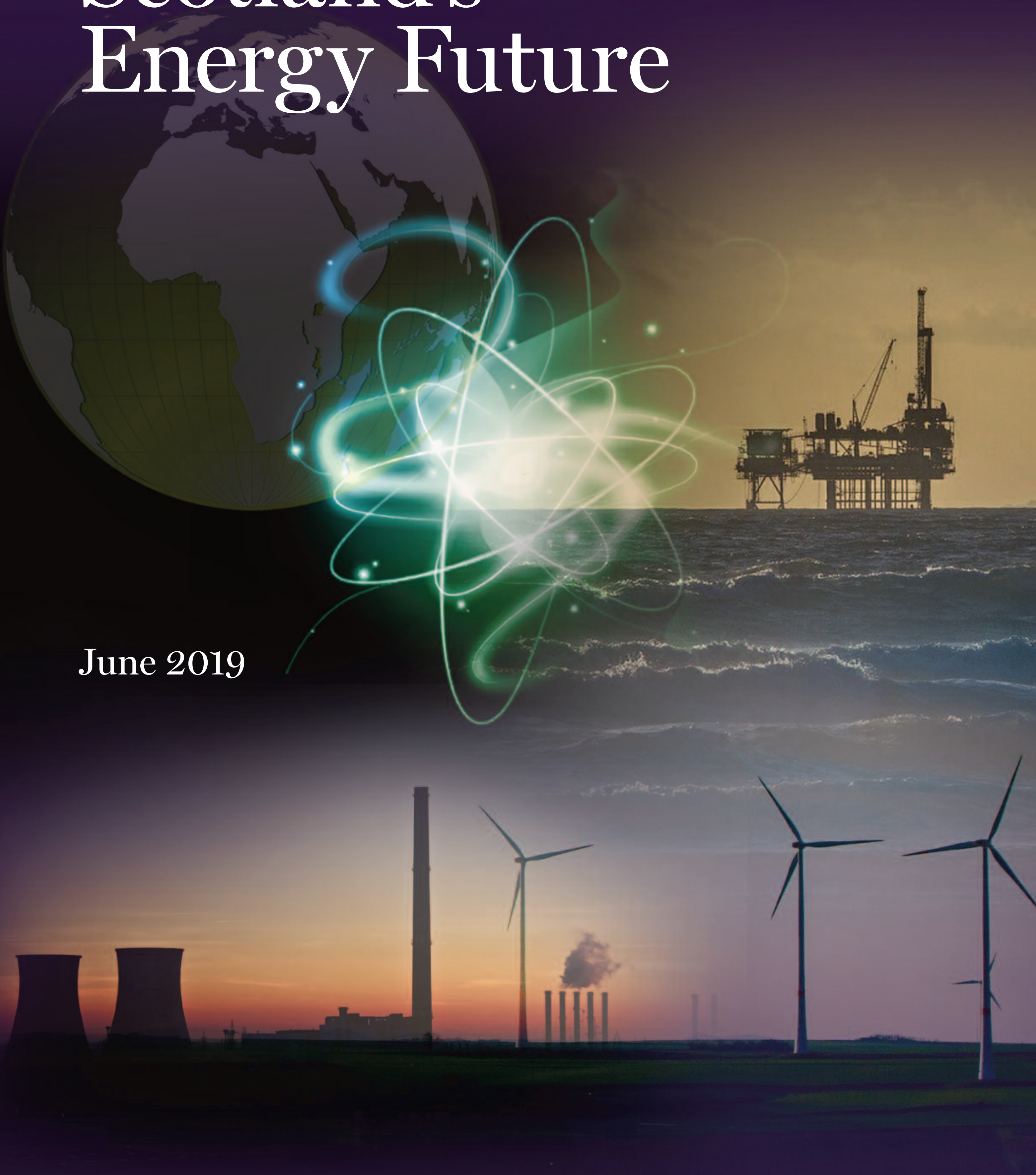

June 2019

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FOREWORD

It has been more than a decade since the Royal Society of Edinburgh (RSE) published its last major inquiry into energy. In this time, a huge amount has changed in the way we produce energy and the way in which we use it. Its importance, however, for the lives of the people of Scotland and for the Scottish economy is undiminished.

There are important issues about the demand for energy and the ways in which it is used; about the supply of energy and security of that supply; and about the impact of supply and demand on our environment, on the climate, and on the lives of consumers throughout Scottish society and in Scottish business.

We need to look at the opportunities that energy offers, in terms of innovation and research in areas such as supply, storage and delivery. We must also recognise the interconnected nature of supply and demand, between Scotland, the UK, Europe and, indeed, the wider energy-supplying world. This thinking will illuminate the constraints and policy options that are available to those tasked with making the important decisions that will affect us all.

As Scotland's National Academy, the RSE is in a unique position of having access to a wide range of expertise, provided by some of the foremost experts in Scotland. Furthermore, the RSE's status as a renowned, impartial, learned society allows it to utilise this experience and knowledge to produce a considered view of the issues Scotland faces regarding energy and the options available to us.

Since the Inquiry launched in 2017, we have received written evidence from a wealth of sources, held discussions with individuals and groups from across all sectors, and held public meetings up and down Scotland to ensure this report engaged with as many stakeholders as possible. This work was only made possible with the backing of the RSE's supporters, to whom we are immensely grateful.

We hope that this combination of expertise, evidence and engagement will allow this report, its findings and its recommendations to continue to inform public policy debate and decision making long past its publication.

It would be remiss if we did not extend our sincere thanks to the group of Fellows and academics who have served with such distinction on the Inquiry Committee, providing the invaluable knowledge, analysis and insight without which the report would not have been possible. Further information on the Committee can be found in the appendix to this report.

Finally, we would also like to acknowledge the work, and life, of our colleague Professor Paul Younger, who was involved in the early stages of this project, but sadly passed away last year.

Sir Muir Russell
Inquiry Chair

Professor Rebecca Lunn
Inquiry Deputy Chair

EXECUTIVE SUMMARY

Objectives and Approach

- No energy policy, no matter how well considered, will ever solve all of the problems and paradoxes of energy supply and use.
- Those developing policy must ask how best to address the competing issues of the 'energy quadrilemma': addressing climate change; ensuring affordability; providing energy security; and developing energy policy which is acceptable to the public, economically sustainable and just.
- Decision makers will need to be honest with the public about what is achievable, what choices must be made, and what changes will need to occur.

Governance and Regulation

- Significant progress has been achieved by the energy governance system for Scotland over the last decade, including the introduction of world-leading climate change legislation.
- Scotland's energy system is entering a challenging period of transition as the policy focus shifts towards the difficult task of decarbonising heat and transport, notwithstanding that difficult issues remain for electricity generation, and the oil and gas sectors.
- Energy governance is highly complex, and while there have been significant successes, progress has been hampered by a systemic lack of transparency; weak planning, monitoring and implementation; and problems with delivering cost-effectiveness and protecting consumers' interests.
- A high level of sustained political cooperation between the Scottish and UK Governments is necessary to maximise the effectiveness of the governance structure and to achieve common objectives. The UK Government retains control of the main levers for energy governance, and so key aspects of the Scottish Government's strategy can only be realised in full with UK Government agreement.
- The energy system must be subject to a continuous process of scrutiny and reform in order to ensure effective governance and regulation. Currently, there is no one official body responsible for the independent, continuous and whole system review of all aspects of energy policy and governance.

Where We Are

- The UK has historically been reliant on fossil fuels to meet its energy needs and, through its leading role in the industrial revolution, was and remains a major contributor to global carbon emissions.
- The majority of Scotland's energy consumption is attributable to heating, with electricity and transport playing smaller roles.
- Energy consumption in Scotland is falling. However, despite over 89% of Scottish electricity being generated by low-carbon technologies, more than 80% of consumption is still attributable to the burning of fossil fuels, with renewables supplying 17.8%.
- The UK is a net importer of energy and has several options through which to import this energy. In the event of interruptions to energy imports, the UK has very limited storage capacity, especially gas storage.
- The Scottish Government has set targets for reducing carbon emissions, which have been met for the past two years. Further, more ambitious, goals have also been set.
- Total global energy consumption continues to increase, although the types of energy consumed, and the profile of this use, varies significantly by region.

Understanding Trade-Offs

- Future Scottish energy policy will rely on various decisions made by a number of actors, including government, industry, communities and individual members of the public.
- Under all scenarios, Scotland will require energy. Difficult choices, which will inevitably have consequences, must be made.
- All of the choices available to Scotland to meet its energy needs require trade-offs. In reaching an informed decision on Scotland's energy future, it is imperative that the compromises that need to be made are understood, discussed and accepted.

Options for Meeting Scotland's Energy Needs

The options below are not listed in order of merit. They represent a range of sources of energy generation and other ways of meeting Scotland's energy needs. Some are more advanced than others and may provide a greater or lesser contribution to meeting demand.

Carbon Capture and Storage

- CCS could potentially facilitate the use of other fuels and technologies while limiting damage to the climate.
- It would require a very high level of continued investment.
- Many geological and technological challenges still exist though, and CCS may be some distance from being viable at scale.

District Heating

- District heating has high up-front costs that would require significant investment.
- Its use provides various social benefits, including the potential to play a role in alleviating fuel poverty, improving quality of life and utilising local sources of warmth in deprived areas.
- For district heating to be economically viable, a longer-term policy and a regulatory approach would be required.

Electrification

- The electrification of transport and heat could significantly reduce carbon emissions, but only if the electricity used is generated from low-carbon sources.
- A move towards electrification would require a significant increase in generating capacity. This increase could potentially be as high as 145% on current peak demand value by some estimates.
- Substantial new infrastructure would be required to facilitate electrification.

Energy Efficiency & Demand Reduction

- Reducing Scotland's energy demand could play an important role in meeting many of its energy goals, and improved energy efficiency will be key to achieving this.
- Reducing demand for energy could assist in significantly reducing Scotland's carbon emissions.
- Improved energy efficiency would require substantial investment and faces a serious obstacle in Scotland's ageing and varied housing stock.

Onshore Gas

- There is a significant amount of geological uncertainty over the size of potential shale gas reserves and uncertainty over the viability of the deposits which exist.
- Continuing to burn substantial quantities of gas will exacerbate the problem faced by climate change and runs counter to the goal of reducing carbon emissions.
- A domestic onshore industry based on shale gas reserves is challenged but, if viable, could improve security of supply.

Offshore Gas

- Significant reserves and resources of gas are estimated to remain in the UK Continental Shelf.
- Continuing to burn substantial quantities of gas will exacerbate the problem faced by climate change and runs counter to the goal of reducing carbon emissions.
- Domestic production of gas to replace UK imports would make Scotland overtly responsible for health and safety and for minimising the industry's environmental impact.

Domestic Oil and Gas Production

- Significant reserves and resources of oil and gas remain in the UK Continental Shelf, albeit in ever diminishing levels. Production of this oil and gas could continue to provide a secure energy source.
- Continuing to extract and burn substantial quantities of oil and gas will exacerbate the problem faced by climate change and runs counter to the goal of reducing carbon emissions.
- Enhanced Oil Recovery and conventional oil and gas exploration and production would make Scotland overtly responsible for health and safety and for minimising the industry's environmental impact.

Options for Meeting Scotland's Energy Needs

Geothermal

- Geothermal energy could play an important role in providing a practical, local source of ground-sourced, low-carbon energy to those in areas most affected by fuel poverty.
- When used domestically, geothermal energy has a minimal carbon footprint.
- Hotter geothermal sources are often sited away from the areas where heat is needed and challenges remain with storage and transportation.

Hydrogen

- A move from natural gas to hydrogen on a mass scale is technically feasible, but would require significant investment.
- For the use of hydrogen to play a major role in reducing carbon emissions, Scotland would also have to substantially increase its renewable energy output, or be able to rely on CCS.
- Hydrogen production and use could improve Scotland's energy security, but would require the importation of methane and considerable additional storage capacity.

Importation

- Importing energy from abroad does not allow Scotland fully to take responsibility for the impacts of its production and use.
- Importation is currently able to meet fluctuating demand and so plays a role in ensuring security of supply, although it does leave the UK reliant on foreign countries.
- The long-term availability of electricity for import may be impacted by implementation of similar electrification policies across Europe.

Large-scale Nuclear

- Nuclear energy provides Scotland with a significant amount of secure, reliable generation.
- Nuclear power has zero carbon emissions at the point of generation and could play a major role in helping Scotland meet its climate targets.
- Replacing the current generation of nuclear power stations would have substantial up-front costs, in addition to the significant investment needed over the longer term for decommissioning and waste management.
- The future of deep geological disposal would be a significant challenge, as would the viability of continuing the current policy of sending spent fuels and certain waste from Scotland to England.

Small Modular Reactors

- SMRs could provide many of the benefits of large scale nuclear energy, but in a form that may prove more acceptable to the public.
- There is a high level of uncertainty over how long this technology will take to sufficiently develop.

Bioenergy

- Relying on bioenergy to produce a significant amount of generation would require mass importation of biomass, or a vast area of Scotland's land being dedicated to energy crops.

Options for Meeting Scotland's Energy Needs

Solar

- Increased use of solar power could play a role in helping Scotland reach its climate targets.
- In order for solar energy to play a significant role in generation, a very significant amount of space for solar panels would be required.

Onshore Wind

- Scotland has very considerable wind energy resources, but attempting to harness these onshore requires significant areas of land and local support.
- Further onshore wind development could play a significant role in helping Scotland meet its energy demand, while simultaneously reducing carbon emissions.
- The variable nature of wind energy means that large-scale storage, or another form of generation, would likely be required in tandem.

Offshore Wind

- Developing Scotland's extensive wind resources offshore would allow Scotland to generate electricity without many of the social concerns surrounding onshore development.
- Offshore wind could play a significant role in helping Scotland meet its energy demand, while simultaneously reducing carbon emissions.
- The variable nature of wind energy means that large-scale storage, or another form of generation, would likely be required in tandem.

Wave and Tidal

- Scotland has some of the best wave and tidal resources in the world and utilising them could help Scotland meet its climate targets.
- Development of wave and tidal energy would require high levels of investment.

Hydropower

- Hydropower has played an important role in helping Scotland achieve its climate change targets in the past and, with development, could continue to do so in the coming decades.

Smart Energy Systems

- Scotland has the recognised research base in energy, technology, data science and wider informatics to capitalise on a move to smart energy systems.
- Greater local renewable generation capacity could play an important role in helping Scotland meet its climate change obligations.
- Smart local systems could facilitate greater community involvement in energy, planning and building community resilience.

Options for Meeting Scotland's Energy Needs

Battery Storage

- Development of large-scale battery storage could be transformative in facilitating the increased use of renewable energy.
- Developing this to the scale required, however, is likely some way off and may ultimately prove prohibitively expensive.

Pumped Hydro Storage

- Increased pumped hydroelectric storage could provide an important level of flexibility to the system, particularly in hours of peak demand.
- Increasing capacity would, however, require substantial investment and have very significant impacts on the local environment.

Gas Storage

- Increasing gas storage capacity in Scotland would improve energy security and may prove necessary to facilitate the use of other options such as hydrogen development.

Guiding Principles and Recommendations

- There is no technological or regulatory solution that will meet all objectives, without hard and generally costly choices being made.
- If correctly grasped, the challenges we face around energy could prove an enormous opportunity for Scotland to invest in the country's prosperity and wellbeing, and position itself as a global innovator.
- Difficult decisions need to be made by government and delaying making these will have consequences.
- Emerging technologies may not reduce the cost of energy; indeed, the best solutions may be significantly more expensive in the short term than the energy upon which we currently rely.
- It is vital that governments rely on robust scientific evidence when developing and implementing energy policy.
- There is a need for significant additional research, development and training in the energy field across all levels of education.

Guiding Principles and Recommendations

The report makes the following recommendations:

1 An independent expert advisory commission on energy policy and governance for Scotland should be established under statute.

2 Decisions on how and in what to invest must be made, and the most effective timeframes for investment activity and the potential nature of returns on different types of investment must be properly considered, by both the Scottish and UK governments, in a timely manner.

3 Scotland requires a clearly articulated position on security of supply and must decide whether domestic energy-generating capacity should be increased.

4 Scotland should look to improve its energy security by increasing the capacity, and diversifying its range, of storage options.

5 Achieving our climate protection targets can be made easier by reducing overall demand for energy and achieving this should be a priority.

6 Enforcing higher standards of energy efficiency in new-build housing and infrastructure should be a regulatory priority.

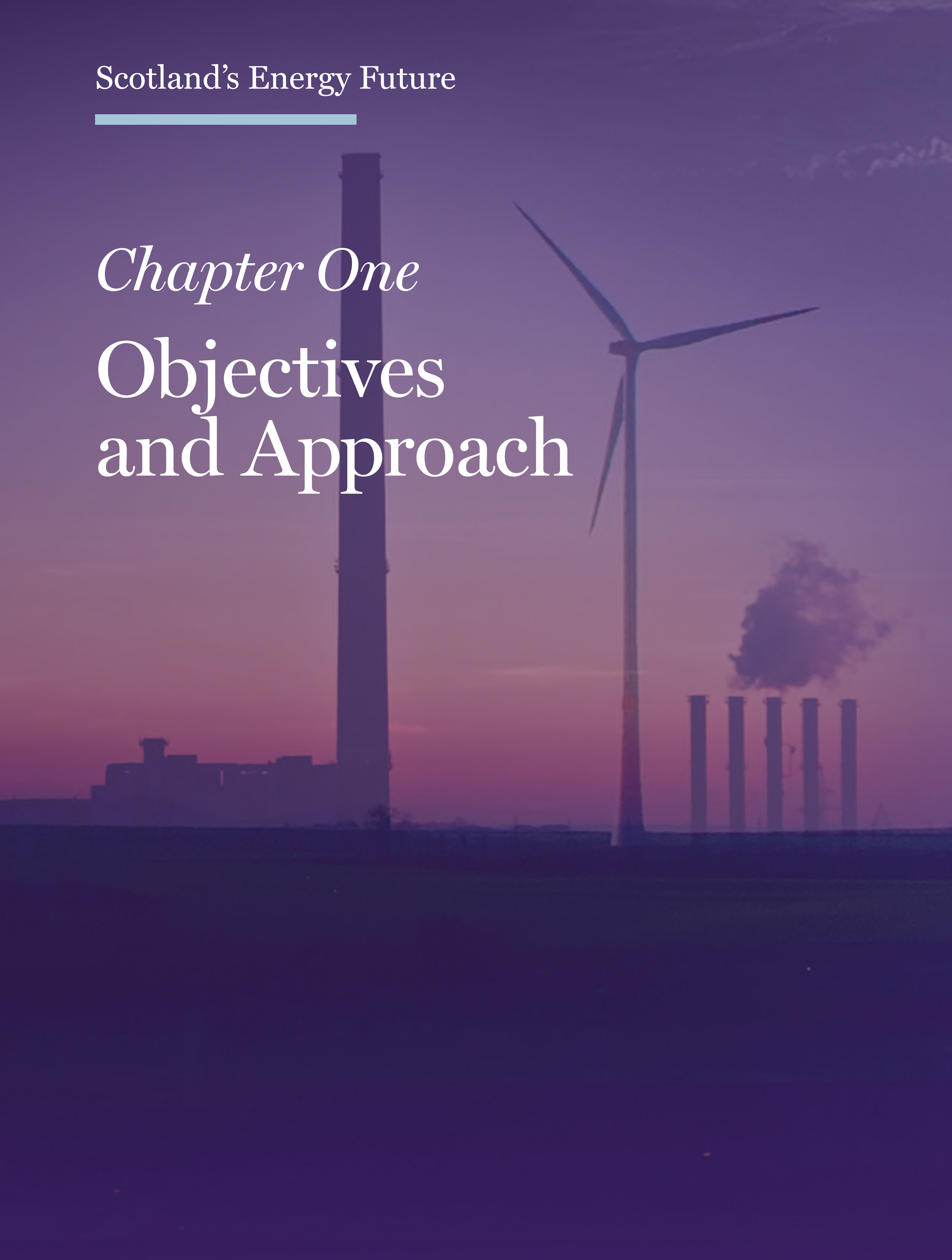
7 Building regulations around energy efficiency and their enforcement should be regularly reviewed to ensure they are both more responsive to R&D and consistent with policy targets.

8 The Scottish Government should review the need for R&D investment and skills development:

- in energy-related areas in which they also consider there to be strong opportunities for economic growth;
- to pilot community energy schemes;
- into low-carbon technologies for the future;
- into energy education throughout the school, college, university and general skills curricula.

9 Serious consideration should be given to how best to socialise the costs of transition to address issues of social justice.

10 All levels of government must be prepared to review and change existing policies where these policies are at odds with, or variant from, the overriding goal of carbon reduction.



Chapter One

Objectives and Approach

Introduction

1 Many of us take the availability of energy for granted. We turn on our lights when it's dark, fire up the boiler when it's cold and fill up our cars when we want to travel. It is increasingly important, however, that as a society we are conscious of how we use energy, know from where it is sourced, and understand the 'whole life' costs of this energy, including its environmental, economic and social consequences.

2 The future options for clean, secure, affordable and resilient energy systems need to be better understood, so that decisions on policy and investment are informed by the best evidence available and not by preconceptions or incumbent interests.

3 The purpose of this Inquiry is to take an overview of the field and offer guidance on the factors that should influence policy on the part of Government, at one end of the spectrum, as well as the choices made by individuals at the other. To capture this in a phrase, this report seeks to bring out the 'pain and gain' of energy policy choices at all levels.

What We Want to Achieve

4 The aim of the Inquiry is to contribute to the debate about Scotland's energy supply, demand and use, while adequately recognising our moral and environmental responsibilities against the backdrop of climate change and a need to reduce carbon emissions.

5 The Inquiry outcomes are intended to provide a forum in which difficult and contentious issues can be debated, enabling a synthesis of objective advice for policy makers in Scotland and beyond.

6 The Inquiry set out with the remit of:

- Reviewing the influences on energy demand in Scotland.
- Examining how that demand may be met, and assessing the feasibility and security of the range of possible options.
- Taking account of the environmental imperative to reduce carbon emissions and associated political commitments.
- Considering the moral and ethical implications of the various options open to Scotland; how and where energy resources are developed, the way in which we use them, and the level of responsibility we have as a nation for the energy we consume.

7 Through this work it is hoped that the Royal Society of Edinburgh (RSE) may achieve the following outcomes:

- Meaningful engagement with the public, industry, communities, local and central government, and other interested bodies, to stimulate debate on Scotland's energy needs, and on the options available to the country to meet these needs.
- Provision of clear information on the merits and demerits of potential energy options available to Scotland across a range of criteria.
- Consideration of the social dimension of energy issues, including affordability, public participation in policy, potential effects on communities, and a just transition towards a low-carbon economy.
- Deliberation on the future of energy in Scotland in the short, medium and longer term; how changing technology, supply, and other variables can be adequately assessed to allow a long term vision for the country to be developed.
- Dissemination of our findings, with specific recommendations for policy makers and stakeholders.

Undertaking the Inquiry

8 The expertise of the Committee tasked with undertaking the Inquiry spans the issues that will be addressed below. We have consulted with, and received input from, both the Scottish and UK governments, a range of major players in the energy supply world, various local and national bodies with relevant interests, and many informed individuals from the academic world and beyond.

9 The Inquiry team has sought to understand and test the inputs received and place them in the context of the factors outlined. We want to stress at the start of this report that that the Committee considers its role as providing a critique on the realism of current policies and aspirations, as espoused by Governments and others, addressing cost, resource and timing implications, rather than offering a prescription for future policy. This seems to us to be realistic in a world where science and technology are constantly evolving, and where the choices individuals are prepared to make may change in response, for example, to geopolitical events and global environmental developments.

Energy Policy Considerations

10 Energy policy has multiple dimensions, and must address a range of concerns and consider a number of factors that do not all point in the same direction. Cogent and consistent policy must consider and balance what the drivers behind the policy are and what outcomes it is looking to achieve; the context and environment in which the policy will exist; and the way in which, and effectiveness of how, it will ultimately be implemented.

Security of supply

11 In the simplest of terms, this addresses whether or not energy is available to use. Can we keep our lights on, heat our homes, provide for our transportation needs and fuel the vital infrastructure of our society?

12 Some reports suggest the UK has come perilously close to running out of energy in recent years, with the combination of particularly cold weather and the closure of the UK–Belgium pipeline due to a faulty pump in 2013 leaving the UK with only six hours' worth of gas left in storage.[1] Liquid Natural Gas brought into the country by tanker eased this crisis.

Climate change

13 Consideration must be given to how we generate energy, and how the different ways in which we use it affect the climate and potentially exacerbate or mitigate the impacts of climate change in ways that are consistent with the Paris Agreement pledge to keep temperature increases below 2°C.

14 How does the moral, and statutory, obligation faced by decision makers to combat climate change weaken or strengthen the range of options available to meet our energy needs?

15 Can we maintain good standards of living for the general population and improve standards for those in energy poverty while carrying out our responsibility to reduce carbon emissions to the extent required to mitigate climate change?

1 Cooper, R, The Telegraph, 24 May 2013, *Britain 'came close to running out of gas',* available at: https://www.telegraph.co.uk/finance/newsbysector/energy/10077796/Britain-came-close-to-running-out-of-gas.html

Regulatory environment

16 The regulatory environment overseeing energy policy is complex, with constitutional arrangements placing jurisdiction for different aspects of policy in the hands of different levels of government. The current system has evolved to promote certain actions, interests and options, and to discourage others.

17 What limitations does the regulatory environment place on freedom to make choices, and conversely are there opportunities to make, perhaps radical, changes to this environment?

18 While major, as yet unforeseen, changes to Scotland's constitutional arrangements could have a major impact on the regulatory environment, this Inquiry does not see its role as speculating on this and so considers this framework in the context of Scotland as part of a wider UK, which has voted to leave, but not yet left, the European Union.

Historical factors

19 Scotland, as part of the UK, played an important role in the industrial revolution and prospered significantly as a result. Inherent in the transition to new manufacturing processes, and eventually heavy industry, was an enormous increase in carbon emissions. As one of the major historic beneficiaries of carbon use, does Scottish energy policy currently go far enough in reducing greenhouse gas emissions and does Scotland have an even greater responsibility develop low-carbon alternatives?

20 Scotland has a long history in coal extraction and over the past 60 years in oil and gas production. The role of fossil fuels continues to be an important contributor to the Scottish economy and the UK energy mix. Energy policy must consider the importance these fuels still play and the jobs and communities that are so intrinsically linked to its production, processing and use.

Political factors and public engagement

21 Governments and parties of all political persuasions face pressure to address numerous issues related to energy, to a greater or lesser extent, as part of the process of developing and implementing policy. Issues such as fuel poverty and energy affordability are of national concern, but particularly impact upon specific social groups and those living in isolated communities. Similarly, the issue of place and where energy development occurs, and upon whom it has the most impact, is significant.

There are a number of choices that face Scotland on its road to a sustainable energy future. For these to be realised, the public will need to be aware of, contribute to the development of, and support, the changed priorities, some of which could see an increased cost. A programme of public dialogue will be required to provide the context for the wider public.

Global context

22 Scottish energy policy does not exist in a vacuum and, to a notable extent, its effectiveness will be impacted by the actions of other countries. Scottish energy policy is unlikely to have significant impacts on, for example, the global price of oil or global trends in the use of certain fuels and their resulting emissions. What limitations do the actions of others place on Scottish energy policy and what role can Scotland play in influencing others through its policy? Energy is supplied by an integrated international market, with flows of energy between Scotland, England, the EU and the wider international market. This market plays a driving role in determining price in the short term and fuel choice in the long term, and in influencing judgement on how secure our supply of energy is and in what areas investment should be made.

23 It should also be kept in mind that many (if not all) of the challenges we face are also obstacles for other countries across the world. Attempts to address the considerations listed above in isolation can, and do, lead to counterproductive and inconsistent policy. A useful illustration of this is the situation in Germany, where the decision to phase out coal (in order to reduce carbon emissions and combat climate change) has led to uncertainty over whether to bring new, more efficient coal-fired power stations on-stream. The resulting indecision, however, has led to ageing and less efficient coal-fired stations, including some burning lignite, remaining open due to concerns over the impact on communities and the resulting unemployment that such closures would cause. This issue has been exacerbated by the country's decision to move away from nuclear energy, closing off one potential avenue of low-carbon energy to which it could transition.

Training needs

24 In order to make the transition from a society powered by burning fossil fuels to one fuelled by low-carbon energy, and ensure Scotland's energy future is sustainable, there will be a need to equip the next generation with the right skill sets through a programme of research and training.

A 'whole-system' approach to energy

25 The individual strands of energy policy – and the supporting and interrelated policies around it – cannot and should not be considered in isolation. Effective planning requires consideration of how housing and transport connect to, and can support, one another, to name but one example.

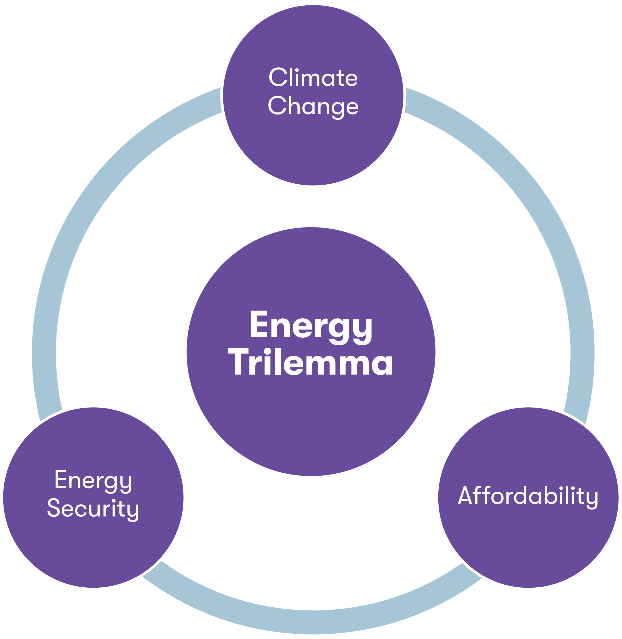
26 Decisions on whether to invest in specific technologies or support particular options should not be made exclusively on the perceived merits or demerits of these choices, but assessed in the wider context of societal needs, goals and values. How can a more strategic approach to energy policy be developed?

Energy Paradoxes

The Energy trilemma

27 The competing problems that energy policy must look to solve have popularly become known as 'the Energy Trilemma'. The term, first defined by the World Energy Council,[2] in essence attempts to convey the three opposing challenges that must be balanced in order to create successful energy policy.

28 Policy must adequately address climate change concerns, through reducing carbon emissions and producing energy in a sustainable manner. The energy needed to heat and light homes, and to fuel transport to-and-from places of work, must remain affordable to the public. And, as far as possible, this supply of energy must be secure and available, as and when it is required.

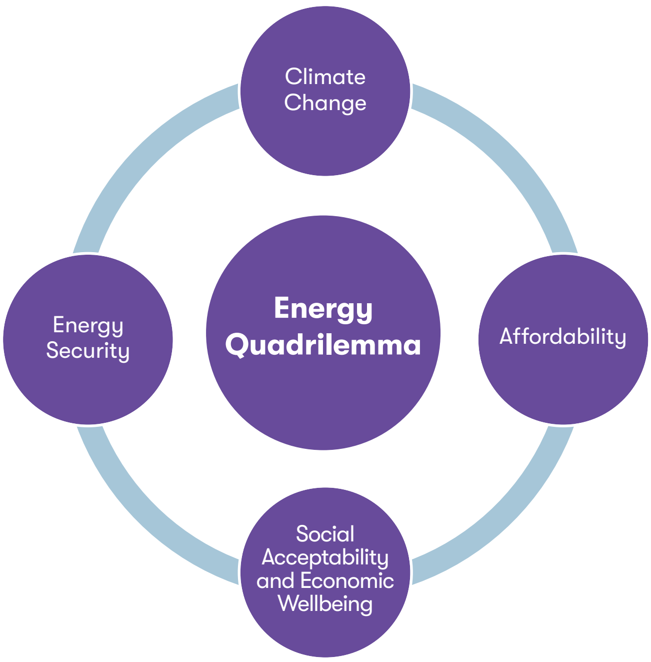


2 World Energy Council Website: https://www.worldenergy.org/work-programme/strategic-insight/assessment-of-energy-climate-change-policy/

The Energy quadrilemma

29 More recent discourse has raised issues over the framing of the Trilemma and whether it adequately encompasses all of the competing problems energy policy must look to address. The additional aspect of social acceptability and economic wellbeing has been proposed, with the argument made that for energy policy to be successful it must not only address climate change, provide security of supply and be affordable, but that the solutions to these issues must also be acceptable to the public.

30 Furthermore, the concept of social acceptability and economic wellbeing can be considered to include wider concerns which the traditional trilemma may overlook, such as the need for economic sustainability.



Demand side considerations

31 Concerns have been expressed, however, that even this expanded framework still prioritises the supply side of energy over the demand side.

32 The average member of the public has little power to make real decisions over how energy is generated, the unit price of electricity or the capacity of the network. Instead, business, industrial and domestic consumers are likely to want the convenience of using energy when and how they choose. This desire, however, competes with a network which would ideally have consumers use energy at times of low demand and contains generators that would benefit from increased use at times of high supply.

33 The average business or household consumer also does not spend a considerable amount of time thinking about their actual energy usage. Rather, they complete daily tasks or functions while using energy, potentially keeping track of the financial cost this will incur. Greater examination of the public's and commercial sectors' actual energy needs, in lieu of solely looking at how much they consume, is key.

34 In terms of affordability on the demand side, policy must focus on trying to offset energy price rises, but also consider just how and when we need to be using energy for certain everyday tasks. Basically, consumers want to meet their energy service needs, but wish to do so affordably and with the flexibility that modern and rapidly changing lifestyles require.[3] Understanding policy actions that can respond to support changes in the way we behave, work and interact with one another could be vital in tackling the issue of affordability.[4]

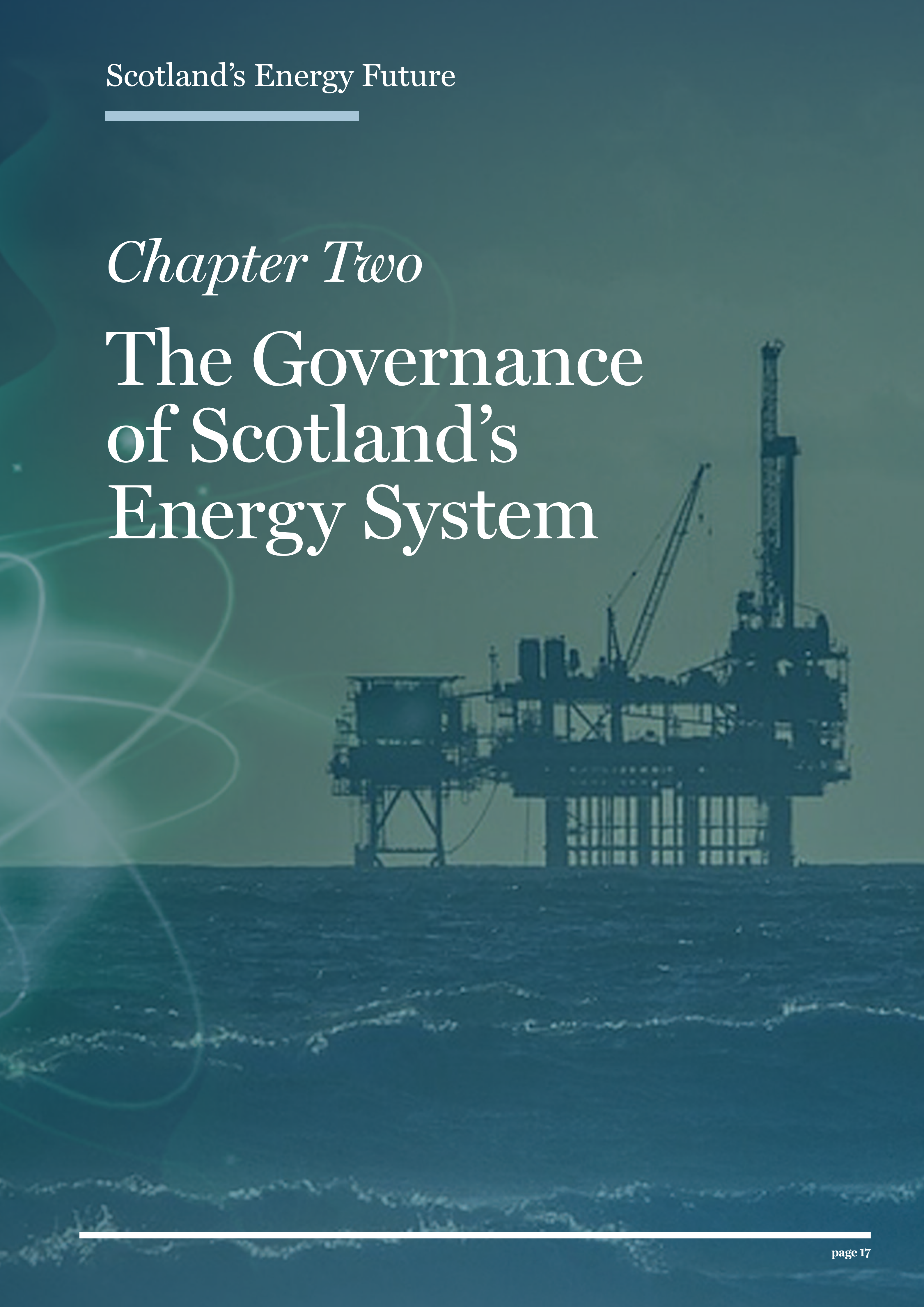
35 In the context of industrial energy demand, understanding and responding to just how and when firms need to use energy, particularly in the context of competitive pressures, is crucial to bring a rapid response from what is already a well-educated demand community.

3 Centre on Innovation and Energy Demand Document, April 2017, available at: http://www.cied.ac.uk/wordpress/wp-content/uploads/2017/04/Demand-side-trilemma-briefing-final.pdf

4 Marchant Ian, University of Strathclyde International Public Policy Institute Occasional Paper, 2016, *5 Things to Consider in Energy Policy*, pp 3-5, available at: https://strathprints.strath.ac.uk/57909/1/Marchant_IPPI_2016_elephants_in_energy_5_things_to_consider_in_energy_policy.pdf

Key Points

- No energy policy, no matter how well considered, will ever solve all of the problems and paradoxes of energy supply and use.
- Those developing policy must ask how best to address the competing issues of the 'energy quadrilemma': addressing climate change; ensuring affordability; providing energy security; and developing energy policy which is acceptable to the public, economically sustainable and just.
- Decision makers will need to be honest with the public about what is achievable, what choices must be made, and what changes will need to occur.



Chapter Two

The Governance of Scotland's Energy System

Introduction

1 The governance of Scotland's energy system is provided for by a large body of complex legal and policy instruments. Its complexity reflects both technical challenges and the fact that the system is the product of political and ideological choices. It is in perpetual flux, with new political events, societal and environmental needs, technological developments and economic risks and opportunities emerging constantly.

2 The policy objectives of the system also generate complexity. The Energy Quadrilemma mentioned in Chapter 1 has as its four elements:

- Reducing carbon emissions;
- Energy security;
- Energy affordability;
- Social acceptability and economic wellbeing.

3 Since these are competing objectives, decision makers are engaged in a continual process of compromise and trade-off. The dynamic has been complicated further by a recent shift in UK Government policy from embracing an ambitious clean energy transformation to making a "least cost transition".[5]

4 This chapter assesses the key features of the energy governance system for Scotland. After outlining where legislative and political power lies, it summarises the main objectives of, and issues arising from, the different UK and Scottish schemes which address the four elements of the Energy Quadrilemma: this is the regulatory and governance context in which any successful future energy policy is likely to operate.

Where Powers Lie

5 The structure governing Scotland's energy system is multi-faceted. The system is governed by Acts of both the UK and Scottish Parliaments, some of which implement EU legislation and international obligations. These statutes are the legal basis for policy making and decision taking, with the detail on how the system operates provided in secondary legislation and "soft law", such as policy guidance documents. For a major change to the energy system to occur, statutory reform, new regulatory standards, licensing rules and industry codes may all be required. Implementing reform can therefore be a lengthy and complex undertaking.

6 The formal division of legislative and political power between the Scottish and UK Parliaments and Governments is a key feature of the system. The Scotland Act 1998 (the Scotland Act) reserved control over energy in Scotland to the UK level, although it also devolved a number of related areas to Scotland.[6] Additional powers were devolved on an *ad hoc* basis,[7] with further competencies given to the Scottish Parliament following the Scotland Act 2016.[8]

5 Gillard, R and Lock, K, Journal of Environmental Policy and Planning 2017 19(6), *Blowing policy bubbles: re-thinking emissions targets and low-carbon energy policies in the U.K.*, pp. 638 – 653

6 *Scotland Act 1998* (as amended), s. 29 and Sched. 5.

7 E.g. The Renewables Obligation (Scotland) Order 2009 (as amended) established the devolved Renewables Obligation scheme in Scotland and placed an obligation on licensed electricity suppliers in Scotland to source increasing proportions of electricity from renewable sources: a similar scheme was set up for England and Wales under the Renewables Obligation Order 2009 and Renewables Obligation Order 2015. The Renewables Obligation Closure Order 2014 came into force in England, Scotland and Wales on 9 September 2014 to close the RO schemes to new generating capacity from 31 March 2017, with onshore wind and solar PV being closed before then. The Closure Order also provided for five grace periods, which enable generating capacity to be accredited after 31 March 2017 provided it meets specified conditions.

8 Little, G, Edinburgh Law Review 2016 20(3), *Energy and the Scotland Act*, pp. 394-399; and McHarg, A, Edinburgh Law Review 2016 20(3), *Crown Estate Devolution*, pp.388 – 394.

Where Powers Lie

While the majority of energy policy is reserved to Westminster, many interrelated competencies have been devolved to Holyrood since the Scottish Parliament reconvened in 1999. This allows Scotland to pursue its own energy policy to some extent using these adjacent powers, while remaining heavily intertwined with the UK Government and operating within the same general framework.

Below are examples of some of the potentially relevant powers for guiding energy policy:

Power:	Status:	Information:
Agriculture, forestry and fisheries	Devolved	All areas devolved in 1998
Education and training	Devolved	All areas devolved in 1998
Energy	Mostly Reserved	The promotion of renewable energy generation and energy efficiency is devolved.
Environment	Devolved	Most areas devolved in 1998. Energy efficiency schemes devolved in 2016.
Health and social services	Devolved	Most areas devolved in 1998. Social security benefits devolved in 2016.
Housing and planning	Devolved	All areas (including policy and building control, and land use planning) devolved in 1998.
Local government	Devolved	This area was devolved in 1998.
Taxation	Mostly reserved	Some areas of taxation (including Land and Buildings Transaction Tax and Landfill Tax) devolved in 2012.
Transport	Mostly reserved	Some aspects (including control over Air Passenger Duty) were devolved in 2012. The majority of powers (including over aviation, shipping and road traffic law) remain reserved.
Welfare	Partly devolved	Some aspects of welfare (including the Winter Fuel Payment and fuel poverty schemes) devolved in 2016.

Source: Scottish Parliament Devolution (Further Powers) Committee

7 The combination of its energy-related powers and control over planning and environmental protection has enabled the Scottish Parliament to pass legislation which impacts directly on Scotland's energy transition, such as the Climate Change (Scotland) Act 2009. The Scottish Government has also been able to block aspects of UK Government energy policy in Scotland; for example, using planning powers to prevent construction of new nuclear power stations.[9] In December 2017, it took the significant step of publishing its own energy policy, *Scottish Energy Strategy: The future of energy in Scotland* (the Strategy).[10]

8 The Strategy is a welcome and ambitious attempt to connect policy making for Scotland with what low-carbon transition might mean in the longer term. It builds on the Scottish Government's 2009 renewable energy targets for 2020.[11]

9 The Strategy proposes a whole-systems approach to energy and sets two new policy targets for 2030. The first is that the equivalent of 50% of the energy for Scotland's heat, transport and electricity consumption should be supplied from renewable sources; and the second is that there should be an increase of 30% in the productivity of energy use across the Scottish economy (although what is meant by energy productivity and the identification of key drivers requires clarification).[12] A further ambition is the almost complete decarbonisation of the Scottish energy system by 2050, involving large-scale transition to low-carbon and renewable transport[13] and a further expansion of renewable energy.[14] The Strategy recognises that the UK Government has strategic control of most of the key energy policy levers.[15]

10 Nonetheless, the Strategy identifies priority areas for the Scottish Government, including: consumer engagement and protection; energy efficiency; renewable and low-carbon solutions; and transitions in the oil and gas industries.[16] While the role of the Scottish Government is often that of engaging with UK Government policy in the Scottish interest, it also sets out a number of potentially significant initiatives.

Reducing Carbon Emissions

11 The reduction of carbon emissions is one of the key components of the energy quadrilemma. Given the energy sector's historic dependence on fossil fuels, it is one of the main emissions producers. UK Government policy therefore seeks to reduce emissions from this sector and to facilitate a successful transition to low-carbon energy in order to mitigate climate change.[17]

9 Little, G., 2018, ibid, pp. 394–396

10 The Scottish Government, December 2017, *Scottish Energy Strategy: The future of energy in Scotland*, available at: https://www.gov.scot/binaries/content/documents/govscot/publications/publication/2017/12/scottish-energy-strategy-future-energy-scotland-9781788515276/documents/00529523-pdf/00529523-pdf/govscot%3Adocument.

11 Ibid, p.34.

12 The Scottish Government's previous efficiency target was to achieve a reduction in final demand for energy of 12% by 2020, set against a 2005-2006 baseline: Scottish Government, 2017, Op. Cit., p.34. See also, Scottish Government March 2015, *Scotland's Economic Strategy*, available at: https://beta.gov.scot/publications/scotlands-economic-strategy/

13 Scottish Government, 2017, Scottish Energy Strategy, Op. Cit., pp. 52-53.

14 Ibid, pp. 34–35.

15 Ibid, p.35.

16 Ibid, pp. 34–75.

17 See UK Government, October 2017 (a), The Clean Growth Strategy: Leading the way to a low carbon future, pp. 93–112, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700496/clean-growth-strategy-correction-april-2018.pdf

12 A number of legislative and policy instruments have been introduced at EU level[18] to give effect to international agreements on greenhouse gas reduction. In the last decade, these have provided the governance and regulatory context within which the UK and Scottish Governments and Parliaments have operated.

13 Brexit presents a number of significant risks, particularly in the case of no deal being reached between the UK and the EU, which are outlined below. There have also been serious concerns expressed by the National Audit Office (NAO) and the House of Commons Public Accounts Committee about the robustness of the governance of emissions reduction and low carbon energy transition at UK level.

UK and Scottish measures on greenhouse gas emission reduction

14 A number of UK-wide legal and policy instruments are in place to support the development of low-carbon energy and energy efficiency in order to bring down greenhouse gas emissions from fossil fuel use: these operate within the context of EU law and policy[19] and international agreements.[20]

15 The keystone of the UK system is the Climate Change Act 2008,[21] which requires the UK Government to meet a legally binding target of cutting emissions by 2050 by at least 80%.[22] The UK Government must set carbon budgets to ensure that it is making progress towards this target.[23] The Act also established the Committee on Climate Change (CCC) to monitor progress on emissions reduction.[24] It is therefore a matter for concern that the CCC has reported that the UK is currently not on track to meet its targets.[25] The shift in UK Government policy since 2015 towards reducing subsidy costs for renewable energy raises the question of whether it will be able to get back on course.[26] The UK, Scottish and Welsh Governments have instructed the CCC to report on whether further action is required for the UK to comply with the Paris Agreement.[27] In May 2019, the CCC reported that the UK should set and pursue goals of reducing greenhouse gas emissions to 'net-zero' by 2050, advising that the Scottish Government should look to meet this goal by 2045.[28] Brexit also raises the issue of whether the UK will need to have a separate target from that of the EU (although it is a signatory to the Paris Agreement in its own right).[29]

18 The EU has provided important legal and policy frameworks and infrastructures which interleave with domestic UK provision. EU legislation is in force to reduce greenhouse gas emissions from major polluting industries, including the energy sector. In particular, the 2020 Climate and Energy Package of directives and subsequent legislation introduced EU-wide targets of reducing greenhouse gas emissions by 20% from 1990 levels, increasing the share of renewable energy used in the EU to 20%, and improving energy efficiency by 20%. The target for greenhouse gas emission reduction was in large measure directed towards the energy industry, which produces around 80% of EU greenhouse gas emissions. Following the Paris Agreement in 2015, the EU committed itself to making further reductions by 2030, and it is putting legislation in place to reduce emissions by at least 40% by 2030. The EU has also developed a 2050 "roadmap" for transitioning to a low-carbon economy. Among other things, this envisages that by 2050 the EU will have reduced its emissions to 80% below 1990 levels solely by making domestic reductions – this is consistent with its commitment to reduce emissions by 80-95% by 2050 in conjunction with developing countries making similar reductions. See European Commission, Energy Strategy and Energy Union, available at: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union.

19 Ibid.

20 Principally the 1992 United Nations Framework Convention on Climate Change; the 1997 Kyoto Protocol; and the 2015 Paris Agreement.

21 Muinzer, T.L, 2018, *Climate and Energy Governance for the UK Low Carbon Transition*, pp. 17 – 27.

22 Climate Change Act 2008, Part 1.

23 Ibid.

24 Ibid, Part 2.

25 Committee on Climate Change Website, June 2018, Reducing UK emissions: Progress report to Parliament, p.11, available at: https://www.theccc.org.uk/publication/reducing-uk-emissions-2018-progress-report-to-parliament/ .

26 Gillard, R, and Lock, K, 2017, Op. Cit., p. 647.

27 Scottish Government, Department for Business, Energy and Industrial Strategy, October 2018, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/748489/CCC_commission_for_Paris_Advice_-_Scot__UK.pdf

28 Committee on Climate Change, May 2019, *Net-Zero: The UK's contribution to stopping global warming*, p11, available at: https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

29 Little, G, Edinburgh Law Review, 2018 22(1), *Brexit and energy in Scotland*, pp 144 – 149 at p 148.

16 The Scottish Parliament passed the Climate Change (Scotland) Act 2009, which set an interim target for Scotland of reducing greenhouse gas emissions by 42% by 2020.[30] This target was met in 2014.[31] The Scottish Government is keen to maintain momentum, and the Climate Change (Emissions Reduction Targets) (Scotland) Bill is currently before the Scottish Parliament. If passed, it will result in Scotland having the most ambitious legally binding phased emissions reduction targets in the world, culminating in a 90% reduction by 2050.[32] It is worth noting that the CCC considers that this "would require actions that are currently at the very limit of feasibility".[33]

17 There are a number of interconnected UK Government schemes which operate in Scotland, which have been devised in order to achieve the targets for emission reduction set out in the 2008 Act. They can be sub-divided into schemes which provide for:

- Carbon pricing
- Low-carbon energy generation and heat
- Energy efficiency
- Finance and investment
- Decarbonising transport

18 These are complemented by Scottish Government schemes and policy objectives for developing renewables and low-carbon solutions, energy efficiency and transport, as articulated in the Scottish Energy Strategy. While there have been some successes, there are also a number of significant concerns about the design and operation of the schemes, as outlined below.

Carbon pricing

The Climate Change Levy (CCL)

19 The CCL operates as a tax on energy use by UK businesses. There are two rates in operation, the Main Rate (which charges companies by fuel type) and the Carbon Price Support (CPS) rate (which applies to combined heat and power operators and energy generating companies with their own supply of fossil fuel). The CPS rate was introduced to provide a carbon price 'floor' amid concerns[34] over the effectiveness of the EU Emissions Trading Scheme (EU ETS).[35] The UK has announced it will remain in the EU ETS until 2020, but UK involvement in the longer term is uncertain.[36] The CCL exemption covered electricity generated by renewables until 2015, and it continues to exempt registered combined heat and power electricity.[37]

30 Climate Change (Scotland) Act 2009, s. 2.

31 Scottish Government, June 2016, *Scotland exceeds 2020 climate targets*, available at: https://news.gov.scot/news/scotland-exceeds-2020-climate-targets

32 Climate Change (Scotland) Bill 2018, cl. 2.

33 Committee on Climate Change, March 2017, Advice on the new Scottish Climate Change Bill, p. 9, available at: https://www.theccc.org.uk/publication/advice-on-the-new-scottish-climate-change-bill/

34 Hirst, D., *Carbon Price Floor (CPF) and the price support mechanism*, House of Commons Briefing Number 05927 (8 January 2018), available at: https://researchbriefings.parliament.uk/ResearchBriefing/Summary/SN05927#fullreport

35 The EU ETS is a 'cap and trade' system. The 'cap' is the set total of greenhouse gas emissions covered by the scheme. European Union Allowances (EUAs) representing a tonne of greenhouse gas are allocated to scheme participants by auction (or for free for specified types of installation). The EUAs are surrendered according to the amount of greenhouse gas emitted, and participants are able to trade EUAs: by imposing phased reductions in the cap, the ETS is able to reduce greenhouse gas emissions over time. The price of EUAs was kept low for economic policy reasons in the aftermath of the 2008 financial crisis. Under the EU 2050 Roadmap, however, the EU ETS – which includes heavy energy-using installations such as power stations – will have to cut emissions by 43% by comparison with 2005 levels. See European Commission, *The EU Emissions Trading System*, available at: https://ec.europa.eu/clima/policies/ets_en

36 House of Commons Business, Energy and Industrial Strategy Committee, 6 November 2017, *Leaving the EU: negotiation priorities for energy and climate change policy: Government Response to the Committee's Fourth Report of Session 2016–17*, HC 550 paras. 20-24, available at: https://publications.parliament.uk/pa/cm201719/cmselect/cmbeis/550/550.pdf

37 See UK Government, *Environmental taxes, reliefs and schemes for businesses*, available at: https://www.gov.uk/green-taxes-and-reliefs . See also D. Hirst, 2018, Op. Cit.

20 The UK's experience of the CPS rate has been mixed. Detractors suggest that it has had little effect on emissions reduction, while putting UK companies at a competitive disadvantage and increasing bills. Industry, and some environmental groups, have, however, generally been supportive of it as a mechanism for encouraging investment in low-carbon transition. Criticisms have been expressed over the ways in which it has been implemented, the absence of long-term certainty for investors, and the fact that the revenue generated goes into the general tax take, rather than being used to support renewable energy.[38]

Low-carbon generation and heat

The levy control framework (LCF) and Control for Low-carbon Levies (CLCL)

21 The LCF was an annual spending cap set by the Treasury. It provided the maximum amount available for the Contracts for Difference, Renewables Obligation and Feed-in Tariff schemes. The cap was divided into limits for each scheme, which were divided again between different types of generation. In 2015, the Office for Budget Responsibility forecast that spending would be higher than anticipated, leading to major reform.[39] Oversight of the LCF was criticised in both an internal report[40] and by the House of Commons Public Accounts Committee. Insufficient transparency and accountability, poor forecasting of costs, overspending and weak governance were all identified as issues.

22 The CLCL – which has the key objective of imposing a moratorium on new low-carbon subsidies until the total cost falls (forecast to be in 2025) – was then introduced. The CLCL represents a significant change in approach to developing low-carbon energy. Although cost to the consumer has undoubtedly been a factor in scaling back subsidies, the CLCL could result in the UK's ambitious emissions reduction targets becoming little more than rhetoric. While parts of the renewables sector may be able to compete without subsidy, and there is qualified support for a shift to a subsidy-free future,[42] the CLCL is viewed by some as indicative of a lack of ambition to build on what has been achieved so far in terms of cutting the cost of low-carbon electricity, and as inconsistent with the UK Government's Clean Growth Strategy. [43]

Electricity Market Reform (EMR) and Scottish Government strategy on developing renewable and low-carbon solutions

23 Through the Energy Act 2013, the UK Government implemented the policy of Electricity Market Reform, introducing a number of new mechanisms with the stated aim of delivering low-carbon energy supplies whilst maintaining security of supply and minimising cost to the consumer. The two most prominent mechanisms introduced were Contracts for Difference (CfD) and a Capacity Market (CM).

38 See Hirst, D, 2018, Op. Cit., para 3.

39 See UK Government, 25 November 2016, *Levy Control Framework*, available at: https://www.gov.uk/government/collections/levy-control-framework-lcf

40 BEIS, 2015, *Management of the LCF: Lessons learned report*, available at: https://www.gov.uk/government/publications/levy-control-framework-lessons-learned-report-and-government-response

41 House of Commons Committee of Public Accounts, February 2017, *Consumer-funded energy policies*, HC 773, available at: https://publications.parliament.uk/pa/cm201617/cmselect/cmpubacc/773/773.pdf

42 See Hirst, D, *Control for low carbon levies*, House of Commons Briefing Number 8187 , 20 December 2017, para 3.3.

43 Ibid, introduction to para 3 and para 3.2.

24 CfD replaced the Renewables Obligation Scotland (and the Renewables Obligation at the UK level) and were devised to facilitate the development of low-carbon electricity generation.[44] Low-carbon generators provide electricity under long-term contracts at an agreed strike price. The generators pay, or are paid, the difference between the strike price (representing the cost of investment) and the reference price (representing the average GB market electricity price). The system aims to incentivise low-carbon electricity generation by shielding generators from volatile wholesale electricity prices, while also protecting customers from paying higher costs.[45]

25 CfD are allocated according to criteria for different qualifying technologies – which includes nuclear power – with separate funding pots for each technology. If there are sufficient funds in each pot to fund all the applications, then these are allocated on the basis of administratively-set strike prices, otherwise a sealed bid auction takes place, giving preference to the lowest bids.[46]

26 While it is still too early to assess the effectiveness of CfD, a number of potential issues can be identified. Friends of the Earth have argued that the system has provided a subsidy for the expansion of nuclear power, and risks entrenching the market domination of big energy companies due to a lack of incentives for big companies to give power purchase agreements (PPA) to independent generators at a rate that is not highly discounted. Concerns have also been raised about the uncertainty of the allocation process, and the potential that this has for destabilising the future growth of renewables.[47] The issue of cost to the consumer is also significant. The NAO reported that the way in which the 2017 auction was conducted will cost consumers considerably more than it could have done, with BEIS recognising that the auction outcome was "suboptimal".[48]

27 The Capacity Market is intended to operate in tandem with CfD as a mechanism to incentivise investment in low-carbon electricity, while keeping costs low[49] and ensuring security of supply through the purchase of reliable sources of capacity. The mechanism – which had been placed on hold following a judgement by the European Court of Justice[50] – has faced similar criticisms of favouring larger producers, in addition to claims that it does not sufficiently support renewable sources and excludes demand reduction bidders.[51]

28 Against this backdrop, community benefit payments in connection with community renewables developments will continue to be provided. Although the Scottish Government has acknowledged that there are issues with the operation and development of shared ownership, it also wants to see an increase in shared ownership of onshore renewable projects to provide communities with a lasting economic asset. Ambitious targets of 1 GW of community-/locally-owned energy by 2020 and 2 GW by 2030 have been set.[52] Currently around 692 MW (around 70% of the 2020 target) are operational.

44 See footnote no.7 above for information on the Renewables Obligation Scotland.

45 See generally BEIS, 11 January 2019 (last updated), *Policy paper: Contracts for Difference*, available at: https://www.gov.uk/government/publications/contracts-for-difference/contract-for-difference. See also National Audit Office, 16 May 2018, HC 949 Session 2017-2019, Part One, Investigation into the 2017 auction for low-carbon electricity contracts, available at: https://www.nao.org.uk/report/the-2017-auction-for-low-carbon-electricity-generation-contracts/ .

46 Ibid.

47 Toke, D, Friends of the Earth, 2012, *A Proven Solution: how to grow renewables with a Fixed Feed-in Tariff*, pp. 17–22

48 National Audit Office, above at n 45, para. 2.20.

49 Ofgem Website: https://www.ofgem.gov.uk/electricity/wholesale-market/market-efficiency-review-and-reform/electricity-market-reform/capacity-market-cm-rules

50 Government Website, 24 July 2014, 19 December 2018 (last updated) https://www.gov.uk/government/collections/electricity-market-reform-capacity-market

51 PV Magazine, 2 February 2019, UK Capacity Market Auction results draw criticism over lack of renewables https://www.pv-magazine.com/2018/02/02/uk-capacity-market-auction-results-draw-criticism-over-lack-of-renewables/

52 Scottish Government, 2017, *Scottish Energy Strategy*, Op. Cit., pp. 43–44.

29 The planning system in Scotland supports onshore wind farm development, grid connections and low-carbon transition infrastructures [53] and the Planning (Scotland) Bill before the Scottish Parliament seeks to further improve its effectiveness. As part of the planning review process, the Scottish Government is considering removing the requirement for planning permission for specified renewables developments, and reviewing solar energy within building regulations.[54] The Scottish Government also wishes to facilitate the development of local energy systems and is considering a new statutory system for Local Heat and Energy Efficiency Strategies.[55] Finally, the Scottish Government has targeted support through rates relief for community renewables, hydropower and district heating, and has committed itself to fast track the plant and machinery consideration for hydropower.[56]

Renewable heat incentive (RHI)

30 The RHI scheme incentivises businesses and households by paying them for installing renewable heating technologies. As it is funded by general taxation, it does not have a direct effect on energy prices.[57]

31 A recent NAO report on the RHI found that the scheme is working to an acceptable standard, but falls short of its potential.[58] The roll-out and administration of the scheme by the UK Government and by the Office of Gas and Electricity Markets (Ofgem) has been mixed. Take up has been much lower than initially projected, resulting in BEIS revising its strategy to focus on a smaller number of businesses and homes that are not connected to the gas grid.

32 The NAO did, however, find examples of good practice and it seems likely that BEIS will achieve its revised objectives. That said, the NAO also indicated that BEIS has not, as yet, compensated fully for the RHI's reduced ambitions for renewable heat through the Clean Growth Strategy.[59]

Feed-in tariffs (FIT)

33 The objective of the FIT scheme is to incentivise development of small-scale low-carbon and renewable electricity generation to a capacity of 5 MW, or 2 kW for micro-combined heat and power. The scheme, operated by Ofgem, enables those who have small-scale generators to get a set payment per kilowatt hour from their supplier for generating their own electricity. The cost of the scheme is met by suppliers and then passed on to customers.[60]

34 While the cost of small-scale solar power panels in particular has reduced considerably, BEIS has closed the scheme to most new applicants from April 2019. In the context of the CLCL, BEIS's main concern has been the cost which is being passed on to consumers – revised estimates suggest the scheme will add up to £1.6 billion per annum to energy bills by 2020. Concerns have been raised that termination of the scheme may see small-scale generators 'spilling' their excess generation onto the grid for free, and without any regulatory protection, thereby unfairly subsidising big electricity firms.[61]

53 Ibid, p. 54. See also the Planning (Scotland) Bill, available at: http://www.parliament.scot/parliamentarybusiness/Bills/106768.aspx

54 Scottish Government, 2017, *Scottish Energy Strategy*, Op. Cit., p. 48.

55 Ibid, pp. 56 – 57.

56 Ibid, p. 50.

57 See UK Government, *Non-domestic Renewable Heat Incentive* (RHI), available at https://www.gov.uk/non-domestic-renewable-heat-incentive; and UK Government, Domestic Renewable Heat Incentive (RHI), available at https://www.gov.uk/domestic-renewable-heat-incentive

58 National Audit Office, HC 779 Session 2017-2019, 23 February 2018, *Low-carbon heating of homes and businesses and the Renewable Heat Incentive*, paras. 9 – 21, available at: https://www.nao.org.uk/wp-content/uploads/2018/02/Low-carbon-heating-of-homes-and-businesses-and-the-Renewable-Heat-Incentive.pdf

59 Ibid, para. 10.

60 See UK Government, *Feed-in tariffs: get money for generating your own electricity*, at https://www.gov.uk/feed-in-tariffs; and BEIS, 19 July 2018, Consultation on the Feed-In Tariff Scheme, pp. 9-11, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/726977/FITs_closure_condoc_-_Final_version.pdf

61 See BEIS, ibid, p.11. See also 30 August 2018, *Open letter on maintaining fair payment for exported electricity from Chris Hewlett, Chief Executive of the Solar Trade Association, to the Rt Hon Claire Perry MP, Minister of State for Energy and Clean Growth* available at: https://www.solar-trade.org.uk/wp-content/uploads/2018/08/Open-Letter-to-Claire-Perry-re-Export-Tariffs.pdf

Energy efficiency and fuel poverty: UK and Scottish government schemes

The Energy Company Obligation and Scottish Government provision for fuel poverty and energy efficiency

35 The Energy Company Obligation is a UK Government energy scheme to support domestic energy efficiency, which is delivered via energy supply companies.[62] The latest version of the scheme applies until 2022 and is focused on low-income and vulnerable households. At least 15% of the supplier's obligations are to be delivered in rural areas, and 25% may be met through the local authority flexibility eligibility, which facilitates identification of households which are most in need.

36 The Scottish Government has developed complementary strategies for fuel poverty and energy efficiency, and Scotland is unique in the UK in the use of public funds to support energy efficiency in the residential sector.[63] A long-term fuel poverty strategy[64] is being developed and the Fuel Poverty (Target, Definition and Strategy) (Scotland) Bill has been introduced to the Scottish Parliament to address fuel poverty by setting new statutory targets and better defining fuel poverty itself.[65]

37 Energy efficiency has been designated by the Scottish Government as a national infrastructure priority through Energy Efficient Scotland (EES).[66] EES provides a map to making Scotland's buildings near zero carbon where feasible by 2050. In the short to medium term, the focus will be on reducing energy demand in buildings.

Smart meters

38 The roll-out of smart meters for domestic and small-scale non-domestic electricity and gas users commenced in 2011, with a target of installing smart meters in all homes and small businesses by 2020.[67] By enabling consumers to see how much energy they are using in real time it is hoped that they will be able to understand and moderate energy use.[68] While progress has been fitful and the scheme is a long way from meeting its target (indeed suppliers have agreed to pay Ofgem fines for missing statutory targets),[69] progress is nonetheless being made,[70] and the Smart Meters Act 2018 has made provision to improve the scheme's effectiveness. It is too early to say whether smart meters will change behaviour significantly and make a real difference to energy use and efficiency.[71]

62 Scottish Government, *The Energy Company Obligation (ECO)*, available at https://beta.gov.scot/policies/home-energy-and-fuel-poverty/energy-company-obligation/

63 I.e. Home Energy Efficiency Programmes for Scotland (HEEPS): area-based schemes; HEEPS: Warmer Homes Scotland; Home Energy Scotland Loan. See Scottish Government, *Energy saving home improvements*, available at https://beta.gov.scot/policies/home-energy-and-fuel-poverty/energy-saving-home-improvements/

64 Scottish Government, *Fuel poverty*, available at https://beta.gov.scot/policies/home-energy-and-fuel-poverty/fuel-poverty/

65 Fuel Poverty (Target, Definition and Strategy) (Scotland) Bill, cl. 1–2.

66 Scottish Government, *Scotland's Energy Efficiency Programme (SEEP)*, available at https://www.gov.scot/Topics/Business-Industry/Energy/SEEP. See also Scottish Government, above at n 6, pp. 39–40.

67 UK Government, 22 January 2013, 4 January 2018 (last updated), *Smart meters: a guide*, available at: https://www.gov.uk/guidance/smart-meters-how-they-work

68 Ibid.

69 Ofgem, April 2019, *SSE pays £700,000 after missing gas smart meter target*, accessible at: https://www.ofgem.gov.uk/publications-and-updates/sse-pays-700000-after-missing-gas-smart-meter-target

70 See Hinson, S, House of Commons Briefing Paper Number 8119, 15 October 2018, *Energy Smart Meters*, paras. 1.4 and 4, available at: https://researchbriefings.parliament.uk/ResearchBriefing/Summary/CBP-8119

71 Ibid, para. 4.2.

Finance and investment

39 The UK Government established the Green Investment Bank in 2013[72] to provide commercial investment for renewables, thereby facilitating the development of riskier technologies. It had invested £3.4 billion of public money into the green economy and attracted £8.6 billion of private capital before being sold to Macquarie Group Limited.[73] The House of Commons Public Accounts Committee issued a strong condemnation of the sale. The Committee noted that the bank's new owners are not legally required to adhere to support for renewables development, and that the sale was reactive and ineffective, without proper assessment of its impact and value.[74]

40 The Scottish Government is committed to building on its Renewable Energy Investment Fund, and to extending it beyond renewables to include low-carbon energy solutions as a new Energy Investment Fund,[75] until the proposed Scottish National Investment Bank comes into being.[76] The Scottish Government also plans to develop its Low Carbon Infrastructure Transition Programme by creating a Low-carbon Innovation Fund.[77] These initiatives have the potential to provide tens of millions of pounds to facilitate further development of the sector in Scotland, although the level of state-backed finance available is modest by comparison to what was available from the pre-sale Green Investment Bank.

41 More broadly, if Brexit results in the UK leaving the European internal energy market, it may no longer be eligible for financial support for large-scale renewables projects of common interest from the European Investment Bank.[78] Uncertainty created by Brexit may also have an adverse effect on investor confidence.[79]

Decarbonising transport

42 The UK and Scottish Governments have introduced a number of policy objectives to decarbonise transport. The UK Government has announced that the sale of all new conventional petrol and diesel cars and vans would be ended by 2040.[80] The 2018 "Road to Zero Strategy" set out the vision for up to 70% of new car sales to be ultra-low-emission vehicles (ULEVs) by 2030.[81] The CCC has stated that 80% of new cars must be electric by 2030 if the UK is to meet its emissions targets.[82]

43 *The Scottish Energy Strategy* makes a commitment to phasing out "the need for" new petrol and diesel cars and vans in Scotland by 2032.[83] It also signalled the Scottish Government's intention to facilitate the use of ULEVs by achieving a range of objectives, including expanding the electric vehicle charging infrastructure.[84]

72 Enterprise and Regulatory Reform Act 2013, Part 1.

73 House of Commons Committee of Public Accounts, Twenty-Fifth Report of Session 2017–19, HC 468, 14 March 2018, *The sale of the Green Investment Bank*, pp. 8 – 11, available at: https://publications.parliament.uk/pa/cm201719/cmselect/cmpubacc/468/468.pdf

74 Notwithstanding the establishment of a special share to protect the bank's green objectives: ibid, pp. 3 – 7. For the UK Government's response, see HM Treasury, May 2018, *Treasury Minutes: Government response to the Committee of Public Accounts on the Twentieth to the Thirtieth reports from Session 2017-19* Cm 9618 pp. 26 – 29, available at: https://www.parliament.uk/documents/commons-committees/public-accounts/Cm-9618-Treasury-Minutes-may-2018.pdf#page=31

75 Scottish Government, 2017, *Scottish Energy Strategy*, Op. Cit., p. 42

76 Ibid.

77 Ibid.

78 Little, G.,2018, Op. Cit., pp. 146 - 149. See also House of Lords European Union Committee, 10th Report of Session 2017–19, HL Paper 63, 29 January 2018, *Brexit: Energy Security*, pp. 33-35, available at: https://publications.parliament.uk/pa/ld201719/ldselect/ldeucom/63/63.pdf

79 House of Commons Business, Energy and Industrial Strategy Committee, Fourth Report of Session 2016–17 HC 909 (2 May 2017), *Leaving the EU: negotiation priorities for energy and climate change policy*, paras. 106 – 111, available at: https://publications.parliament.uk/pa/cm201617/cmselect/cmbeis/909/909.pdf; and Little, G, 2018. ibid. For the UK Government response, see House of Commons Business, Energy and Industrial Strategy Committee at n 35 above, paras. 32 – 41.

80 DfT press notice, "Plan for roadside NO2 concentrations published", 26 July 2017.

81 DfT, *The Road to Zero: Next steps towards cleaner road transport and delivering our Industrial Strategy*, (July 2018), p. 2, available at https://www.gov.uk/government/publications/reducing-emissions-from-road-transport-road-to-zero-strategy (accessed 21 November 2018).

82 BBC News, 17 January 2018, Most new cars 'must be electric by 2030, ministers told'.

83 Scottish Government, 2017, Scottish Energy Strategy, Op. Cit., pp. 52 – 54.

84 Ibid.

44 The Strategy's reference to phasing out "the need for" petrol and diesel vehicles recognises that many powers on transport remain reserved.[85] As such, the realisation of these ambitions is partly contingent on the approach of the UK Government. That said, the Scottish Government's devolved control on planning provides it with potentially significant powers around the charging infrastructure.

45 UK Government policy commits £1 billion to facilitate the uptake of ULEVs[86] (although subsidies to support the purchase of hybrid vehicles have been discontinued, and the subsidy for purchasing electric vehicles reduced[87]). The Automated and Electric Vehicles Act 2018 empowers the UK Government to introduce regulation to support the delivery of the UK's policy objective for 2050 by providing for the development of the electric vehicle charging infrastructure.[88]

46 In anticipation of the likely additional demand caused by the rollout of ULEVs, National Grid forecasts that peak demand from electric vehicles will result in around an 8% increase by 2050.[89] While significant, the implications of this should be kept in proportion, with consumer behaviour and new technology likely to mitigate and moderate the impact of electric vehicle charging. Moreover, there is the potential for the batteries of charged vehicles to become an asset to the National Grid with "Vehicle to Grid" technology possibly enabling charged vehicles to release electricity back into the grid.[90]

47 Both Governments are planning for the large-scale and almost complete decarbonisation of the transport network. It remains to be seen, however, just how quickly ULEVs will replace conventional petrol and diesel vehicles or the extent to which the phasing out policy will contribute to meeting emissions reduction targets.

Energy security

48 Energy security is crucial to society and the national interest. There is a range of measures in place to ensure that the GB energy system is in continuous balance, and that there is sufficient energy supply available. Both the electricity and gas markets have complex balancing mechanisms, and there are also physical infrastructures for interconnection with the European single energy market, and for gas storage.[91]

49 The UK as a whole is unable to supply its own requirements for heat and power from indigenous sources and has an increasing reliance on importing gas and electricity.[92] As a result, the UK had a key role in developing the European internal energy market and the EU Energy Union Package of Measures.[93] In this context, Brexit has the potential to raise difficult issues, including whether the UK can continue as a member of the European internal energy market.[94]

85 Scotland Act 1998, Schedule 5, Head E.

86 UK Government, 2017, *Clean Growth Strategy*, Op. Cit., p87

87 Office for Low Emission Vehicles, 2 November 2018, 21 November 2018 (accessed), *Changes to the plug-in car grant,* available at: https://www.gov.uk/government/publications/plug-in-car-grant-changes-to-grant-level-november-2018/upcoming-changes-to-the-plug-in-car-grant

88 Automated and Electric Vehicles Act 2018, Part 2.

89 Butcher, L; Hinson, S; and Hirst, D, House of Commons Briefing Paper Number CBP07480, 20 February 2018, 21 November 2018 (accessed), *Electric vehicles and infrastructure*, pp. 20–22, available at: https://researchbriefings.parliament.uk/ResearchBriefing/Summary/CBP-7480

90 Ibid.

91 For a summary of these arrangements, see Competition and Markets Authority, *Energy market investigation*, 24 June 2016, Appendix 2.1, paras. 126 – 156, available at https://assets.publishing.service.gov.uk/media/5773de34e5274a0da3000113/final-report-energy-market-investigation.pdf

92 See House of Lords European Union Committee Report, *Brexit: energy security*, 10th Report of Session 2017-19, HL Paper 63 (29 January 2018), para 22, available at https://publications.parliament.uk/pa/ld201719/ldselect/ldeucom/63/63.pdf

93 Ibid, para. 12.

94 For the UK to remain in the internal energy market as 'third country' is likely to require it to accept the jurisdiction of the Court of Justice of the European Union ('CJEU'), which at the time of writing is one of the UK Government's Brexit negotiation 'red lines'. See ibid paras. 62–66.

50 Brexit therefore presents potential challenges to UK, and therefore Scottish, energy security. The UK will be able to continue as a member of a number of European organisations and networks developing international energy transmission systems,[95] but is likely to cease to be a member of the EU Agency for the Cooperation of Energy Regulators (ACER)[96] and the European Atomic Energy Community (Euratom).[97] It is still unclear whether the UK could have some sort of observer status at ACER, and develop a new relationship with Euratom: the latter is particularly important in the short term, as Euratom is vital to the security of the UK nuclear energy sector,[98] and hence to Scotland's nuclear power stations. Brexit could also potentially cause disruption for cross-border UK/EU energy governance, policy making, regulation, enforcement and funding.[99]

Energy affordability

Energy markets and pricing: the political context

51 From the 1980s, a key UK Government policy objective has been the liberalisation of the energy sector, which had been in public ownership since the 1940s. The core UK governing statutes are the Gas Act 1986 and the Electricity Act 1989.[100]

52 The Utilities Act 2000 continued the process of liberalisation and introduced a number of important reforms. The Gas and Electricity Markets Authority (GEMA)[101] was created – it is the governing body for Ofgem[102] – and the basis of the current wholesale electricity market rules were established in the New Electricity Trading Arrangements (NETA).

53 The liberalisation of the GB gas and electricity industries has brought about enormous change to Scotland's energy sector. In fewer than forty years, it has gone from being publicly owned, closely regulated by the state and working at the local level to being a market-based, cross-border industry, with private energy companies operating according to licences issued under statutory authority by Ofgem and largely self-regulatory industry codes.

54 When the process of liberalisation was started, however, it was not envisaged that there would need to be a major shift away from fossil fuels and the large-scale development of new low-carbon alternatives. Even with large sums of targeted subsidy provided to support the development of renewable energy, low-carbon transition requires massive, long-term investment and presents significant challenges to the market model.

55 The current UK Government remains committed to maintaining the market-based system, while seeking to respond to concerns about energy affordability and overcharging of customers by enabling Ofgem to take tougher regulatory action and cap energy prices.[103] It remains to be seen whether the recently introduced cap will be successful in moderating prices and protecting consumers. More fundamental questions may be asked about whether a market-based sector is capable of protecting customers' interests while delivering effective climate change mitigation and low-carbon transition. In this context, the Labour Party 2017 manifesto contained a pledge to nationalise key parts of the supply network and a commitment to nationalise all of the energy grid infrastructure.[104]

95 IE the European Network of Transmission System Operators for Gas, the European Network of Transmission System Operators for Electricity and the European Network Treaty.

96 For information on ACER, see http://www.acer.europa.eu/en/Pages/default.aspx

97 European Union (Notification of Withdrawal) Act 2017 s 1. Euratom is part of the EU in this context and the UK is therefore leaving it as well as the EU.

98 House of Lords European Union Committee Report, above at n 89, para. 159.

99 Little, G, 2018, Op. Cit., pp146 – 149.

100 For discussion of the History of British utilities regulation, see Stern, J, 2014, 31 *Utilities Policy, The British utility regulation model: Its recent history and future prospects*, pp. 162-172. For a useful summary of key aspects of the UK regulatory system, see CMA, above at n 88.

101 Utilities Act 2000, Part 1.

102 For further information, see https://www.ofgem.gov.uk.

103 See Domestic Gas and Electricity (Tariff Cap) Act 2018, ss. 1–3.

104 The Labour Party, *For the many not the few: the Labour Party manifesto* 2017, p.20, available at: https://labour.org.uk/wp-content/uploads/2017/10/labour-manifesto-2017.pdf

Energy market regulation: consumer protection and energy affordability

56 Currently, the GB gas and electricity market is dominated by the "Big Six" energy companies.[105] While there are number of mid-tier electricity generators and smaller suppliers of gas and electricity operating in the market, the Big Six (and, in the Scottish context, SSE, EDF and Scottish Power) have dominant market share. Given the interest of these companies in maximising market share and profits, it is important to be aware of concerns about the way in which the regulatory system has protected domestic consumers' interests and energy affordability, and in particular the issues reported on by the Competition and Markets Authority (CMA) in 2016.

57 Responsibility for regulating the energy market rests with Ofgem and the UK Government, both of which also share statutory responsibility for the principal obligation of protecting the interests of consumers. To comply with the latter, Ofgem and the UK Government are empowered to promote and facilitate effective competition.[106] Ofgem is also able to regulate the gas and electricity industries through comprehensive licensing systems and the use of Standard Licensing Conditions which require compliance with industry codes.[107] Ofgem can also investigate suspected anti-competitive activity impacting on energy affordability and take action accordingly.

58 Following a reference by Ofgem in 2014, the CMA conducted a major investigation into the supply and acquisition of gas and electricity in the GB system. The Authority's report, which was published in 2016, found that the sector had generally performed well in relation to security of supply, emissions reduction and the deployment of renewables. It also, however, flagged up a number of issues in relation to domestic price increases and standards of service for domestic customers.[108] Most strikingly, the CMA highlighted that in the period 2012–2015 domestic customers of the Big Six paid on average £1.4bn per year more than they would have done in a well-functioning market.[109] In this context, the CMA found that the structure and governance of the regulatory framework was such that it increased the risk of policies being developed which are contrary to customers' interests.[110]

59 A number of regulatory issues were identified by the CMA. It was concerned to find that Ofgem had argued that its duty to facilitate competition had been downrated and that it was a constraint on its ability to pursue competition-based policies.[111] The CMA felt that the division of shared responsibility between Ofgem and the UK Government was such that there was the risk that Ofgem could be perceived as being insufficiently independent.[112] The report also highlighted a lack of transparency in a number of areas,[113] ineffective communication and a lack of relevant financial reporting by energy companies on costs, profits and profitability.[114] These factors resulted in an adverse effect on competition.[115]

105 I.e. British Gas, EDF Energy, E.ON, Npower, Scottish Power, and SSE.
106 See the Gas Act 1986, s. 4AA; and the Electricity Act 1989, s. 3A.
107 See the Gas Act 1986, ss. 5–8A; and the Electricity Act 1989, ss. 4–10.
108 See Competition and Markets Authority, 2016, Energy market investigation, Op. Cit., pp. 1–2 and 5–6.
109 Competition and Markets Authority, 24 June 2016, *Modernising the Energy Markets*, para. 28, available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/531204/overview-modernising-the-energy-market.pdf
110 See generally Competition and Markets Authority, 2016, Energy market investigation, Op. Cit., pp.70–79.
111 Ibid, pp. 70–71.
112 Ibid, p. 71.
113 Ibid, p. 72.
114 Ibid, pp. 72–73.
115 Ibid.

60 The CMA also identified significant deficiencies in Ofgem's ability to direct and influence the development and implementation of industry codes, which were viewed as being essentially a matter for industry self-regulation.[116]

61 In order to address the flaws in the governance structure, the CMA made a number of recommendations, which amounted to a "reset" of the regulatory framework. Its objective was to facilitate decisions which are "robust, efficient and timely, and driven by a concern for the interests of… customers."[117]

62 It is, however, important to note that the recommendations have only been implemented in part. While Ofgem has taken major steps to improve the quality of financial reporting, and has undertaken to comment publicly on relevant government policies, the response of BEIS has been less proactive.[118] It qualified its support for the CMA's desire to see more clarity on the interaction between government and Ofgem, arguing that producing detailed joint statements was not always the correct approach.[119] It also disagreed with the CMA's recommendations for legislation to revise the duties of both Ofgem and the Government regarding competition, and the need for Ofgem to publish opinions on Government policy.[120]

63 The reluctance of BEIS to act on the CMA's recommendations is perhaps not surprising, given that they could limit its freedom to manoeuvre and potentially lead to Ofgem publicly opposing government policy. That said, the position is a matter for concern. Acting in the public interest, the CMA made recommendations to improve the design and governance of the regulatory system. BEIS's reluctance to adopt them in full has the potential to perpetuate the lack of robustness, independence and transparency in regulatory decision making identified by the CMA, which may in turn increase the risk of future policy decisions being made which impact adversely on competition, customers and affordable energy.

64 The Scottish Government has, however, used its devolved remit in fuel poverty initiatives and community development to attempt to intervene on behalf of Scottish consumers. It is supporting schemes to promote impartial tariff switching and financial health checks to address the so-called poverty premium by helping people switch to cheaper energy tariffs.[121]

65 The Scottish Government is also in the process of establishing a publicly owned and not-for-profit energy company by 2021. It is intended that this company will have the objective of helping the growth of community energy projects. It is also envisaged that it will sell energy to Scottish consumers at as low a price as possible and offer people greater choice.[122] Whether such a policy can succeed in its stated goals is still unclear, with potential issues arising from EU State Aid rules. A Strategic Outline Case, commissioned by the Scottish Government and undertaken by the consultancy EY, concluded that there were significant challenges to success in a "highly innovative, competitive and evolving energy retail market."[123]

116 Ibid, pp. 73 – 74.

117 Ibid, p. 78.

118 See BEIS, February 2018, *Government Response to the Competition and Markets Authority Energy Market Investigation*, available at: https://www.gov.uk/government/publications/cma-energy-market-investigation-government-response .

119 Ibid.

120 Ibid.

121 Scottish Government, 2017, *Scottish Energy Strategy*, Op. Cit., p.37.

122 Ibid, p. 38. For further information, see also Scottish Government, Public Energy Company, at https://www2.gov.scot/Topics/Business-Industry/Energy/POEC

123 Scottish Government, Publicly Owned Energy Company: Strategic Outline Case (SOC), 29 March 2018, available at: https://www.gov.scot/publications/public-energy-company-strategic-outline-case/

Social Acceptability and Economic Wellbeing

66 Until recently, the challenge of developing successful energy policy was often framed around an energy trilemma; with the key aspects considered to be lowering carbon emissions, energy security and affordability. As discussed in Chapter 1, however, more recent discourse has seen social acceptability and economic wellbeing included as an important consideration. Social acceptability will depend on differing attitudes and values associated with the three points of the trilemma, *and* impacts of policy actions on other areas and outcomes not captured in the trilemma framing.

67 In practice, this puts a further restriction on policy development of ensuring that energy policy must be seen as ethical and fair by the general public. In particular, the Paris Agreement brings consideration of the importance of jobs, income and economic wellbeing to current populations in achieving energy and climate policy targets. Inherent in achieving this, is finding a way in which the move towards a low-carbon energy future does not disadvantage certain communities and, in fact, leads to the development of a fairer society.

68 To this end, the Scottish Government's Just Transition Commission[124] was launched with the task of advising on how Scotland can transition from an economy largely based on fossil fuels and maximise any economic and societal opportunities that might be available from decarbonisation in a way that is regarded as fair and just by Scottish citizens and stakeholder groups and minimises the adverse impacts of this to the greatest extent possible.

69 This Commission, within a two-year period, is tasked with providing recommendations to Scottish Ministers on how to maximise the opportunities of moving towards a low-carbon economy, build on Scotland's strengths, and understand and mitigate risks in relation to regional cohesion, equalities, poverty and a sustainable and inclusive labour market.

70 These recommendations must be consistent with the Just Transition principles[125] of successfully transitioning to environmentally and socially sustainable jobs, creating opportunities to develop sustainable economic approaches which ameliorate inequality and fuel poverty, and create fair and high value work in a manner which does not negatively affect current workers.[126]

71 The Commission has received a level of criticism, however, with some unions representing energy industry workers expressing concerns that, while well intentioned, the Commission's remit does not give adequate weight to Scotland's current and long-term energy needs or the views of workers in the sector. There is an argument that the tensions between social acceptability and reducing carbon emissions cannot truly be resolved. In this context, the concern is that the Commission provides politicians with a vehicle to delay having an honest conversation with the public about the realities of the move towards a low-carbon economy.

72 The convening of the Commission is a welcome step, as is the decision of the Scottish Parliament to consider providing it with a statutory footing. Of most importance, however, will be the manner in and extent to which the Scottish Government implements its eventual recommendations.

73 The UK Government has, thus far, been less active in looking to tackle the issue of social acceptability. While the Clean Growth Strategy stresses a desire to cut carbon emissions, grow the economy, ensure energy is affordable and create "good jobs",[127] a need for a fair transition or reference to the Just Transition principles was not present.

124 Scottish Government Website, Just Transition Commission, available at: https://www.gov.scot/groups/just-transition-commission/

125 International Labour Organisation, 2015, *Guidelines for a just transition towards environmentally sustainable economies and societies for all*, available at: http://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_432859.pdf

126 Scottish Government Website, Just Transition Commission, available at: https://www.gov.scot/groups/just-transition-commission/

127 HM Government, October 2017, *The Clean Growth Strategy*, p5, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700496/clean-growth-strategy-correction-april-2018.pdf

Key Points

- Significant progress has been achieved by the energy governance system for Scotland over the last decade, including the introduction of world leading climate change legislation.
- Scotland's energy system is entering a challenging period of transition as the policy focus shifts towards the difficult task of decarbonising heat and transport, notwithstanding that difficult issues remain for electricity generation, and the oil and gas sectors.
- Energy governance is highly complex, and while there have been significant successes, progress has been hampered by a systemic lack of transparency; weak planning, monitoring and implementation; and problems with delivering cost-effectiveness and protecting consumers' interests.
- A high level of sustained political cooperation between the Scottish and UK Governments is necessary to maximise the effectiveness of the governance structure and to achieve common objectives. The UK Government retains control of the main levers for energy governance, and so key aspects of the Scottish Government's strategy can only be realised in full with UK Government agreement.
- The energy system must be subject to a continuous process of scrutiny and reform in order to ensure effective governance and regulation. Currently, there is no one official body responsible for the independent, continuous and whole system review of all aspects of energy policy and governance.

Chapter Three

Where we Are

Introduction

1 In order to properly assess the options available to Scotland, it is important to consider the landscape in which we currently find ourselves and understand how we reached this point. All policy decisions that will be made, and the impacts of these decisions, are inherently tied to influencing this landscape in a positive direction. Context on which areas will be the most challenging to tackle, or in which sectors significant progress has, or has not, been made is vital to providing a robust platform for informed debate on Scotland's energy future.

2 The most recent statistics available provide information on Scotland's energy landscape for the years up to, and occasionally including, 2017. While this provides an illustration of where we were during this period, significant changes have occurred since; for example, the closure of Scotland's sole remaining coal-fired power station in 2016 means that statistics on the electricity generation mix and types of fuels imported will have changed markedly. This chapter serves to show the energy landscape that existed over the past several years and how it reached this point. All information relates specifically to Scotland, unless otherwise stated and uses the most recent statistics available at the time of writing.[128]

3 Also included in this chapter is some historical information on UK energy consumption, generation and resulting emissions to provide greater context on how the current energy landscape was formed over the longer term. This information relates to the United Kingdom as a whole, due to the difficulty in finding historical data for the individual countries of the UK. Information is also given on the world energy landscape to provide background on the wider global situation in which Scotland operates.

4 This Chapter serves to provide some factual context in which decisions on Scotland's energy future can be made.

Historical UK Figures

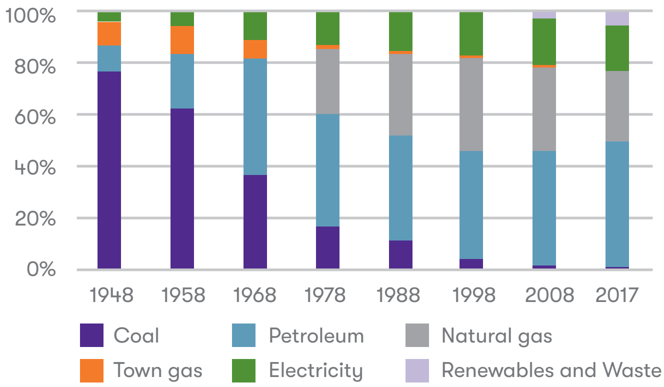
5 Historically, the UK has been reliant on the use of fossil fuels to meet its energy needs. Almost 80% of UK energy consumption in 1948 was coal. Energy generation from coal has decreased markedly over the decades, falling to just over a third by 1968, a tenth by 1998, and to under 1% of consumption by 2017. In this same period, the use of both petroleum and natural gas has increased significantly from 10% and 0% (9.5% for town gas) to around 48% and 29%, respectively.

6 Historical transitions from coal to oil, gas and nuclear represent a long-term trend of increasing energy density and increasing carbon intensity, although these transitions have generally been slow.

128 Please note carefully the year given. In endeavouring to provide the most recent available data on the landscape, the date of the statistics differs.

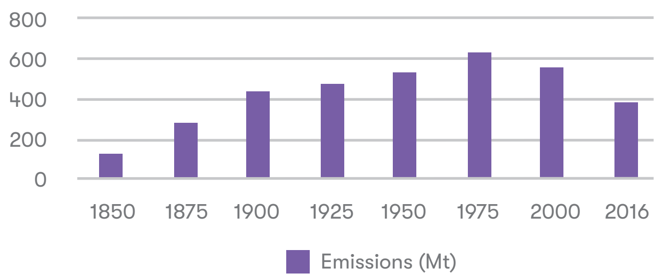
7 As a result of the UK's leading role in the Industrial Revolution, between 1750 and the end of the 18th Century it accounted for almost all global carbon dioxide emissions. This figure did not fall to below 50% until the mid-19th Century. The United States overtook the UK as the biggest emitter in the late-19th Century, with China consistently producing greater annual emissions than the UK by the 1970s. As of 2016, the US and China are the two countries with the highest CO_2 emissions.[129]

Final energy consumption, UK (1948 – 2017)



8 Despite the UK's share of global CO_2 emissions falling dramatically since the 19th century, its actual total emissions increased steadily between 1850 and the 1970s. Since the end of the 1970s emissions have consistently fallen, with 2016 levels comparable to those seen in the 1890s.[130]

UK CO_2 emissions (1850 – 2016)



Conventional Oil and Gas Exploration

9 Until the early 20th Century, oil played a limited role in the energy system. The advent of the motor car, conversion of the naval fleet and initiation of air travel contributed to a rise in demand for transportation. Oil also became more widely used for heating and power generation.

10 This need for petroleum and its products led to an onshore exploration campaign, where several petroleum provinces were discovered and developed. Exploration success saw the UK Continental Shelf transformed into a major oil and gas hub, the production of which has been encouraged by a stable political regime and favourable fiscal policy

11 Forty-two billion barrels of oil and its equivalents have been produced to date and it is now considered a mature basin in late life. This significant production led to the UK being self-sufficient until the early 2000s, since when production has been in steady decline and the country is now dependent on imports for over 50% of its oil and gas needs.

12 A relative lack of exploration success, smaller discoveries, spiralling costs and the oil price crash of 2014–16 all contributed to a downturn in the industry.

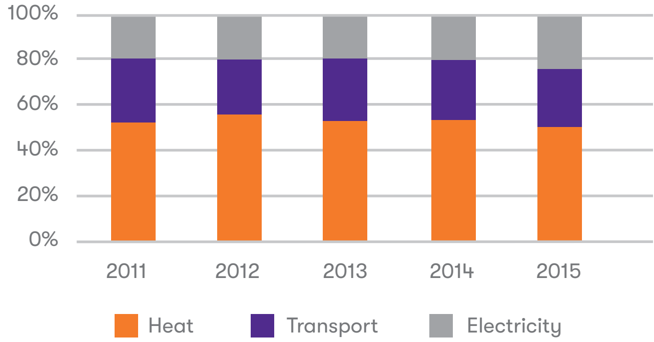
Consumption

13 Data for 2015, published by the Scottish Government in February 2018, show that over half of the energy consumed in Scotland (51%) was used for heating. The proportion share of consumption which can be accounted for by heat has decreased steadily, if marginally, from 55% when figures were first published for 2011.

129 Ritchie, H, Roser, M, Our World in Data, 2019, *CO_2 and other Greenhouse Gas Emissions*, available at: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

130 Evans, S, Carbon Brief Website, 6 March 2017, *Analysis: UK carbon emissions fell 6% in 2016 after record drop in coal use*, available at: https://www.carbonbrief.org/analysis-uk-cuts-carbon-record-coal-drop?utm_source=Daily+Carbon+Briefing&utm_campaign=39a3d041b1-cb_daily&utm_medium=email&utm_term=0_876aab4fd7-39a3d041b1-303476449

Total final energy consumption by sector and year (2011 – 2015)



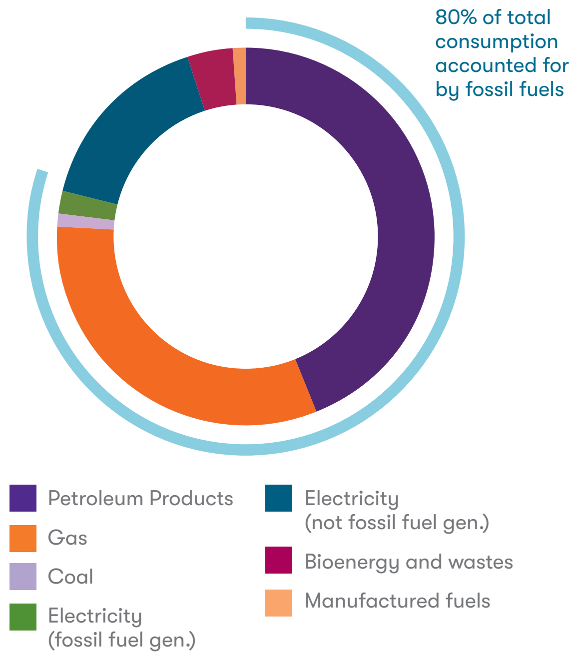
16 Across all sectors in 2015, petroleum products made up the largest proportion of energy consumption at 43.8%. This was followed by gas (32.1%), electricity (18.4%), bioenergy and wastes (3.9%), coal (1.1%), and manufactured fuels (0.7%).[133]

17 Taking account of the gas, coal and oil which combined to produce 13.2% of electricity generation, in 2015/16 around 80% of Scotland's energy consumption was produced by burning fossil fuels. Renewable sources supplied 17.8% of Scotland's total energy consumption in 2015.

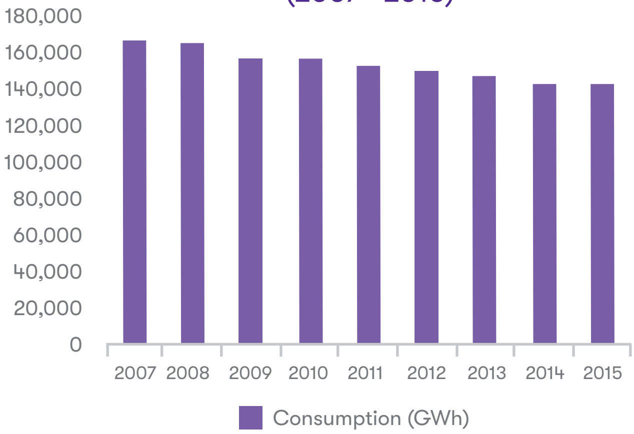
14 Transport constituted the next highest usage with 25%. The share of consumption attributable to transport has remained constant since 2011. The proportion of consumption which can be accounted for by electricity was 24% in 2015. This share has increased modestly from 21% in 2011.[131]

15 The total amount of energy used by Scotland has fallen fairly consistently since 2007.[132] Final consumption decreased by around 15% between 2007 and 2015 from 166.3 TWh to 141.8 TWh.

Final Energy Consumption by fuel type (2015)



Energy Consumption (2007 – 2015)



131 Scottish Government, 2012-2018, Energy in Scotland 2012 – 2018

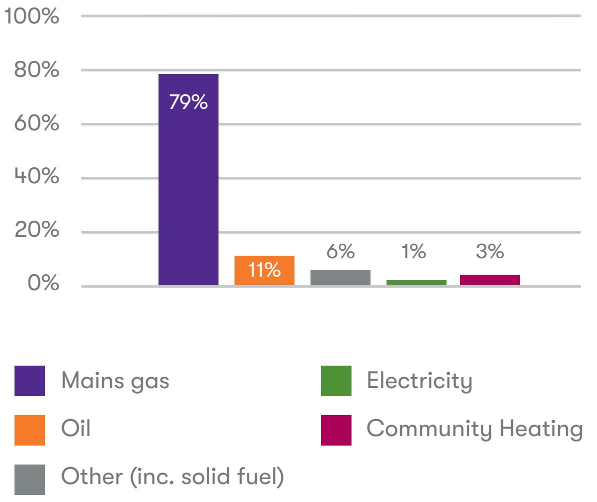
132 Government Website, 22 January 2013, 12 February 2019 (updated), *Total final energy consumption at regional and local authority level*, available at: https://www.gov.uk/government/statistical-data-sets/total-final-energy-consumption-at-regional-and-local-authority-level

133 Petroleum products + coal + gas + proportion of electricity generated using fossil fuels

Heating

18 Mains gas was the primary heating fuel for almost four-fifths of homes (79%) in Scotland in 2016. This share has remained steady since figures were first published on this for 2013. Electricity (11%) and oil (6%) accounted for all but 4% of the remaining homes.

Primary heating fuel for households (2016)

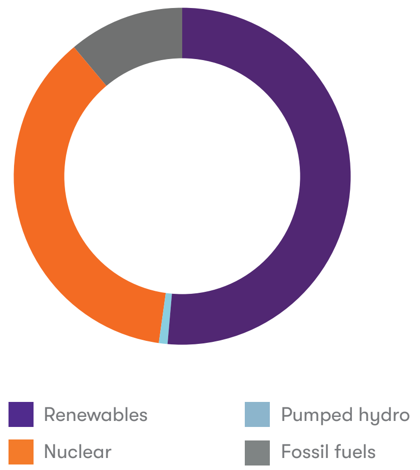


Electricity Generation

19 By some distance, the largest contributors to electricity generation in Scotland in 2017 were the renewables sector, which accounted for 51.7%, and nuclear energy, which accounted for 36.6%. Fossil fuels (10.5%) and pumped hydro (1.2%) made up the rest.

20 Scotland's reliance on coal to generate electricity has fallen markedly and consistently since 2010, when it was the source of around 30% of generation. Scotland's last coal-fired power station, Longannet, was closed in March 2016.

Electricity Generation Mix (2017)



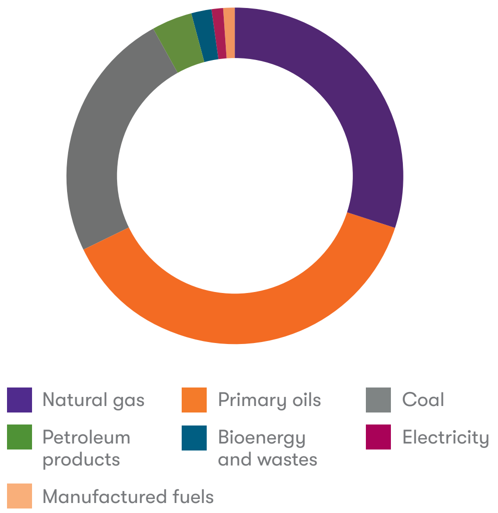
21 The reduction in total electricity production, due to the closure of coal-fired power stations means that, proportionally, nuclear energy has taken on a larger role, increasing from around 30% in 2010 to almost 43% in 2016. This figure fell again, however, to 36.6% in 2017. Scotland's two remaining nuclear power stations, Hunterston B in North Ayrshire and Torness in Dunbar, are scheduled to operate until 2023 and 2030 respectively. It should be noted, however, that both have already had their operating lives extended.

22 Renewable sources have likewise increased in prominence, more than doubling their share of electricity generation from around 20% in 2010 to nearly 51.7% in 2017.[134] This increase in proportion can be accounted for by a combination of increased total capacity and reduced total electricity generation.

134 Scottish Government,2012-2018, Energy in Scotland 2010 – 2018 and Scottish Government, *Energy Statistics Database*

Importing and Exporting

23 In 2017, the UK imported 151,891 ktoe of energy. For reference, final consumption of energy for that year was 149,139 ktoe. Of the imported energy, 38.5% was oil, 29.7% was natural gas, 24.2% was petroleum products, 3.8% was coal, 2.3% was bioenergy and wastes, 1% was electricity, and 0.6% was manufactured fuels.



24 In 2017, the UK exported 79,323 ktoe of energy.[135] Over 98% of this was accounted for by petroleum products, primary oils and natural gas. It should be noted that while oil and gas produced from the UK Continental Shelf is included in the figures for UK exports, the Scottish Government does use a different system of apportioning activities in the UKCS between Scotland and the rest of the UK.[136]

Pipelines and terminals

25 The UK has access to eight operational pipelines through which to import natural gas, four terminals at which to import LNG and two operational pipelines through which to export natural gas.[137]

Interconnectors

26 The UK has four interconnectors allowing import and export of electricity to and from Europe. These link the UK directly to France, the Netherlands and the Republic of Ireland. In 2017 the UK was a net importer through these interconnectors, importing a net total of 14.8TWh.[138]

Origin of imports

27 In 2017 the UK imported 523,755 GWh of natural gas. The largest share (75.1%) of this came by pipelines from Norway. Much smaller shares came by pipelines from Belgium (5.6%) and the Netherlands (4%). Liquid Natural Gas accounted for (15.3%) of total gas imports. The vast majority of LNG imported into the UK in 2017 came from Qatar (12% of total gas imports/84% of imported LNG). The other countries of origin for imported LNG in 2017 were Algeria, Dominican Republic, Nigeria, Norway, Peru, Russia, Trinidad and Tobago and the United States.

28 It should be noted that while the gas piped into the UK is reported as coming from the stated countries, this does not indicate where the gas actually originated, rather it gives information on which county the UK is linked by pipeline.[139] So, for example, in 2017 38.5% of gas imported into the European Union came from Russia.[140]

135 BEIS, July 2018, *Digest of UK Energy Statistics* 2018, p30
136 Fuller description of Scottish Government apportioning in Scottish Government, February 2018, *Energy in Scotland* 2018, pp117–118
137 BEIS, July 2018, *Digest of UK Energy Statistics* 2018
138 BEIS, July 2018, *Digest of UK Energy Statistics 2018*, p113
139 BEIS, July 2018, *Digest of UK Energy Statistics* 2018
140 European Commission website https://ec.europa.eu/eurostat/statistics-explained/index.php/EU_imports_of_energy_products_-_recent_developments#Main_suppliers_of_natural_gas_and_petroleum_oils_to_the_EU

Gas Storage

29 In 2017 the UK had nine gas storage facilities with a combined storage space of 1.14 billion m^3. All of the facilities are located in England, with Rough going through the process of closure at the time of writing.[141]

30 Few oil and gas fields exist in onshore parts of Scotland. Those that do, are small, have long been depleted and have since been abandoned, meaning there is little potential for onshore gas storage.

31 In contrast, neighbouring waters of the North Sea are replete with producing and depleted oil and gas fields, all of which could be candidates for gas storage. New opportunities will arise with time as producing fields move towards later life, abandonment and decommissioning.

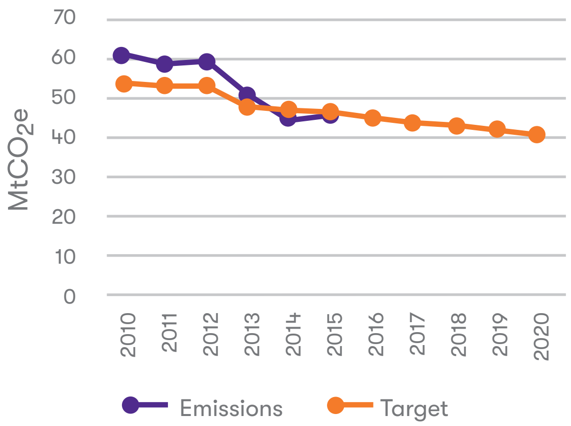
Carbon Emissions and Renewables Targets

32 Both the Scottish and UK governments accept the scientific consensus on climate change and have set, or agreed to, particular targets by which to reduce carbon emissions.

33 The Climate Change (Scotland) Act 2009 set the target for the Scottish Government of reducing emissions of greenhouse gases by at least 42% by 2020 and by 80% by 2050.[142, 143] The Scottish Government failed to meet its annual emissions reduction targets for the first three years following passage of the Act. It met the annual target for the first time in 2014 and again in 2015.[144] Emissions decreased by more than 25% between 2010 and 2015, from 60.7 million tonnes of carbon dioxide equivalent ($MtCO_2e$) to 45.5 $MtCO_2e$.

34 The Scottish Government's Energy Strategy sets the target of supplying the equivalent of 50% of the energy for Scotland's heat, transport and electricity consumption from renewable sources by 2030.

Carbon Emissions and Fixed Annual Reduction Targets (2010–2020)



141 BEIS, July 2018, *Digest of UK Energy Statistics* 2018

142 Compared to a 1990 baseline for emissions of carbon dioxide, methane and nitrous oxide, and a 1995 baseline for hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and nitrogen trifluoride.

143 Scottish Government Web Archive Website (a): https://www.gov.scot/Topics/Environment/climatechange/meetingemissionstargets

144 Scottish Government Web Archive Website (b): https://www.gov.scot/Topics/Environment/climatechange/meetingemissionstargets

Jobs and Economy

35 The energy growth sector[145] in Scotland employed 70,000 people in 2016, accounting for 2.7% of total employment. Of those employed in the sector, 52.9% were located in either Aberdeen City or Aberdeenshire local authority areas.[146]

36 Statistics for 2016 showing Gross Value Added to the Scottish economy by broad sector state that the sector including electricity, gas, steam and air conditioning supply accounted for over £4.5 billion, or 3.4%, of Scotland's GVA.[147]

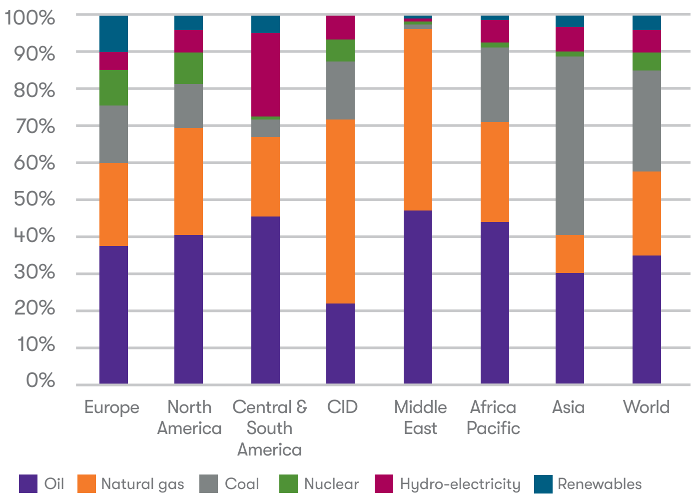
World Energy Trends

37 Total global energy consumption has increased every year since 2012, rising from 12,589 Mtoe to over 13,511 Mtoe in 2017; an increase of over 7%.

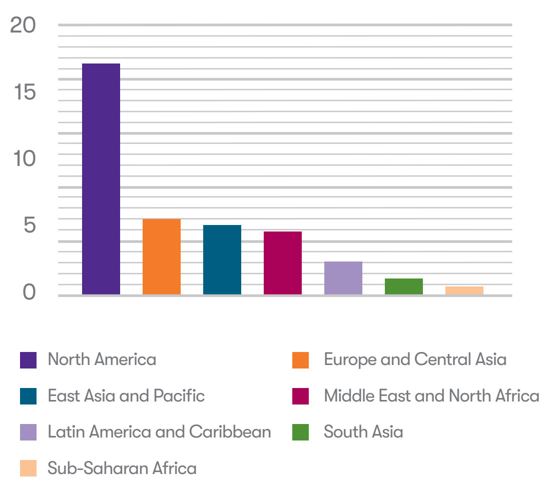
38 The roles that different types of fuels play in total consumption differs markedly by region. For example, coal accounts for almost half of consumption in Asia Pacific, but accounts for only less than 1% in the Middle East. Conversely, the Middle East relies upon natural gas and oil for over 98% of its consumption, whereas these two fuels only combine to account for around 40% in Asia Pacific.

39 World Bank figures for 2014 (which group regions slightly differently than above) show North America with by far the highest carbon emissions per head of any world region, at 16.4 metric tons of CO_2.[148]

Regional consumption, by fuel type (2017)



Per Capita Carbon Dioxide Emissions, by region (2014)



145 This does not include those working in supply chains – fuller definition can be found in Scottish Governemnt, 2018, *Energy in Scotland* 2018, p18

146 Scottish Government, 2018, *Energy in Scotland* 2018, p18

147 O'Connor, A, SPICe Briefing, 2018, *A Guide to Gross Value (GVA) in Scotland*, available at: https://sp-bpr-en-prod-cdnep.azureedge.net/published/2018/2/23/A-Guide-to-Gross-Value-Added--GVA--in-Scotland/SB%2018-15.pdf

148 World Bank website, *World Development Indicators: Energy dependency, efficiency and carbon dioxide emissions*, available at: http://wdi.worldbank.org/table/3.8

Key Points

- The UK has historically been reliant on fossil fuels to meet its energy needs and, through its leading role in the Industrial Revolution, was and remains a major contributor to global carbon emissions.
- The majority of Scotland's energy consumption is attributable to heating, with electricity and transport playing smaller roles.
- Energy consumption in Scotland is falling. However, despite over 89% of Scottish electricity being generated by low-carbon technologies, more than 80% of consumption is still attributable to the burning of fossil fuels, with renewables supplying 17.8%.
- The UK is a net importer of energy and has several options through which to import this energy. In the event of interruptions to energy imports, the UK has very limited storage capacity, especially gas storage.
- The Scottish Government has set targets for reducing carbon emissions, which have been met for the past two years. Further, more ambitious, goals have also been set.
- Total global energy consumption continues to increase, although the types of energy consumed, and the profile of this use, varies significantly by region.

Chapter Four

Understanding Trade-offs

Introduction

1 The form that Scotland's energy future takes will depend on a series of decisions made primarily by government, but also by industry, communities and individual members of the public. One of the few certainties in this debate is that Scotland will require energy.

2 What is less certain is how we produce this energy. Scotland has a wealth of options available, ranging from fossil fuels that have been in use for hundreds of years, to emerging technologies and energy sources that have yet to prove their merits. What cannot be escaped, however, is that the choices we make in deciding how we source and produce energy will have profound impacts on the environment, the economy, our behaviour and our standard of living. No silver bullet exists that will vastly reduce carbon emissions, have no environmental impact, and create jobs, all while remaining affordable and allowing the public the freedom to live their lives as they choose.

3 Difficult choices must be made, and these choices will inevitably have consequences. Heavy investment in one technology may mean another goes undeveloped. A choice that could dramatically reduce carbon emissions may also require significant behavioural change from the public and economic change in society. A decision that provides ample energy at a low cost could also result in irreparable damage to the environment, and hence to viability of life and the stability of societies.

4 This is to say that all the choices available to us require trade-offs. In reaching an informed decision on Scotland's energy future, it is imperative that the compromises that need to be made are understood, discussed and accepted. This chapter will provide a guide to the trade-offs by which this report will consider the options available to Scotland. Evidence submitted to the Inquiry, a wealth of statistical information and policy documents, and more directed meetings and conversations with stakeholders, have all formed the basis on which these trade-offs have been analysed. Where information is scarce or incomplete we have attempted to highlight this, although the expert judgement of the Inquiry Committee has also been used to make determinations where necessary.

5 Many of the criteria overlap or are interconnected, and so they have been grouped together into the four aspects of the energy quadrilemma, discussed in Chapter 1, to best illustrate how well they meet the potential needs of energy policy and where the most significant issues lie.

6 In providing information on the options, comparisons have been drawn on some criteria where considered appropriate. Caution should be exercised, however, when directly comparing technologies or when looking at international examples.

7 The options will be evaluated under the relevant following criteria:

Climate Change

- Global climate impact

Affordability

- Investment required
- Cost to the consumer
- Social issues
- Lifetime cost

Energy Security

- Ability to meet demand
- Security of supply
- Viability and timescale

Social Acceptability and Economic Wellbeing

- Economic opportunity
- Environmental and social justice
- Behaviour and acceptability

Climate Change

Global climate impact

8 The Royal Society of Edinburgh, and almost every organisation and individual who submitted evidence to the Inquiry, accepts the global scientific consensus on climate change. As discussed in Chapter 2, so do both the UK and Scottish governments, who have, respectively, set targets and policies to reduce carbon emissions.

9 As a signatory of the Paris Agreement, the UK has agreed to take domestic action in order to play a role in mitigating the impacts of global climate change. The Agreement ultimately aims to keep global temperature increases well below 2°C, with a target of keeping this increase to 1.5°C.[149] Research suggests that in order to have at least a 50% chance of meeting even the 2°C goal, globally, a third of oil reserves, half of gas reserves and over 80% of coal reserves will need to remain unused.[150]

10 While energy production and use accounts for the majority of global greenhouse gas emissions, it must be noted that a significant portion of emissions (around a quarter) are attributable to agriculture and land use.[151] In Scotland, this figure is 26.1%.[152] Reducing emissions from the energy sector is key to combating climate change, but it is not the only sector which must be transformed.

11 Similarly, Scotland's contribution to global emissions must be viewed in perspective. In 2016, Scottish greenhouse gas emissions were estimated to be 38.6 $MtCO_2e$,[153] out of global emissions amounting to 4,441 $MtCO_2e$,[154] making Scotland responsible for around 0.87% of global emissions. This is not to imply that Scotland's emissions do not need to be substantially reduced, but rather it must be acknowledged that action taken in Scotland must be as part of a global effort. Scotland's historic contribution to climate change, however, cannot be ignored. For large parts of the 18th and 19th centuries, carbon emissions from the UK were higher than the rest of the world combined. Showing global leadership in this area could therefore serve to encourage other, larger carbon emitters to take action.

12 As part of our analysis, each option will be considered as to whether it is likely to increase or decrease Scotland's carbon emissions. As Scotland, the UK and the UN have climate charge targets, does the option help or hinder in meeting these goals?

13 This criterion will also examine whether the option requires mass transportation or energy-intensive transformation or processing, which would add to carbon emissions. Many measurements of individual countries' carbon footprints include only direct domestic consumption and do not factor in fugitive emissions, leakages, the relocation of carbon-intensive industries abroad, or transport losses from importing fuels and goods across the globe. These must be taken into account for a fair assessment of global climate impact to be made.

Affordability

Investment required

14 Irrespective of which options or approaches are considered, all will require some level of public and/or private sector investment. The differing levels and timing of investment required, by whom and how they are paid for are less certain.

149 United Nations Climate Change Website, *What is the Paris agreement?*, available at: https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement

150 McGlade, C and Ekins, P, Nature Journal, 2015, *The Geographical Distribution of Fossil Fuels Unused When Limiting Global Warming to 2˚C*

151 United States Environmental Protection Agency, 13 April 2017 (last updated), *Global Greenhouse Gas Emissions Data*, available at: https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data#Sector

152 Scottish Government, 12 June 2018, *Scottish greenhouse gas emissions* 2016, available at: https://www.gov.scot/publications/scottish-greenhouse-gas-emissions-2016/pages/3/

153 Scottish Government Website: https://www.gov.scot/publications/scottish-greenhouse-gas-emissions-2016/

154 European Environment Agency, 19 December 2018, *Total greenhouse gas emission trends and projections*, available at: https://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-6/assessment-2

15 The type of investment required for different options and the timeframe over which investment will be required will also vary. Some approaches may require exceedingly high up-front costs, others may incur higher running costs. The level of up-front and running costs will also vary, dependent on when investment decisions are taken and when investment activity actually takes place, and who is involved, and in what way (for example, in terms of addressing and managing risk associated with large-scale investment in new areas).

16 It may also be a requirement of some policy options that investment be directed into developing skills that are lacking in the current workforce, in order to ensure we have the ability to develop, implement and effectively utilise the approach in question.

17 Such changes may require the education system to respond through new degree and postgraduate research and training initiatives to support the next generation of practitioners.

18 Similarly, options that require public engagement and/or participation, but with which the public are unfamiliar, will require appropriate investment in education, consultation, outreach and other means of bringing about significant change in behaviour and/or raising awareness.

Cost to the consumer

19 A further inevitability is that the public will need to pay for the development, production and use of the energy Scotland will need. This burden can be distributed in several ways, each of which will have merits and disadvantages. The costs can simply be passed directly onto consumers through bills, money could be raised through specific duties – such as on carbon use – or funding can be drawn from general taxation.

20 Chapter 2 gave a number of examples of how increased uptake of renewable generation or energy efficiency schemes have been funded using a variety of mechanisms.

21 Each option will be evaluated on the potential impact it could have on consumer bills or public taxation.

Social issues

22 Alleviating fuel poverty in Scotland is a priority for the Scottish Government. Despite this, in 2017 24.9% of Scottish households were considered to be in fuel poverty, with 7% considered to be in extreme fuel poverty.[155] The Fuel Poverty Strategy for Scotland,[156] published in June 2018, sets the target of no more than 5% of households being fuel poor by 2040. Each option will be assessed on its potential impact to alleviate or worsen fuel poverty in Scotland.

23 Also assessed will be the ability of an option to allow for greater community or individual involvement in the use of energy and its production. Can the approach examined only work exclusively on a large or small scale or is it adaptable?

24 Some options may more easily allow for public participation in decision making, such as where developments can take place or to what extent. Some may also provide community benefits to the areas in which they are stationed, such as new jobs, supply chain opportunities, improved infrastructure or a source of income. Conversely, certain approaches may mandate increased traffic, noise pollution or an influx of temporary workers.

155 Energy Action Scotland, *Scottish House Condition Survey*, available at: https://www.eas.org.uk/en/scottish-house-condition-survey_50534/

156 Scottish Government, June 2018, *Fuel Poverty Strategy for Scotland*, available at: https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2018/06/draft-fuel-poverty-scotland-2018/documents/00537470-pdf/00537470-pdf/govscot%3Adocument

Lifetime cost

25 Each option will be assessed on what the cost across the lifetime of the approach is likely to be. This will take account of running costs, the frequency with which replacement or renewal is necessary and over what period of time costs will be spread. An option with high initial costs may prove more cost-effective than one that initially appears cheaper if it has low running costs, less of a need for refurbishment, and a longer lifecycle. Some options may require decommissioning or oversight for centuries to ensure waste or dangerous materials are safely stored or recycled, a cost which will fall on future generations.

Energy Security

Ability to meet demand

26 Simply, what contribution could the option make towards producing the amount of energy Scotland requires to keep the lights on, make people comfortable in their homes and keep the economy running?

27 The purpose of this report is not to attempt to forecast or model what future demand will be in Scotland. Other organisations are better placed to undertake this sort of work. Rather, we have looked at existing data to provide an illustration of the likely range of demand Scotland may have in the coming decades. Against this we can broadly judge whether a particular option has the potential to play a small, medium or large role in Scotland's future demand for energy.

28 As many of the written responses we received allude to, the profile and totality of Scotland's energy demand over the next thirty years is highly dependent on the choices we make in the coming years. While we can make assumptions over the likely route of travel from the policies enacted at different levels of government – for example support for electrification of vehicles, targets to reduce carbon emissions – governments and policies change, and there are numerous examples of technologies and approaches which have been publicly championed, only later to be discarded. This uncertainty mandates that the range be broad and that focus is placed on the role each option may be able to play in the larger system.

29 To provide this broad illustration of what demand may look like in the future, below are outlines of work undertaken by National Grid at the UK level and the Scottish Government at the Scottish level.

30 Future Energy Scenarios, published by National Grid in July 2018, suggests four potential scenarios which may reflect the path the UK chooses to follow:

- Consumer evolution is a decentralised scenario with a less aggressive speed of decarbonisation. Under this scenario the UK Government's 2050 decarbonisation target would not be met.
- Steady progression is a centralised scenario with a less aggressive speed of decarbonisation. Under this scenario the UK Government's 2050 decarbonisation target would not be met.
- Community renewables is a decentralised scenario with a more aggressive speed of decarbonisation. Under this scenario the UK Government's 2050 decarbonisation target would be met.
- Two degrees is a centralised scenario with a more aggressive speed of decarbonisation. Under this scenario the UK Government's 2050 decarbonisation target would be met.[157]

31 As an illustration, if Scotland's electricity and gas demand followed the trend of the scenarios provided by National Grid for Britain as whole, Scotland's energy demands by 2050 would be somewhere around:

- 30 – 35.5 TWh for electricity
- 14.1 – 36.9 TWh for natural gas

157 National Grid, July 2018, *Future energy scenarios in five minutes*, p3, available at: http://fes.nationalgrid.com/media/1357/fes-2018-in-5-minutes-web-version.pdf

32 As part of the Scottish Government's Energy Strategy, two possible future scenarios for 2050 are posed:

- An electric future sees electricity generation account for around half of all energy delivered. Electricity demand has increased significantly to supply transport.
- A hydrogen future sees much of the demand currently met by natural gas transferred to hydrogen. This scenario assumes successful CCS development.[158]

33 Under the scenarios published by the Scottish Government, Scotland's energy demands by 2050 would be:

- 26–52 TWh for electricity
- 0–18 TWh for natural gas

34 The significant differences in the potential ranges above serve to highlight the difficulties both in forecasting future demand and forming policy based on these forecasts.

35 The ability of a particular option to meet demand, however, is not solely judged on the contribution it can make to total demand. Equally important is aptitude and responsiveness to meeting the varying peaks and troughs of demand which are present both during different times of the day and during different seasons of the year. For example, in the three-year period from January 2014 to January 2017 daily electricity demand in Scotland did not fall below 50 GWh or rise much above 100 GWh, while gas demand fell to almost 50 GWh during some summers and rose to around 340 GWh during some winters. Whether an option can be used for electricity generation, space heating or transport (or all the above) and the flexibility it provides to meet fluctuating demand, will also be considered.

Security of supply

36 There are both technological and international relations implications as to how we source energy. Imperative to a well-functioning energy system is a strong level of confidence that energy supply will continuously be able to meet demand, that infrastructure can be relied upon to deliver that supply, and that the overall system is resilient enough to handle issues that may arise, for example increases in fuel prices or geopolitical turmoil.[159]

37 As discussed in Chapter 2, Scotland is part of a GB electricity network, and European and global energy markets. The idea of energy 'self-sufficiency' may appear tempting, but is, arguably, an increasingly dated concept. Scotland is connected to the rest of Great Britain for electricity which, as a whole, shares interconnectors with the Netherlands, France and the Republic of Ireland.

38 Natural gas is piped into the UK from Belgium, the Netherlands and Norway, while Liquid Natural Gas is brought in from Qatar. Even this, however, does not show the true picture of origin, as the gas entering the UK from pipelines in Western Europe may have been produced in Russia, Saudi Arabia or elsewhere.

39 To some extent, and for some options, security of supply can be bought – storage facilities constructed, new suppliers found, or additional domestic generation produced. Finding the right balance, however, between reliability and the cost of providing energy security is paramount.

40 Some options assessed will be able to be produced domestically, while some will leave us reliant on other countries.

41 Analysis of each option will factor in the level of reliability a certain technology or approach provides and its flexibility in ensuring supply under different circumstances.

158 Scottish Government, 2017, *Scottish Energy Strategy*, p29

159 The Scottish Parliament, Economy, Energy and Tourism Committee, 26 October 2015, *Plugged-in Switched-on Charged-up: Ensuring Scotland's Energy Security*, available at: http://www.parliament.scot/S4_EconomyEnergyandTourismCommittee/Reports/EETS042015R08Rev2.pdf

Viability and timescale

42 Paramount to whether Scotland may wish to pursue a particular option as part of its energy future will be whether the approach is viable and on what timescale it can be developed. Some options may theoretically solve all of our problems and provide plentiful, cheap and carbon-free energy, but are so far off or require such significant leaps forward in technological advancement that they offer little in the here and now. Others may have severe limitations, but be established technologies and able to offer a much-needed stop gap until other options mature.

43 Inherent in this critique will be factors surrounding the particular options assessed. Does Scotland have the skills base needed or would we require a significant period of time to educate or re-skill? Does the necessary infrastructure exist, can existing infrastructure be adapted to suit the new need or would it need to be constructed from scratch?

44 Some options may also be entirely reliant on other technologies being developed; for example, an approach that ticks numerous boxes when combined with effective carbon capture and storage or an as-yet-undeveloped type of battery may be entirely redundant without these developments.

45 The report will consider how close each option is to functioning as we would need it to, how long it might take to develop and to what extent the skills, infrastructure and complementary technologies it might rely on, are likely to be available.

Social Acceptability and Economic Wellbeing

Economic opportunity

46 The continuation or development of certain options may bring financial benefits through the creation of quality/relatively high-value jobs – both directly in evolving and emerging industries and indirectly through Scottish supply chains to support them.

47 While some approaches may be highly successful at reducing carbon emissions, or providing a high level of security of supply, it is important that we also analyse what positive or negative impacts on workers, employment and communities may result from embracing these choices. Would particular options create, expand or sustain the continued role and presence of existing industries in Scotland? New industries may work alongside existing ones, but if they are likely to supplant them, are the net jobs resulting sufficiently plentiful and of a high enough quality to provide employment, comparable income and work security, as compared to those industries being displaced?

48 Whether investment in particular options would likely result in incomes and wealth remaining within or leaving the Scottish and UK economies is an important consideration. Certain industries may develop new skills or ingrain existing skills in the Scottish workforce that could then provide the basis for income generation from export opportunities. Could investment unlock, sustain or potentially increase value generation in different parts of the economy?

Environmental and social justice

49 The report will consider the implications for the environment of each option assessed. Does the option produce waste, and if so, how can this be dealt with safely? Some approaches may require the use of specific geographic locations which could potentially damage the existing environment or displace communities or wildlife.

50 Some options will require, potentially rare, materials to be found, mined and processed. Consideration must be given to the scarcity and location of these materials, the way in which they will be accessed and the impact that mining them could have on the local environment and communities. Other options, particularly those required to be spread over a wide area, will mandate significant resources of other materials, such as steel, concrete and land.

51 The international dimension of exporting pollution or carbon emissions to producing countries from whom we import energy or resources will also be examined. An option that does not produce environmental damage, dangerous waste or high-carbon emissions in Scotland, may simply do so elsewhere.

52 Also assessed will be whether approaches are likely to adversely impact particular areas or communities, either in Scotland or abroad. Does a particular option allow for governance, regulation and, ultimately, accountability to lie with the Scottish or UK governments? Some approaches will ensure that the safety of workers involved and environmental standards required are within our gift, while others may necessitate this responsibility lying with other countries.

53 Each option will be assessed on the level to which it can be considered environmentally and socially responsible.

Behaviour and acceptability

54 The potential success or failure of any option or approach will likely rely on how acceptable the public consider it to be and the extent to which people will be required to change the way they currently live their lives. There is seldom a single public consensus on any matter and so attitudes are likely to vary across different groups, with variables such as education level, social class and age all potentially playing a role. Perceptions can be changed and attitudes and behaviours altered, but doing so will almost certainly require targeted action and strong leadership.

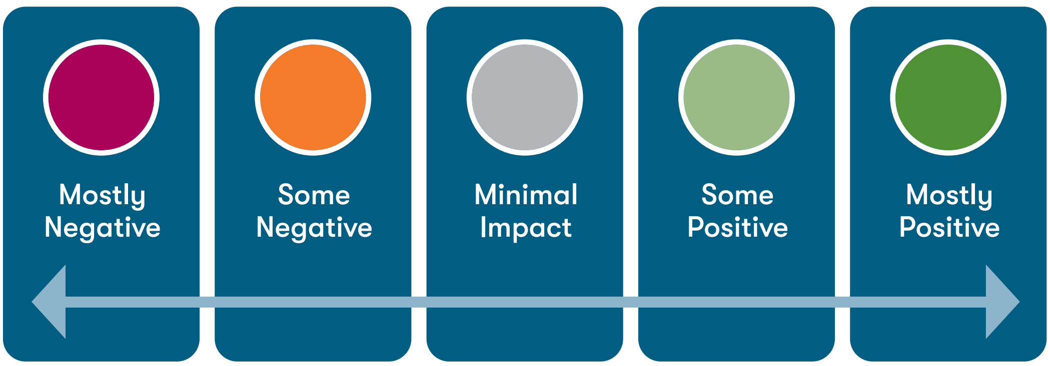
55 Would the public accept the need for and be willing to change the way in which they currently use energy if doing so significantly reduced carbon emissions or greatly reduced their household bills? Are negative public views on particular forms of energy so ingrained that the political cost of pursuing them would simply be too high? On the other hand, are there ways to incentivise changes in public behaviour that could see the four aspects of the energy quadrilemma being met?

56 The report will assess whether options require little, moderate or significant changes in public behaviour to succeed and how difficult it might be to bring about these changes.

57 Also considered will be in which groups such changes would have to occur, what the behavioural changes would seek to achieve, and whether they would genuinely prove effective.

Summary Matrix

59 To provide the reader with an easy illustration of the areas in which the Inquiry considers there to be the most significant issues, each option will include an image of the energy quadrilemma with the different aspects ranked on the scale below.

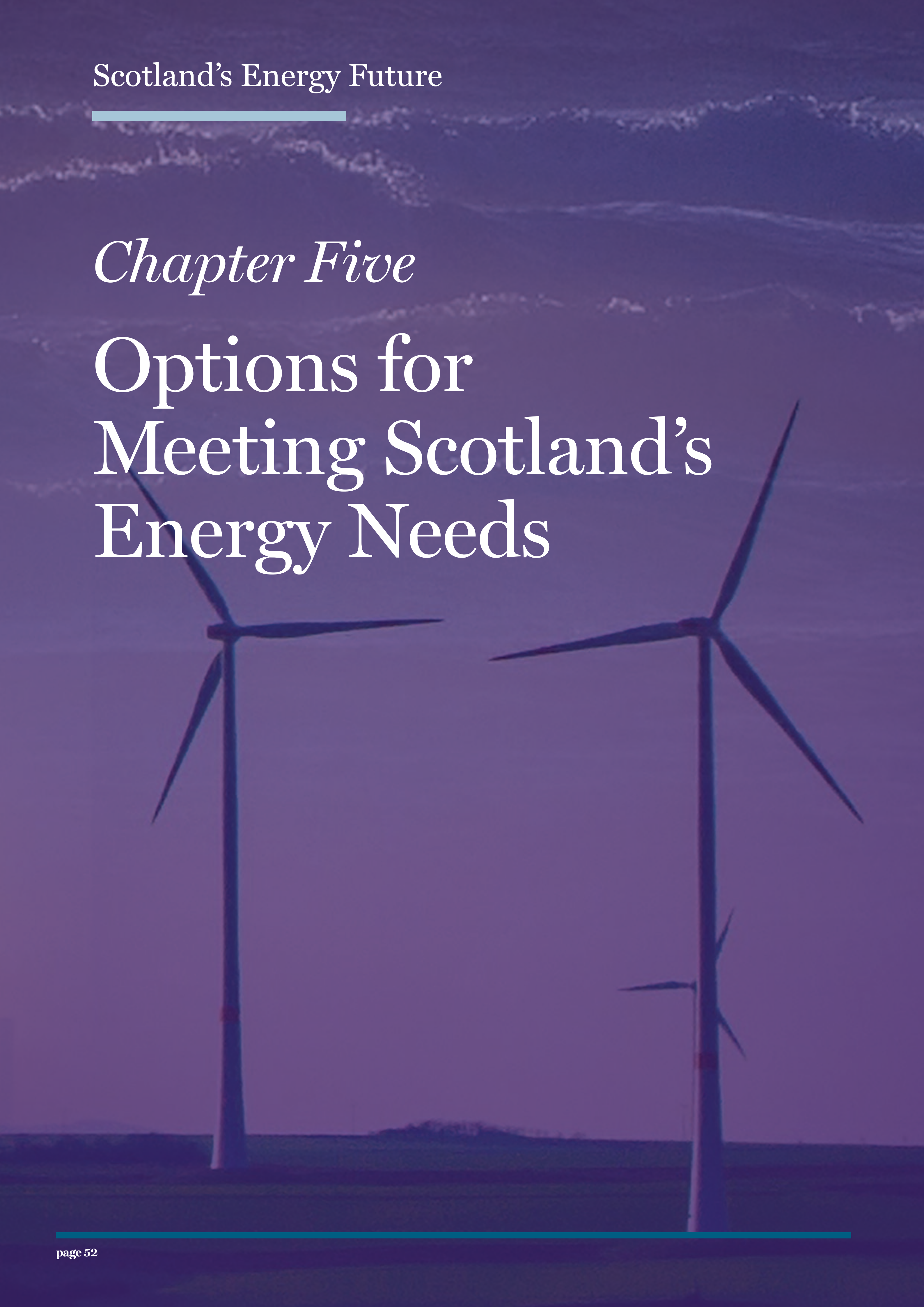


Key Points

- Future Scottish energy policy will rely on various decisions made by a number of actors, including government, industry, communities and individual members of the public.
- Under all circumstances, Scotland will require energy. Difficult choices, which will inevitably have consequences, must be made.
- All of the choices available to Scotland require trade-offs. In reaching an informed decision on Scotland's energy future, it is imperative that the compromises that need to be made are understood, discussed and accepted.

Chapter Five

Options for Meeting Scotland's Energy Needs



The following options are not listed in order of merit. They represent a range of sources of energy generation and other ways of meeting Scotland's energy needs. Some are more advanced than others and may provide a greater or lesser contribution to meeting demand.

Carbon Capture and Storage

1 Carbon capture and storage (CCS)[160] technology would allow the capture of carbon emissions produced through the use of fossil fuels in order to prevent these emissions from entering the atmosphere.

2 A functioning, industrial-scale CCS industry in Scotland could, theoretically, allow coal-, oil- and gas-fuelled power plants to continue producing electricity without adversely impacting the climate. Fossil fuels, however, would still be required to meet demand.

Climate change

3 Carbon capture and storage technology could play an important role in reducing carbon emissions by capturing the carbon at source and storing it. It could also assist in the decarbonisation of the energy sector by providing the supply needed to facilitate the electrification of transport and heating. Forecasts undertaken by the International Energy Agency suggest that CCS could contribute to reducing carbon dioxide emissions by 12.3% by 2060.[161]

Affordability

4 Developing a functioning CCS industry would, however, require significant investment. The UK Government initially, through its 2012 CCS Roadmap,[162] committed to launching a CCS commercialisation programme with £1 billion of capital support. This funding was withdrawn in 2015, leading to proposed projects in Peterhead and Yorkshire being cancelled.[163] The UK and Scottish Governments, along with industry, have provided a smaller amount of match funding of the European Commission-funded Acorn project centred on the St Fergus Terminal north of Aberdeen.[164]

5 The funding needed to develop the industry to the necessary scale would be far greater. The Energy Technologies Institute (ETI) in a 2015 report found that the capital investment required to deploy CCS with around 10GW of capacity would be between £21 billion and £31 billion.[165] The estimated combined capacity of the UK's existing power stations is around 90 GW.[166]

6 The high cost of carbon capture and storage to the consumer was cited by the then Prime Minister, David Cameron, as an explanation for why support for the industry was withdrawn by the UK Government. The Prime Minister told a Commons Select Committee that investment per megawatt-hour was significantly higher than for other low-carbon alternatives, such as nuclear or onshore wind, and that the additional cost would have gone *"on bill payers' bills."*[167]

7 Conversely, a significant cost to the consumer of delaying development of CCS has also been suggested. The Energy Technologies Institute estimates that by 2050, additional costs above the best achievable cost for reducing carbon emissions would be between £1 billion and £2 billion per year without CCS.[168]

160 Also known as carbon capture, usage and storage (CCUS)

161 International Energy Agency, 6 June 2017, *Energy Technology Perspectives* 2017, available at: https://www.iea.org/etp2017/summary/

162 Department of Energy and Climate Change, April 2012, *CCS Roadmap: Supporting deployment of Carbon Capture and Storage in the UK*, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/48317/4899-the-ccs-roadmap.pdf

163 Parliament, House of Commons Library, 23 January 2017, *UK decarbonisation and carbon capture and storage*, available at: https://researchbriefings.parliament.uk/ResearchBriefing/Summary/CDP-2017-0023

164 BBC News, November 2018, *UK's first carbon capture and storage project 'operational by mid 2020s'*, available at: https://www.bbc.co.uk/news/uk-scotland-scotland-business-46358715

165 Energy Technologies Institute, 2015 (a), Carbon capture and storage *Building the UK carbon capture and storage sector by 2030 – Scenarios and Actions*, available at: https://s3-eu-west-1.amazonaws.com/assets.eti.co.uk/legacyUploads/2015/03/CCS-Building-the-UK-carbon-capture-and-storage-sector-by-2013.pdf

166 EDF website, *Energy in the UK: Overview*, available at: https://www.edfenergy.com/future-energy/uk-energy

167 Liaison Committee HC 712, 12 January 2016, Oral evidence: Evidence from the Prime Minister, available at: http://data.parliament.uk/WrittenEvidence/CommitteeEvidence.svc/EvidenceDocument/liaison/evidence-from-the-prime-minister-12-january-2016/oral/26761.htm

168 Energy Technologies Institute, 2015, Dr David Clarke letter to Angus McNeil MP, available at: https://www.parliament.uk/documents/commons-committees/energy-and-climate-change/ETI-letter-to-Chair-on-Future-of-CCS.pdf

Energy security

8 Depleted oil and gas fields and saline aquifers on the UK Continental Shelf offer CCS opportunities. They are not without their challenges, however, and it is important that their seal integrity (i.e., their ability not to leak) is stress-tested and proven for each potential field before use, although certain statutory requirements for leakage monitoring which prove expensive can affect economic viability. Only those fields that currently contain carbon dioxide provide proof that CO_2 can be contained in natural subsurface structures over geological timescales for storage.[169] It will also be important to evaluate whether fault reactivation and earthquakes could be induced by injection.

9 Current and recent proposals for carbon storage in offshore waters have largely been driven by field availability as depleted fields come up for decommissioning (e.g., Goldeneye and Atlantic in the Moray Firth and Hamilton in the East Irish Sea, none of which house carbon dioxide) rather than any proposed field being the most likely field to provide a robust trap. Given that none of these examples house CO_2, the question to be addressed is: Did they once contain carbon dioxide, which has since leaked, or if they were to be injected with CO_2 can it be shown that they will retain it?

10 Given that there are no onshore oil and gas fields currently in production in Scotland, their small size, the fact that they are no longer producing and the public opposition that might be expected, it seems unrealistic that such sites will form part of any CCS future.

11 In addition to the geological challenge of CCS, there is a considerable engineering challenge, since carbon dioxide requires chrome plated pipes because of its highly corrosive properties. This means that most existing infrastructure cannot simply be reverse engineered and converted from taking oil and gas to transporting carbon dioxide. To do so would demand new facilities and incur considerable expense. Some infrastructure, however, does exist, which was built using chrome pipes.

12 One option that the oil industry may consider deploying is the use of carbon dioxide as a drive for enhanced oil recovery (EOR), as this is something that has the potential to realise additional oil reserves whilst sequestering carbon in fields reaching the end of their natural field life. However, the leakage rate of carbon dioxide from EOR projects would still need to be assessed if it is to contribute to meeting long-term carbon reduction targets.

13 Assuming the challenge of appropriate offshore site selection and engineering can be addressed, the potential ability of CCS to reduce emissions may be of particular importance, given continued Scottish and, to a greater extent, global reliance on fossil fuels. Over 80% of Scotland's energy consumption is still accounted for by fossil fuels, with this figure rising to over 85% globally. Furthermore, while Scotland has decreased the amount of coal (the fossil fuel with the highest carbon emissions) as a proportion of its consumption to around 1%, the proportion of global consumption accounted for by coal is almost 28%. This figure is even higher for specific regions and countries, with coal accounting for over 48% of consumption in the Asia Pacific region and over 60% in China specifically.[170]

14 In its Clean Growth Strategy, the UK Government committed to investing up to £100 million to bring down the cost of CCS technology. The ETI report estimated that by 2030, with the correct support and investment, a 10GW CCS sector with the capacity to capture and store around 50 million tonnes of carbon dioxide emissions per year is feasible.[171]

169 The Conversation Website, John Underhill, 2017, *Storing carbon under the North Sea: are wrong sites being looked at*, available at: http://theconversation.com/storing-carbon-under-the-north-sea-are-wrong-sites-being-looked-at-88337

170 BP, 2018, *BP Statistical Review of World Energy*, p9

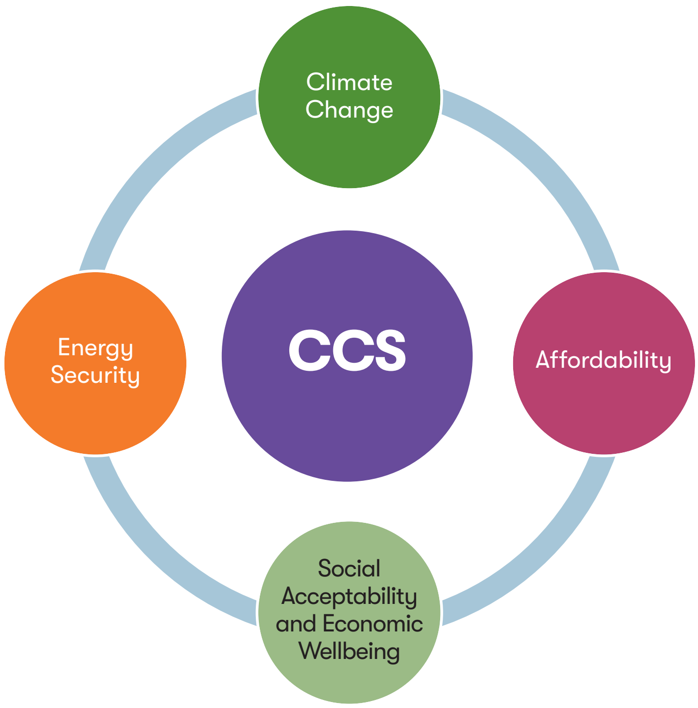
171 Energy Technologies Institute, 2015 (b), *Carbon capture and storage Building the UK carbon capture and storage sector by 2030 – Scenarios and Actions*, available at: https://s3-eu-west-1.amazonaws.com/assets.eti.co.uk/legacyUploads/2015/03/CCS-Building-the-UK-carbon-capture-and-storage-sector-by-2013.pdf

Social acceptability and economic wellbeing

15 Development of a substantial CCS sector has the potential to create jobs throughout the supply chain. Furthermore, it could facilitate a renewal in the current oil and gas industry in Scotland, which would maintain a substantial number of workers with the prerequisite skills and infrastructure. A recent report by the International Public Policy Institute highlighted the potentially important role CCS could play in sustaining Scottish jobs both directly and indirectly linked to the oil and gas sector and industries related to it.[172] Successfully utilising CCS could also benefit energy intensive industries based in Scotland, such as petrochemicals at Grangemouth.

Key Points

- CCS could potentially facilitate the use of other fuels and technologies while limiting damage to the climate.
- It would require a very high level of continued investment.
- Many geological and technological challenges still exist though, and CCS may be some distance from being viable at scale.



172 Turner, K., Race, J., Oluwafisayo, A. and Low, R., 2018, *Making the Macroeconomic Case for Near Term Action on CCS in the UK? The Current State of Economy-wide Modelling Evidence*, available at: https://strathprints.strath.ac.uk/63554/8/Turner_etal_IPPI_2018_Making_the_macroeconomic_case_for_near_term_action_on_CCS_in_the_UK.pdf

District Heating

1 District heating (DH) uses an underground network of pipes carrying hot water from shared heat sources to clusters of buildings nearby. It is a mature technology already serving significant areas of European cities. Its economics and carbon-saving potential depend on density and diversity of heat demand, which means that it is particularly suited to urban areas, although it may also provide solutions for heat in some rural areas, by enabling use of particular local heat sources, such as biomass or geothermal.

Climate change

2 The development of low-carbon heating and hot water systems could help Scotland meet its commitment to reduce greenhouse gas emissions and support the commitments of the Paris Agreement. Energy used for space and water heating in Scotland comprises 53% of the total, much more significant than transport (25%) or electricity (22%). In households, heating and hot water comprise 87% of energy use.[173]

3 The majority of this heating comes from burning natural gas, making low-carbon heat a challenging policy area, as solutions are likely to require significant change, both social and technical, with considerable financial cost and uncertainty over shares of costs and benefits.

4 DH infrastructure is not tied to one particular heat source, and its value in a low-carbon system is based on this flexibility. By aggregating the heat (and sometimes the cooling) demands of multiple buildings, DH is able to make efficient use of any locally-available resources.[174] The network is especially suited to accessing larger-scale heat sources which are usually wasted. These include 'waste' heat produced by industrial and commercial processes, heat from large-scale water- or ground-source heat pumps; surplus electricity from intermittent renewables, and hydrogen.

Affordability

5 The total costs of low-carbon heat are likely to be higher than the current system.[175] Opportunities for low-carbon heat are expected to vary in different places, depending on existing infrastructures, resources, skills and building stock, with different cost implications. One means to address the issues of social justice that are likely to result would be to socialise the costs of transition, either through energy bills or general taxation. If energy bills are used, then impacts on low-income households would need to be mitigated.

6 In common with any new network infrastructure, DH has high upfront capital costs, although these are offset by long-term durability, and associated revenues from heat sales. Non-profit DH systems run by Aberdeen Heat and Power Ltd, for example, demonstrate effective solutions to fuel poverty and improved quality of life.[176]

Energy security

7 Despite the fact that district heating in the UK is small scale, supplying only around 2% of heat demand, various policy and future scenario models treat it as part of the low-carbon mix. Estimates of viable development up to 2050 vary, ranging from around 10 – 45% of heat demand.[177, 178, 179] In *Scotland's Energy Strategy*, irrespective of the chosen scenario, heat networks are envisaged as meeting around 10% of residential and service sector demand.

173 Scottish Government, 2018, *Energy in Scotland* 2018

174 Lund, H., Werner, S., Wiltshire, R., Svendsen, S., Thorsen, J., Hvelplund, F., Mathiesen, B., 2014, *4th Generation District Heating (4GDH): Integrating smart thermal grids into future sustainable energy systems* Energy 68, 1 – 11

175 Energy Research Partnership, 2017, *The Transition to Low-carbon Heat*, available at: http://erpuk.org/wp-content/uploads/2017/10/ERP_heat_transition-Oct-2017.pdf

176 Rao, L,. Chittum, A., King, M., Yoon, T., 2017, *Governance Models and Strategic Decision-Making Processes for Deploying Thermal Grids International Energy Agency Technology Collaboration Programme on District Heating and Cooling*, available at: https://www.districtenergy.org/viewdocument/governance-models-and-strategic-dec

177 Scottish Government, February 2018, *Energy in Scotland* 2018

178 Energy Technologies Institute, 2018, *District Heat Networks in the UK: Potential, Barriers and Opportunities*, available at: https://d2umxnkyjne36n.cloudfront.net/insightReports/District-Heat-Networks-in-the-UK-Final.pdf?mtime=20181105145836

179 DECC, 2013, *The Future of Heating: Meeting the Challenge*, available at: https://www.gov.uk/government/publications/the-future-of-heating-meeting-the-challenge

8 By providing thermal energy storage, and electricity demand side response from combined heat and power (CHP) engines, DH also contributes to energy system balancing, and to reducing the costs of electrification of heat, which are associated with mass take-up of individual heat pumps. Thermal storage through DH reduces the required investment in the electricity grid which would be necessary to serve winter heat demand peaks, but results in considerable redundancy during much of the year.[180]

9 DH could contribute to security of supply in Scotland. With powers over heat being devolved, the Scottish Government has identified planning low-carbon heat as a priority concern in Scotland's Energy Strategy. Forecasting predicts that by 2025, 67% of UK gas will be imported, creating exposure to geopolitical unknowns, globally fluctuating prices and uncertain supply. Development of DH could reduce such insecurities by accessing local 'waste' heat sources.

10 Small pilot schemes are already working to supply heat from coal mining areas to a housing estate in Rutherglen and a swimming pool in Stanley, County Durham. The Scottish Government's Geothermal Energy Challenge Fund is supporting studies at Fortissat, North Lanarkshire, Polkemmet in West Lothian and Grangemouth in Stirlingshire. In addition, a sedimentary aquifer project is being investigated at the site of an old paper mill at Guardbridge near St Andrews, a large-scale district heating network is serving a low-carbon development in Kilmarnock, and Scottish Borders Campus in Galashiels is utilising heat from wastewater networks for use in space and water heating.

11 Funded through the Department of Business, Energy & Industrial Strategy (BEIS), commissioned by the Natural Environment Research Council (NERC) and delivered by the British Geological Survey (BGS), the UK Geoenergy Observatories (UKGEOS) project will assess the feasibility of heat sources from abandoned mine workings. The Clyde Gateway lies above former coal mines in which the main seams occur at depths of up to 300m below the surface and at an ambient temperature of around 15°C. The site could test whether geothermal energy in abandoned mines offers an alternative source to gas-fired domestic heating that can be scaled up to provide a cheap, local alternative source of warmth to areas with some of the highest levels of fuel poverty in Scotland.

Social acceptability and economic wellbeing

12 An integral component of the Scottish Government's Energy Efficient Scotland route map are proposals to introduce a statutory power for local authorities, requiring development of comprehensive Local Heat and Energy Efficiency Strategies (LHEES), and implementation plans. LHEES potentially provide the opportunity for a more integrated strategic approach to energy efficiency and heat decarbonisation. Integrated analysis of supply and demand, of the type promised by LHEES proposals, is critical for cost-benefit appraisal of low-carbon heat options in different places. This is because reducing heat demand has significant implications for the preferred type and level of investment in low-carbon heat supply.[181, 182]

13 The capacity of local authorities and regional partnerships to develop and implement such plans will, however, depend on an effective national framework to coordinate with, and support, local planning, and on systematic development of technical skills and resources.[183]

180 Sansom, R., 2014, *Decarbonising low grade heat for a low carbon future*, availabel at: https://spiral.imperial.ac.uk/bitstream/10044/1/25503/1/Sansom-R-2015-PhD-Thesis.pdf

181 Eyre, N. and Baruah, P., 2015, *Uncertainties in future energy demand in UK residential heating*. Energy Policy.

182 MacLean K, Sansom, R., Watson, T., Gross, R., 2016, *Managing Heat System Decarbonisation: Comparing the impacts and costs of transitions in heat infrastructure*, available at: https://www.imperial.ac.uk/media/imperial-college/research-centres-and-groups/icept/Heat-infrastructure-paper.pdf

183 Webb, J., Tingey, M. & Hawkey, D., 2017, *What we know about local authority engagement in UK energy systems*, available at: http://www.ukerc.ac.uk/publications/what-we-know-about-local-authority-engagement-in-uk-energy-systems.html

14 In current proposals, LHEES would include local authority powers to designate 'heat zones' and 'DH concession areas'. Regulations are also proposed under a licensing system intended to reduce financial risk, ensure common performance standards and inter-connectivity of systems, and to protect customers from risks associated with network monopoly. A national licensing body, combining licensing and concessions, and with appropriate powers of enforcement, seems likely to be most effective.

15 Proposals also include the introduction of much-needed consumer protections. The structure of tariffs and the rationale for price setting will also need to be transparent, and standard accounting rules introduced. The proposals, however, lack a requirement on building owners to connect to the network and take the heat supply,[184] which could result in there being no effective means of securing financial returns from investments.

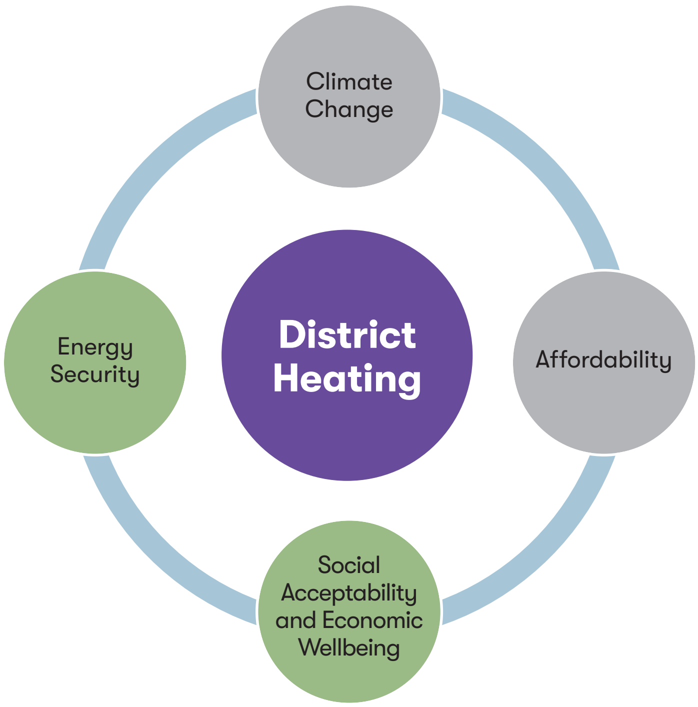
16 Proposed new arrangements are potentially insufficient to secure the economies of scale necessary for significant carbon savings. To enable DH to work at scale as a carbon-saving measure, the policy approach would need to change from focusing on the near-term business/financial case, where natural gas from the grid is the cost comparator, to focusing on the longer-term societal case for action, where comparators are other available low-carbon heat technologies.[185, 186]

17 Conservative analysis suggests that the likely extent of cost-effective DH is approximately 50% higher when a long-term planned approach is taken, in lieu of when the current financial approach is used.[187]

18 DH can be environmentally beneficial, as it reduces air and water pollution from industrial or commercial waste heat usually emitted to rivers, seas or the atmosphere.

Key Points

- District heating has high up-front costs that would require significant investment.
- Its use provides various social benefits, including the potential to play a role alleviating fuel poverty, improving quality of life and utilising local sources of warmth in deprived areas.
- For district heating to be economically viable, a longer-term policy and regulatory approach would be required.



184 Bush, R., Hawkey, D. and Webb J., 2015, *Regulatory Options for District Heating in Scotland*. Report to Scottish Government Working Group on District Heating, available at: https://heatandthecity.org.uk/wp-content/uploads/2017/11/Expert_commission_DH_SWG_Regulatory_Options-1.pdf

185 Energy Research Partnership, 2017, *The Transition to Low-carbon Heat*, available at: http://erpuk.org/wp-content/uploads/2017/10/ERP_heat_transition-Oct-2017.pdf

186 Hawkey, D., Bush, R., Tingey, M. and Webb, J., 2018, *Response to Scottish Government's "Second consultation on local heat & energy efficiency strategies, and regulation of district and communal heating"*. www.heatandthecity.org.uk Working Paper.

187 Hawkey, D., 2018, *Urban infrastructure planning under uncertainty – analysis of potential District Heating Areas in Scotland*, www.heatandthecity.org.uk Working Paper.

Electrification

1 Moving away from the direct use of fossil fuels for powering vehicles and space heating and towards a heavier reliance on electricity is one potential option Scotland could pursue – and currently is pursuing – to meet the energy needs of the public while also attempting to reduce carbon emissions.

2 Both the Scottish and UK governments have vowed to stop the sale of traditional petrol and diesel cars, by 2032 and 2040 respectively, and supported the uptake of electric vehicles by the public. Similarly, both governments have set targets to increase the proportion of space heating produced via renewable sources. The Scottish Government has set targets of low-carbon technologies providing 35% of Scotland's heat and cooling demand in domestic buildings by 2032 (rising to 70% in non-domestic buildings), with 50% of all demand (heat, electricity and transport) coming from renewables by 2030.[188]

Climate change

3 The electrification of heat and transport in Scotland would require substantially more electricity to be produced, particularly at peak times, in order to meet the demand currently serviced by fossil fuels. In order for this move to reduce carbon emissions overall, this electricity must be low carbon. Indeed, burning fossil fuels to create electricity, which is then used to run cars and heat homes, would likely prove less efficient than the status quo.

Affordability

4 If electrification of transport and heat is to develop, it will require substantial infrastructure. The Scottish Government has committed £20m to the Low-carbon Transport Loan, as well as investing £15 million in new charging infrastructure.[189] In addition to significant increases in the availability of public charging points (as of August 2017 there were 1,133 charge points in the ChargePlace Scotland Network[190]) significant upgrades to the residential power grid, along with adoption of smart technologies, would be required.

5 Another consideration is the tax contribution to the Exchequer currently made through hydrocarbon oils duties – the tax on fuels used by motor vehicles. In 2017/18 this brought the UK Exchequer £27.9 billion in revenue.[191] Moving away from vehicles fuelled by petrol and diesel will reduce and potentially eliminate this tax stream, although increased VAT receipt from the sale of electricity could temper this.

6 A move away from vehicles using an internal combustion engine would require the public to purchase new models of vehicle which run on electricity. This expense, however, is tempered by government incentives such as the Electric Vehicle Loan, and, to some extent, the natural cycle of people upgrading their cars. Research also suggests that running an electric car may be more economical, with a fully charged electric car providing around 100 miles for £2–4 compared to £13–16 for a petrol or diesel vehicle.[192]

7 The cost to the consumer of heat electrification is more uncertain and would depend on the route followed to achieve this; i.e., increasing the number of people using electric central heating vs. using electricity to produce hydrogen which is then used for heating. Irrespective of this, households would require upgrades, although government could provide incentives and grants to assist with this. Currently, it is generally cheaper to heat homes with gas than with electricity.

188 Scottish Government, 2018, *Climate Change Plan*, available at: https://www.gov.scot/publications/scottish-governments-climate-change-plan-third-report-proposals-policies-2018-9781788516488/pages/11/

189 Scottish Government, 3 September 2019, *Green transport funding pledge*, available at: https://news.gov.scot/news/green-transport-funding-pledge

190 Makwana, B, RAC Foundation, December 2017, *Electric Vehicle Charge Point Usage in Scotland*, available at: https://www.racfoundation.org/media-centre/scottish-ev-charge-point-data-2017

191 HM Revenue and Customs, July 2018, *Annual Report and Accounts* 2017-18 (For the year ended 31 March 2018), available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/726849/HMRC_Annual_Report_and_Accounts_2017–18__web_.pdf p164

192 Energy Saving Trust Website, *Electric Vehicles*, available at: http://www.energysavingtrust.org.uk/transport/electric-vehicles

Energy security

8 National Grid's Future Energy Scenario predicts that up to 35 million electric vehicles could be on UK roads by 2040. At the time of writing there are around 172,000 ultra-low-emissions vehicles registered in the UK.[193] National Grid has estimated that in the most extreme scenario, where uptake of electric vehicles is unexpectedly high, peak demand by 2046 could be as much as 30GW higher than the current peak demand value of around 61GW. The most likely scenario it foresees, however, has peak demand at around 5GW higher – an increase of 8% on the current figure.[194]

9 A move to electrification of space heating would require also substantial change. Heat accounts for 51% of Scotland's total energy consumption, with only 11% of this coming from electricity. The vast majority of Scottish homes (79%) rely on mains gas, with six percent using oil.[195] A study by KPMG in 2016 found that in a scenario where all residential and commercial space heating in the UK was provided by the electricity grid, peak demand would increase to somewhere around 150GW by 2015 – around a 145% increase on the current UK peak demand value.[196]

10 While various models of electric and hybrid-electric cars are available, they are still more costly than most petrol and diesel vehicles and make up a small fraction of total registered vehicles. In 2016 there were over 2.9 million registered vehicles in Scotland, with only 7,000 of these being purely electric, and 14,000 hybrids.[197] If the decision to end the sale of new petrol and diesel cars from 2032 remains in place, the proportion of electric and hybrid vehicles on the road will almost certainly increase dramatically over the next decade.

Social acceptability and economic wellbeing

11 The lithium-ion batteries used for EVs require materials including lithium, cobalt, and graphite. In 2017, more than three-quarters of lithium production was in Australia or Chile, almost two-thirds of cobalt production was in the Democratic Republic of the Congo (DRC), and more than three-quarters of natural graphite production was in China.[198] Significant reserves of lithium remain in Australia, Chile, China and Argentina. Australia and DRC have significant cobalt reserves, and considerable amounts of graphite remain in Brazil and China.[199]

12 Environmental and social concerns have been expressed over the mining and production of materials used in the batteries for, and motors of, electric vehicles.[200] EV motors also require various rare earth elements (REE) with over 80% of REE production occurring in China. While China houses more than one third of the world's REE reserves, the country also controls significant amounts located in the DR Congo, Brazil and Russia.[201]

13 Regulation of the mining and refining of rare earth elements has been historically poor, leading to serious environmental damage.[202] As the metals and elements necessary for EVs do not exist in Scotland, the raw materials would need to be imported, and Scotland would not be in a position to regulate and oversee their production.

193 UK Government. 14 April 2016, 10 January 2019 (updated) Statistical Data Set: Data on all licensed and registered vehicles, produced by Department for Transport, available at: https://www.gov.uk/government/statistical-data-sets/all-vehicles-veh01

194 UK Parliament, House of Common Libraries, 20 February 2018, *Electric vehicles and infrastructure*, available at: https://researchbriefings.parliament.uk/ResearchBriefing/Summary/CBP-7480

195 Scottish Government, 2018, *Energy in Scotland* 2018, p81

196 KPMG, July 2016, *2050 Energy Scenarios The UK Gas Networks role in a 2050 whole energy system*, available at: https://www.energynetworks.org/assets/files/gas/futures/KPMG%20Future%20of%20Gas%20Main%20report%20plus%20appendices%20FINAL.pdf p.50

197 Transport Scotland, 2017, Chapter 1: *Road Transport Vehicles*, available at: https://www.transport.gov.scot/publication/scottish-transport-statistics-no-36-2017-edition/chapter-1-road-transport-vehicles/

198 BP, 2018, *BP Statistical review of World Energy*, p50

199 BP, 2018, *BP Statistical review of World Energy*, p51

200 Please see section on Storage for further discussion of EV batteries

201 BP, 2018, *BP Statistical review of World Energy*, pp50-51

202 Bradsher, K, The New York Times, 22 October 2013, *China Tries to Clean Up Toxic Legacy of Its Rare Earth Riches*, available at: https://www.nytimes.com/2013/10/23/business/international/china-tries-to-clean-up-toxic-legacy-of-its-rare-earth-riches.html

14 While electrifying transport and heat using low-carbon, renewable, domestic sources of energy could play an important role in achieving carbon emissions targets, while meeting public energy demand, some benefits could be missed by the most vulnerable in society. Almost 60% of households in the social rent sector do not possess a car, compared to 44% in the private rent sector and just 13% in owner-occupier properties.[203] Those living in flats may also find it more difficult or expensive to use domestic electricity to charge a vehicle. The large-scale electrification of public transport, however, could ameliorate this disparity.

15 The proportion of those in social housing already using electricity to heat their homes (15%) is already higher than those in the private sector (10%).[204]

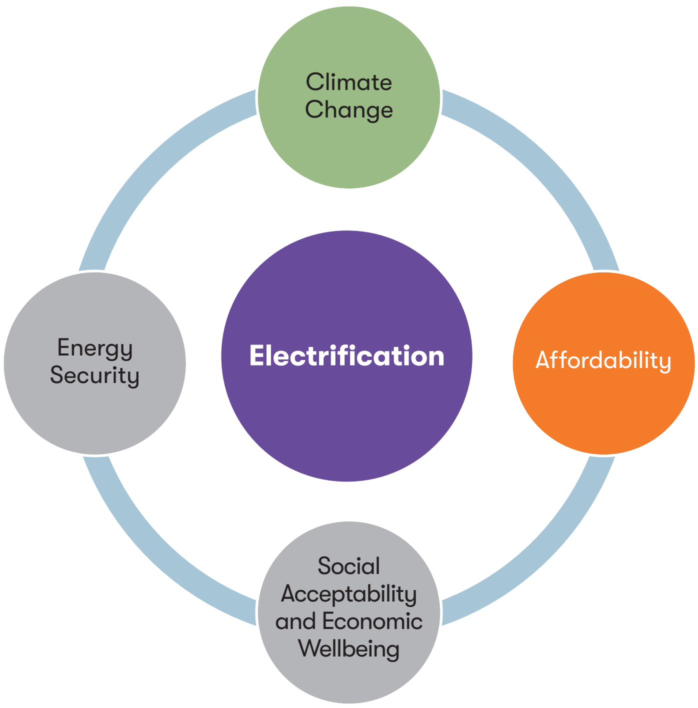
16 Electrification of transport and heat would require significant behavioural change from the public. Vehicles would need to be charged at specific times to avoid putting too much strain on the grid during peak hours. Behavioural change on a large scale is possible, and numerous precedents exist. Attempting to predict, however, the potentially unexpected impacts of mass change and how people will adapt to and use new technology is incredibly difficult.

17 There would likely need to be significant public information campaigns aimed at encouraging the public to adopt new vehicles and educating them on how to efficiently charge them, and similarly on the need to move away from the gas boilers currently heating the vast majority of homes.[205]

18 There is also public anxiety about the limited range of current electric vehicles compared to petrol and diesel cars, although battery technology is advancing and many models now have a range of around 200 miles.[206] Similar concerns exist over the amount of time charging a vehicle takes in comparison to fuelling a car at a petrol station. Either technology will have to improve, or the public will need to be convinced of workable solutions to these issues.

Key Points

- The electrification of transport and heat could significantly reduce carbon emissions, but only if the electricity used is generated from low-carbon sources.
- A move towards electrification would require a significant increase in generating capacity. This increase could potentially be as high as 145% on current peak demand value by some estimates.
- Substantial new infrastructure would be required to facilitate electrification.



203 Scottish Government, 4 September 2018, *Scotland's People Annual Report* 2017, available at: https://www.gov.scot/publications/scotlands-people-annual-report-results-2017-scottish-household-survey/

204 Scottish Government, 5 December 2018, Scottish house condition survey 2016: key findings, available at: https://www.gov.scot/publications/scottish-house-condition-survey-2016-key-findings/pages/5/

205 PWC, April 2018, *Charging ahead! The need to upscale UK electric vehicle charging infrastructure*, available at: https://www.pwc.co.uk/power-utilities/assets/electric-vehicle-charging-infrastructure.pdf

206 House of Commons, Business, Energy and Industrial Strategy Committee, 19 October 2018, Electric vehicles: driving the transition – Fourteenth Report of Session 2017-2019, available at: https://publications.parliament.uk/pa/cm201719/cmselect/cmbeis/383/383.pdf p17

Energy Efficiency and Demand Reduction

Energy efficiency

1 Increased energy efficiency measures could play an important role in reducing energy consumption in Scotland. Energy efficiency has been deemed a National Infrastructure Priority by the Scottish Government since 2015.

2 Improving the energy efficiency of existing buildings and ensuring high standards from new builds could prove key, as could continuing to increase the efficiency of consumer products and transport options.

Climate change

3 The reduced demand for energy resulting from improved efficiency could assist significantly in lowering Scotland's carbon emissions and improve security of supply by reducing reliance on sources of generation or production.

Affordability

4 The investment required to significantly raise energy efficiency standards would be substantial. The Scottish Government estimates that its Energy Efficient Scotland programme will require £10–12 billion of investment to meet its goals.[207] More ambitious targets would require additional funding, likely through substantial long-term programmes providing grants and loans to support investment.

5 While the substantial investments required to increase energy efficiency will need to be paid for, there is significant evidence that increased efficiency measures reduce household consumption and therefore energy bills. Across the UK, between 2004 and 2015, total household energy consumption fell by around 20%. This is estimated to have saved the average dual fuel household £490 a year. Measures which decreased energy consumption by a further 25% could save households an additional £270 per year.[208]

6 Increased energy efficiency in homes has the potential to simultaneously reduce energy consumption, carbon emissions and fuel poverty. Decreased fuel bills would assist in lifting some people out of fuel poverty and potentially make heating homes to a comfortable level more achievable for those on low incomes. Improved housing conditions are also linked to a litany of improved outcomes for residents, including benefits to their health.[209]

Energy security

7 Improved energy efficiency measures could significantly reduce Scotland's energy demand over the coming decades. Indeed, the more than 15% reduction in energy consumption between 2005 and 2015 was largely driven by improved energy efficiency measures. The Scottish Government's Energy Efficient Scotland Programme seeks further reductions of 15% from domestic buildings and 20% from non-domestic buildings by 2032.[210]

8 There is, however, uncertainty about what can be achieved by efficiency measures in buildings. Models have tended to overstate savings, resulting in part from poor performance in the construction sector with respect to specification and installation of facilities. Furthermore, it is possible that the "rebound effect" – whereby savings achieved through energy efficiency are negated by the resulting changes in behaviour – could temper the overall reduction in consumption if not correctly addressed.[211]

207 Scottish Government, 2018, *Energy Efficient Scotland*

208 Rosenow, J; Eyre, N; Sorrell, Steve; Guertler, P; UKERC/CIED Policy Briefing, 5 September 2017(c), *Unlocking Britain's First Fuel: The potential for energy savings in UK housing*, available at: http://www.cied.ac.uk/wordpress/wp-content/uploads/2017/09/3900_UKERC_CIED_briefing_final.pdf

209 Bramley, G; Fitzpatrick, S; Liddell, C; & Webb. J, Scottish Government, November 2017, *A new definition of fuel poverty in Scotland: A review of recent evidence*, ISBN: 978-1-78851-242-8, available at: https://www.gov.scot/Resource/0052/00527017.pdf

210 Scottish Government, 2 May 2018 (a), Energy Efficient Scotland: route map, available at: https://www.gov.scot/publications/energy-efficient-scotland-route-map/

211 Guardian, 22 February 2011, Could the rebound effect undermine climate efforts? https://www.theguardian.com/environment/blog/2011/feb/22/rebound-effect-climate-change

9 Research jointly undertaken by the UK Energy Research Centre and the Centre on Innovation and Energy Demand suggests that by 2035 around 25% of the energy being used in UK households could be saved through socially cost-effective investments in various energy efficiency technologies. With decreasing costs of equipment and taking account of wider benefits, it may be possible to reduce energy demand in homes by as much as 50%.[212]

10 Scotland's varied, and ageing, housing stock presents a serious obstacle to increasing energy efficiency. The Scottish Government's set aims are to see all Scottish homes achieve an EPC C rating by 2040, with as many rented homes as possible reaching EPC B by 2032. The targets aim for all private rented homes to reach EPC E by 2022, EPC D by 2025 and EPC C by 2030.[213]

11 The most recent statistics available show that just 39% of homes in Scotland are in EPC C or above. The majority of owner-occupied (67%) and private-rented (62%) homes are EPC D or below, with 48% of the social sector falling into these categories.

Social acceptability and economic wellbeing

12 A drive towards higher fuel efficiency could present economic opportunity through greater numbers of jobs in refurbishing homes and installing energy efficiency technologies. The Scottish Government estimates that every £100 million spent on energy efficiency improvements supports around 1200 jobs across the Scottish economy.[214]

13 Research suggests that adequate investment in efficient heating, insulation, control, lighting and appliances could benefit the UK economy to the tune of £7.5 billion. Further, a more experimental study – which includes additional benefits accrued from associated improved health outcomes, increased economic activity and benefits to the electricity system – estimates the full economic benefits to the UK economy of reducing energy demand by 25% could be as high as £47 billion.[215]

14 While there are compelling arguments that adopting energy efficiency measures benefit consumers, encouraging home owners to invest in this will likely prove difficult. Even with low-interest loans available, the time taken to make back the money invested on improvements can often reach into decades. In reviewing the performance of the UK Government's now defunct Green Deal initiative,[216] the National Audit Office noted that the scheme did not deliver any meaningful benefit, and in fact added to supplier costs and household bills, as a result of failing to *"persuade householders that energy efficiency measures are worth paying for."*[217]

15 Despite this difficulty in convincing homeowners to take action, research commissioned by the Consumer Futures Unit found that empowering the public to make energy-efficient choices through the provision of advice, information and incentives, was preferred by consumers to enforced regulation.[218] Gaining public acceptance and buy-in on the need to act would be incredibly challenging and require, as only one part of such a project, a significant communications campaign. There would similarly need to be a significant increase in activity in the skills and supply chain in the transition phase; a fact the Scottish Government acknowledges in its Energy Efficient Scotland route map.[219]

212 Rosenow, J; Eyre, N; Sorrell, Steve; Guertler, P; UKERC/CIED Policy Briefing, 5 September 2017(a), *Unlocking Britain's First Fuel: The potential for energy savings in UK housing*, available at: http://www.cied.ac.uk/wordpress/wp-content/uploads/2017/09/3900_UKERC_CIED_briefing_final.pdf

213 Scottish Government, 2018, *Energy Efficient Scotland*, p7

214 Scottish Government, 2018, *Energy Efficient Scotland*

215 Rosenow, J; Eyre, N; Sorrell, Steve; Guertler, P; UKERC/CIED Policy Briefing, 5 September 2017(b), *Unlocking Britain's First Fuel: The potential for energy savings in UK housing*, available at: http://www.cied.ac.uk/wordpress/wp-content/uploads/2017/09/3900_UKERC_CIED_briefing_final.pdf

216 This scheme allowed homeowners, landlords and tenants to pay for the cost of improvements over time through a charge added to their electricity bill.

217 National Audit Office, Department of Energy & Climate Change, 14 April 2016, *Green Deal and Energy Company Obligation*, available at: https://www.nao.org.uk/report/green-deal-and-energy-company-obligation/

218 Fraser, S, Citizens Advice Scotland, 2015, Coming in from the Cold: based on the evidence of independent research and Citizens Advice Bureau clients across Scotland Minimum Standards of Energy Efficiency in Private Sector Housing – The View from Consumers and Bureaux, available at: https://www.cas.org.uk/system/files/publications/coming_in_from_the_cold_final_combined.pdf

219 Scottish Government, 2018, *Energy Efficient Scotland*, p62

Demand reduction

16 Scotland could look to find part of the solution by significantly reducing its demand for energy. Notable progress has been made in this area, with Scottish Government figures showing a 15.4% decrease in total energy consumption between a 2005–2007 baseline and 2015.[220] Thus far, the reduction has been primarily driven by energy efficiency measures, as opposed to changes in public behaviour.

Climate change

17 A considerable reduction in overall energy demand could play a significant role in reducing Scotland's carbon emissions. Over the last decade, the fall in energy consumption has mirrored the fall in carbon emissions. Furthermore, reducing consumption does not export any of these emissions abroad. Changing public behaviour towards using less energy also inherently improves the country's energy security by requiring a reduced level of supply.

Affordability

18 Significant investment would be required by government in a number of ways if it was serious about effecting serious change in public behaviour. A widespread and engaging communications campaign would be required to inform the public of why and how this change is required. Investment would also be needed to ensure necessary alternatives were in place for a transition, such as radically improved public transport options, if the public are to be encouraged away from the use of private vehicles. Government could utilise tax penalties and regulation to drive behaviour, as well as tax incentives which would likely require significant funds.

19 Theoretically, reducing consumption of energy should reduce the amount of money individual members of the public spend. Action, however, that looks to drive public behaviour away from high energy usage through increasing its cost would see the public pay the same or more as they do now, but receive less. Incentivisation of certain schemes through tax relief would also need to be paid for from the public purse.

20 Linked to an increase in energy costs would be the impact on the poorest in society. Over a quarter of households in Scotland are already fuel poor and policy decisions that look to decrease energy consumption through increasing price would either burden low-income households even more, or drive them not to use energy that they genuinely need. Furthermore, powers to take this action do not lie with the Scottish Government at present.

Energy security

21 A broad spectrum encompasses the possible extent to which Scotland can reduce its energy consumption, and the severity of behavioural change from the public required to achieve this. The scenario posited by the Scottish Government (referenced in Chapter 4) with the lowest final consumption by 2050 puts demand at 110TWh; around 30% lower than its stated 2015 baseline.[221]

22 The ability of Scotland to significantly reduce demand is limited by the current demand profile of energy in the country. The majority of Scotland's energy use continues to be for space heating (51%). Public awareness of the importance of not overheating or unnecessarily heating homes can play a role in reduction, although there is also scope to change how the public uses electricity and transport.

23 This challenge is exacerbated by the fact that Scotland consumes more energy per household than the British average,[222] as it faces colder temperatures than in other regions of the UK.

220 Scottish Government, 2018, *Energy in Scotland* 2018, p29

221 Scottish Government, 2017, *Scottish Energy Strategy*, p29

222 Scottish Government, 2018, *Energy in Scotland* 2018

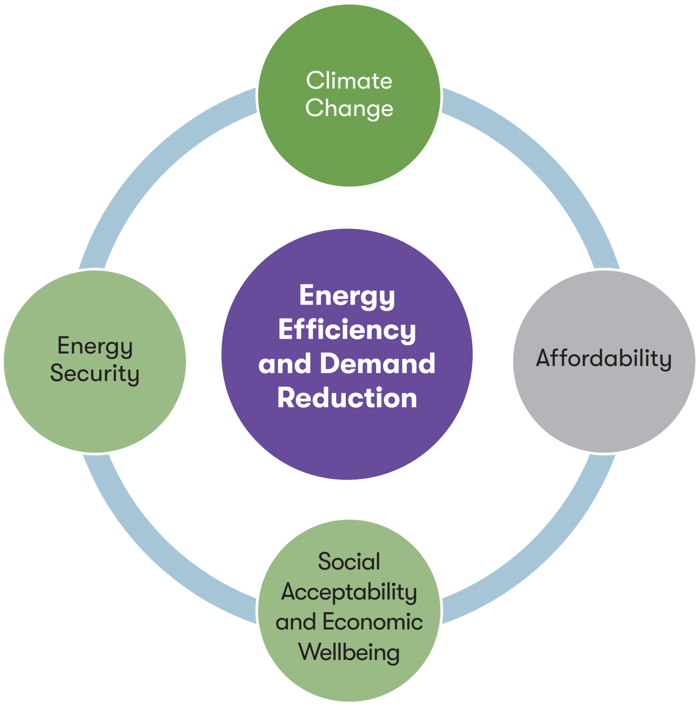
Social acceptability and economic wellbeing

24 A large reduction in public use of energy could see adverse impacts for the economy if coupled with a decrease in economic consumption. This being said, the Scottish economy has grown every year since 2011[223] as overall energy consumption has fallen. The International Energy Agency has expressed optimism that the 'decoupling' of energy-related emissions with economic growth is possible, and has been occurring in some regions of the world. It is, however, difficult to draw conclusions from existing data as, in the UK, emissions reductions are not separated from economic activity. It may be the case that reductions in emissions are simply a result of the Great Recession.[224]

25 Reducing demand for energy on a large scale would likely mandate substantial changes in public behaviour which would be hard to achieve. Most people take the ability to use energy for granted. A move to restrict use of electronics, ability to travel independently, or freedom to conduct day-to-day life as is currently the case, would be incredibly hard to gain popular support for.

Key Points

- Reducing Scotland's energy demand could play an important role in meeting many of its energy goals, and improved energy efficiency will be key to achieving this.
- Reducing demand for energy could assist in significantly reducing Scotland's carbon emissions.
- Improved energy efficiency would require substantial investment and faces a serious obstacle in Scotland's aging and varied housing stock.



223 Scottish Government Website, Purpose Target, available at: https://www2.gov.scot/About/Performance/scotPerforms/purposetargets/economicgrowth#Chart

224 International Energy Agency, 2015, *Energy and Climate Change: World Energy Outlook Special Report*, p30, available at: https://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChange.pdf p30

Domestic Oil and Gas Production

1 Whilst oil and gas prospectivity may be more limited, the basin's life is still being extended through near-field exploration (NFE) and infrastructure-led exploration (ILE) driven by the location and ownership of production hubs and pipelines

2 In addition, new uses are being sought for the basin as exemplified by the expansion of wind farms including some using old installations (e.g. Beatrice in the Inner Moray Firth) or as storage sites for methane or for possible carbon sequestration

3 A rich database has been collected over the years of exploration and now resides in the OGA's National Data Repository (NDR), which was launched earlier this year.[225] This database will prove to be invaluable, not only in helping to unlock new reserves but also to characterize the subsurface for use as a carbon store.

4 The technological advances made during the development of the North Sea petroleum province represent an asset, since they can be deployed to great effect in new and emerging oil and gas provinces to ensure safe extraction that meets stringent environmental criteria.

5 The UK is a world leader in research and training in the geoscientific methods and their application to image and parameterise the subsurface. The skill sets are not only relevant for oil and gas exploration and production but, significantly, are also essential for clean energy, since the same methods are needed to characterise sites with a potential for carbon storage and geothermal.

6 The North Sea and other basins of the UK Continental Shelf (UKCS) such as the West Shetlands and East Irish Sea will continue to produce oil and gas, but in much lower and ever diminishing levels compared to those of the 1980s and 1990s.

7 OGA's current estimate of remaining recoverable hydrocarbon reserves and resources from UKCS's producing fields, undeveloped discoveries and mapped leads and prospects is in the range of 10 to 20 billion barrels of oil equivalent (boe).

8 As a consequence, the OGA estimates that the UK still has enough oil reserves to sustain production for the next 20 years, but significant investment will be required in new field developments for untapped potential to be realised.

9 Natural gas currently plays a highly significant role in Scotland's energy mix. Including the gas used to generate electricity, around a third of final energy consumption in Scotland is attributable to natural gas. This is higher than the global proportion of consumption accountable to natural gas, which is around 23%.[226]

10 Gas is particularly important as a heating fuel in Scotland, with around 79% of households relying on gas for space heating.[227]

11 As a result of the net decline in UKCS oil and gas production, there will be a need to import oil and gas from reliable and secure sources to make up the shortfall, or to accelerate other energy sources to replace them. The drive to wean ourselves off fossil fuel dependence adds further urgency to this challenge.

225 Oil and Gas Authority, *National Data Repository*, available at: https://www.ogauthority.co.uk/data-centre/national-data-repository-ndr/

226 BP, 2018, BP Statistical Review 2018 and Scottish Government, 2018, *Energy in Scotland* 2018

227 Scottish Government, 2018, *Energy in Scotland* 2018

Onshore Shale Gas

1 Meeting Scotland's future energy needs through onshore production of gas could take several forms, including development of shale gas or coalbed methane (CBM). The process of underground coal gasification (UCG) could also be utilised.

2 The Scottish Government commissioned independent reviews into unconventional oil and gas (shale gas and CBM)[228] and underground coal gasification[229] in 2014 and 2016 respectively. Both unconventional oil and gas extraction and underground coal gasification are currently prohibited and subject to a moratorium by the Scottish Government.

Climate change

3 Continuing to burn substantial quantities of gas is almost universally accepted as exacerbating the problem of climate change. Whether gas is extracted through conventional or unconventional methods likely makes little difference to its overall carbon footprint, research suggests. A study commissioned by DECC in 2013 found that emissions from shale gas extraction and use are likely to be comparable to gas extracted from conventional sources, although lower than those from liquefied natural gas (LNG).[230]

Affordability

4 As with many nascent industries, developing onshore gas would require substantial government support, most likely through subsidies or tax incentives. The KPMG report estimated in its central scenario that in Scotland direct expenditure of £2.2 billion would be required.[231] The significant geological risk around developing such an industry could result in little or no return on this investment, with no jobs or economic value created, although investment would stop if it became apparent this was the case.

5 As Scotland is part of an international energy market, it is highly unlikely that a successful onshore gas industry in Scotland would lead to a decrease in the price of gas. Again, significant investment would be required.

6 Boreholes used as part of the hydraulic fracturing process require decommissioning. The UKOOG has developed industry best practice for this.[232]

Energy security

7 Substantial reserves of onshore shale gas may exist in Scotland which could play a role in meeting our future demand for energy, particularly in regard to space heating. The geological uncertainty over the size of potential reserves, however, is significant. A British Geological Survey (BGS)/Department of Energy and Climate Change (DECC) report examining the Midland Valley of Scotland[233] found that while resources of shale gas do exist in this region, the complex geology, specific mineralogy and lack of data result in *"relatively high uncertainty"*.[234] The report went on to conclude that while gas from the reviewed area did have the potential to add to the UK resource base, the lack of testing and data mean the amount of ultimately recoverable shale gas cannot be accurately estimated.

228 Scottish Government, 2014, Independent Expert Scientific Panel – *Report on Unconventional Oil And Gas*, available at: https://beta.gov.scot/publications/expert-scientific-panel-report-unconventional-oil-gas/

229 Scottish Government, 6 October 2016, *Independent Review of Underground Coal Gasification* – Report, available at: https://beta.gov.scot/publications/independent-review-underground-coal-gasification-report/

230 MacKay, D.J.C & Stone, T.J, Department of Energy and Climate Change, 9 September 2013, *Potential Greenhouse Gas Emissions Associated with Shale Gas Extraction and Use*, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/237330/MacKay_Stone_shale_study_report_09092013.pdf p3

231 Scottish Government, 2016, *Unconventional oil and gas: Economic Impact Assessment and scenario development of unconventional oil and gas in Scotland*

232 UKOOG Website, Industry Guidelines, available at: http://www.ukoog.org.uk/onshore-extraction/industry-guidelines

233 Department of Energy and Climate Change, British Geological Survey, 2014, *The Carboniferous shales of the Midland Valley of Scotland: geology and resource estimation*, available at: https://www.ogauthority.co.uk/media/2765/bgs_decc_mvs_2014_main_report.pdf

234 Department of Energy and Climate Change, British Geological Survey, 2014, *The Carboniferous shales of the Midland Valley of Scotland: geology and resource estimation*, p85

8 Further uncertainty over the viability of shale deposits has been raised, with the suggestion that the complexity of sedimentary basins has not been adequately considered and that, potentially, uplift and co-seismic fault activity millions of years ago could have led to depressurising, source rock maturation being curtailed, and gas escape.[235]

9 If Scotland did produce significant quantities of onshore gas, this would be able to meet the peaks and troughs of demand at different times of the day or in different seasons without issue.

10 Scotland's energy security would be bolstered if any onshore gas industry was developed, by decreasing reliance on imports. Furthermore, the nature of some wells could allow for the drilling and 'banking' of gas which could later be produced, fairly quickly, as needed.

11 Scotland possesses the infrastructure and technical skills to develop an onshore gas industry, provided reserves are present. The scenarios put forward in the KPMG report forecast that output from a shale gas industry in Scotland would reach peak levels by around 2048.[236]

Social acceptability and economic wellbeing

12 The economic opportunity from such an uncertain industry is hard to predict, although some studies have projected that a UK-wide industry could create tens of thousands of jobs.[237] A report produced in 2016 by KPMG for the Scottish Government examining the economic impact of an unconventional oil and gas industry in Scotland[238] found that such an industry could, up to the year 2062, create 1,400 additional jobs throughout the supply chain, with £1.2 billion additional economic impact created.

13 The development of an onshore shale gas industry in Scotland would allow for regulations on health and safety and the environment to be set and enforced by the Scottish Government. This would allow scrutiny of these controls to ensure best practice for workers and the environment is followed. Producing gas domestically also allows for a more representative picture of Scotland's progress in reducing its carbon emissions to be presented and does not see responsibility for consumption transferred abroad.

14 A significant onshore shale gas industry would hold different characteristics from the onshore industry with which the Scottish public is familiar. Development would necessitate significantly increased traffic, and noise and light pollution during certain phases of drilling and development. Transport disturbances can, however, be mitigated through piping gas and waste water off-site. The demographics of communities may also see short-term transformation, with an influx of workers during early phases of development.

15 All members of United Kingdom Onshore Oil and Gas (UKOOG), the representative body for the industry, have committed to providing a benefits scheme for local communities in which production takes place.[239] This scheme would provide financial rewards depending on the revenues generated. The industry maintains that such funds could transform communities.

235 The Conversation, 16 August 2017, *There may be a huge flaw in UK fracking hopes – the geology*, available at: https://theconversation.com/there-may-be-a-huge-flaw-in-uk-fracking-hopes-the-geology-80591

236 Scottish Government, 2016, Unconventional oil and gas: *Economic Impact Assessment and scenario development of unconventional oil and gas in Scotland*

237 Taylor, C; Lewis, D & Byles, D, Institute of Directors – Infrastructure for Business 2013 (6), *Getting shale gas working*, available at: https://www.iod.com/Portals/0/Badges/PDF's/News%20and%20Campaigns/Infrastructure/Infrastructure%20for%20business%20getting%20shale%20gas%20working%20report.pdf?ver=2016-04-14-101231-553

238 Scottish Government, 8 November 2016, *Unconventional oil and gas: Economic Impact Assessment and scenario development of unconventional oil and gas in Scotland*, available at: https://beta.gov.scot/publications/unconventional-oil-gas-economic-impact-assessment-scenario-development-unconventional-oil/

239 United Kingdom Onshore Oil and Gas Website, *Benefits of Onshore Oil and Gas*, available at: http://www.ukoog.org.uk/community/benefits

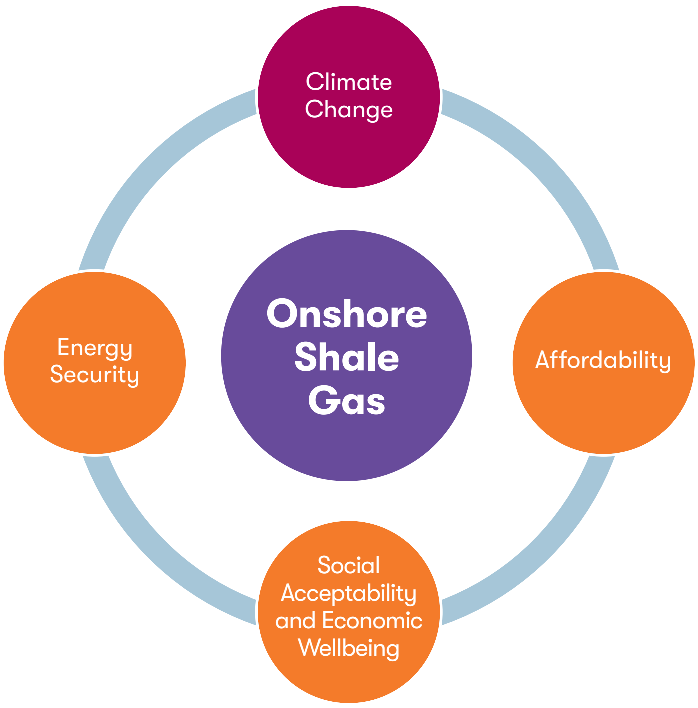
16 Onshore shale gas exploration has proved highly controversial. The quarterly public attitudes tracker published by the Department for Business, Energy and Industrial Strategy has shown opposition to extracting shale gas at higher levels than support in recent additions. Those surveyed who either 'oppose' or 'strongly oppose' extraction has increased fairly steadily from 21% in December 2013 to 32% in March 2018. Those who either 'support' or 'strongly support' extraction has fallen from 28% to 17% in the same period. Perhaps most importantly, those neither supporting nor opposing, and those who 'did not know' made up a large plurality – and often a majority – throughout the period.[240] This suggests public opinion is not as firm one way or the other as is often perceived.

17 The process of hydraulic fracturing to retrieve shale gas requires significant quantities of water. Flowback waters from the process may contain naturally occurring radioactive materials, which constitutes waste and would require treatment. The Expert Scientific Panel on Unconventional Oil and Gas convened by the Scottish Government found that the environmental impact of disposing of such flowback waters, given existing regulation, should be minimal.[241]

18 Hydraulic fracturing comes with a risk of potentially damaging seismic activity, although this is low. A 2012 report by the Royal Society and Royal Academy of Engineering noted that seismic activity produced by hydraulic fracturing is generally of a lesser magnitude than could be expected from coal mining and that an emerging consensus existed that this activity would be felt by few people and would have negligible, if any, surface impact.[242]

Key Points

- There is a significant amount of geological uncertainty over the size of potential shale gas reserves and uncertainty over the viability of the deposits which exist.
- Continuing to burn substantial quantities of gas will exacerbate the problem faced by climate change and runs counter to the goal of reducing carbon emissions.
- A domestic onshore industry based on shale gas is challenged but, if viable, could improve security of supply.



240 UK Government, 16 August 2018, BEIS Public Attitudes Tracker: Wave 26, available at: https://www.gov.uk/government/statistics/beis-public-attitudes-tracker-wave-26

241 Scottish Government, 2014, Expert Scientific Panel on Unconventional Oil and Gas Report

242 The Royal Society, June 2012, *Shale gas extraction in the UK: a review of hydraulic fracturing*, available at: https://royalsociety.org/~/media/policy/projects/shale-gas-extraction/2012-06-28-shale-gas.pdf

Offshore Gas

1 Scotland has a long history of developing gas offshore. This could take the form of extraction through conventional or unconventional processes.

2 The Scottish Government has expressed backing for Scotland's offshore oil and gas industry. The Energy Strategy explicitly supports *"investment, innovation and diversification"*[243] in the sector and names *"maximising the recovery of remaining resources"*[244] among its key priorities.

Climate change

3 The global climate impact from offshore gas is similar to that of onshore gas, as are the energy security benefits derived, although as existing deals are in place for the sale of offshore gas, its ability to assist domestically in meeting gas shortages is constrained.

Affordability

4 Offshore production faces many of the same economic risks as onshore development, with the additional drawback of higher costs, both in terms of extraction and decommissioning. Additional offshore development of gas in Scotland would not constitute business as usual. While further conventional reserves may be found and exploited, it is likely that new, and more expensive, technology will be required to access future gas reserves. Profit margins for investors are likely to be smaller than has been the case in the past and greater investment may be required.

5 Significant investment will be required for future exploration of reserves. Whether it is economical to do so will primarily be determined by global oil prices, although government could decide to subsidise the cost if it felt the energy security benefits and potential to develop new markets were great enough.

6 As Scotland is part of an international energy market, it is highly unlikely that a renewed offshore gas industry in Scotland would lead to a decrease in the price of gas. Furthermore, either consumers or the taxpayer will be required to pick up the cost of decommissioning. The most recent estimates from the OGA suggest that the cost of decommissioning oil and gas infrastructure in the UKCS – shared between government and industry – will be around £58 billion.[245] The OGA has set a target of reducing this cost to less than £39 billion.

Energy security

7 The UK Oil and Gas Authority (OGA) estimates that significant recoverable reserves and resources still exist in the UK Continental Shelf (UKCS). Proven and probable reserves are estimated to constitute 5.4 billion barrels of oil equivalent (boe) – enough to sustain production for at least another 20 years.[246]

8 Estimates for the end of 2017 put combined discovered reserves and resources and prospective resources in the range of 10 to 20 billion boe. As with onshore development, offshore gas would be able to meet the peaks and troughs of demand at different times of the day or in different seasons without issue.[247]

9 Scotland already possesses a world-class oil and gas sector with all of the necessary skills and infrastructure.

243 Scottish Government, 2017, *Scottish Energy Strategy*

244 Scottish Government, 2017, *Scottish Energy Strategy*

245 Oil and Gas Authority, June 2018, *UKCS Decommissioning*, p3, available at: https://www.ogauthority.co.uk/media/4999/decommissioning-a5-2018-pdf-version.pdf

246 Oil and Gas Authority, November 2018, *UK Oil and Gas Reserves and Resources as at end 2017*, p3, available at: https://www.ogauthority.co.uk/media/5126/oga_reserves__resources_report_2018.pdf

247 Oil and Gas Authority, November 2018, *UK Oil and Gas Reserves and Resources as at end 2017*, p3

Social acceptability and economic wellbeing

10 While UK Government revenue from Petroleum Revenue Tax (PRT) has increased over the last several years, from costing the Exchequer £150 million in 2015/16 to bringing in £1.21 billion in 2017/18, this still falls significantly short of the figures between 2005 and 2012. During this period, the Government received over £10 billion in multiple years. A renewed offshore industry – potentially including opening up new regions for exploration in the West of Shetland and in other areas – could create significant jobs, increased tax revenue and value added for Scotland and the UK.

11 Producing gas offshore domestically makes Scotland overtly responsible for the health and safety of those working in the industry and the environmental impact the country has. An expansion of the offshore industry in Scotland could present environmental challenges. It is possible that marine ecology, while well-studied, could suffer, although Scotland would be in a position to take action and enforce regulations to mitigate such damage, and has a long record of administering an offshore industry without causing such damage.

12 Offshore production offers the opportunity to extract gas out of the public's sight, meaning it may prove more acceptable to other options which require infrastructure or development close to communities.

Key Points

- Significant reserves and resources of gas are estimated to remain in the UK Continental Shelf.
- Continuing to burn substantial quantities of gas will exacerbate the problem faced by climate change and runs counter to the goal of reducing carbon emissions.
- Domestic production of gas to replace UK imports would make Scotland overtly responsible for health and safety and for minimising the industry's environmental impact.

Geothermal

1 Geothermal energy is energy stored as heat below ground. This can be harnessed for space heating, hot water, or to produce electricity in some cases. In Scotland there is the potential to utilise geothermal energy from three primary sources: abandoned mines; hot sedimentary aquifers; and hot dry rocks/petrothermal sources.[248]

2 Deep geothermal energy is most easily accessible in countries with high levels of volcanic activity; for example, Iceland, where the majority of electricity and heating demand is met through geothermal. Various other countries, including New Zealand and the Philippines, generate significant proportions of their electricity through deep geothermal energy.

Climate change

3 Geothermal energy has a minimal carbon footprint when used domestically, with estimates suggesting its carbon emissions per kilowatt hour, when used for non-electric space and water heating, are less than five percent of those produced by a gas boiler. When used for electric heating, it was estimated for 2015 that ground source heat pumps have a carbon footprint of somewhere between 70 – 190g CO_2/kWh compared to around 370g CO_2/kWh for electric heaters.[249]

4 Geothermal power plants producing from intermediate to high temperature resources do emit greenhouses gases, although at levels significantly lower than those of plants powered by fossil fuels. The global average estimate for greenhouse gas emissions from geothermal plants in 2001 was around 122g CO_2/kWh,[250] compared to around 487g CO_2/kWh for gas-fired, 650g CO_2/kWh for oil-fired and 870g CO_2/kWh for coal-fired.[251]

Affordability

5 While there is limited information available on exactly how much investment would be required to develop geothermal energy substantially, example cases do exist which illustrate costs. The 2013 report provides a range of examples – many only proposed or conceptual projects – with heat-only plants across Europe costing between £2.8 million and £18 million; combined electricity generation and heat projects in the UK costing between £14 million and £59 million; and geothermal energy power developments in New Zealand and Southeast Asia costing between £26 million and £109 million. The ranges present different types of plant, producing varying amounts of power.[252] The considerable infrastructure required to connect low-temperature geothermal sources to properties and the need to adapt current heating systems would also require investment.

6 Geothermal energy could be well positioned to help alleviate fuel poverty. A large proportion of those in fuel poverty reside in densely populated urban areas which grew up around heavy industry and manufacturing. While much of this industry has shuttered the mines below, they still exist, potentially providing a low-carbon form of energy in close proximity to those who require it.[253]

248 Scottish Government Website, *Renewable and low carbon energy*, available at: https://www2.gov.scot/Topics/Business-Industry/Energy/Energy-sources/19185/GeothermalEnergy

249 UK Parliament, Parliamentary Office of Science and Technology, 3 May 2016, *Carbon Footprint of Heat Generation*, available at: https://researchbriefings.parliament.uk/ResearchBriefing/Summary/POST-PN-0523

250 World Energy Council Website: https://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Resources-Full-report-2016.10.03.pdf

251 EDF Energy, Technical and Safety Support, 2018 *Report Hinkley Point B Power Station Annual Report for the Hinkley Point Site Stakeholder Group on Radioactive Discharges and Environmental Monitoring at Hinkley Point B Power Station During 2017*, available at: https://www.edfenergy.com/sites/default/files/hinkley_annual_discharges_and_environmental_monitoring_report.pdf

252 Harber, H & Gilles, I, Scottish Government Project AEC/001/11 (1) (2), 2013, *Study into the Potential for Deep Geothermal Energy in Scotland*

253 The Scotsman website, 2018, John Underhill: *Coal mines have an eco-friendly future*, available at: https://www.scotsman.com/news/opinion/john-underhill-coal-mines-have-an-eco-friendly-future-1-4815190

Energy security

7 While Scotland does not have the same levels of volcanic activity as some of the aforementioned countries, it could still access geothermal energy at more shallow depths – where heat produced through solar radiation is stored – through a number of methods depending on conditions, using open-loop and closed-loop ground source heat pumps.[254] Scotland also possesses some geological features which could allow for geothermal energy deeper underground, where temperatures are unaffected by the Sun.[255]

8 A 2013 study undertaken by the British Geological Survey and AECOM, looking at the potential for deep geothermal energy in Scotland, found that abandoned mines could hypothetically produce a third of heat demand in Scotland. Unfortunately, constraints such as inefficiency of transport, unsuitability of some mines and issues of compatibility with existing housing stock mean the actual contribution is likely to be notably lower. The report also estimates that if exploited to the fullest possible extent, heat in mine waters could provide a resource for at least 37 years.[256]

9 The report found that the prospects for geothermal energy from hot sedimentary aquifers (HSA) are much more uncertain, with the best prospect in Scotland likely to be in the Cairngorms, where the geothermal gradient is highest, but they lie away from the conurbations that need the heat. Similarly, the study found that the evidence base for assessing the potential for geothermal energy from hot dry rock (HDR) is limited.[257]

10 Appraisal in the 1990s of potential resources of radiothermal granites – granite rock naturally enriched in potassium, uranium and thorium which produce heat through the radioactive decay of isotopes – found these to be unsuitable for geothermal energy. More recent investigation, however, has looked to re-evaluate their potential.[258]

11 Heat from mine waters provides an alternative ground-sourced heat supply, but can only provide ambient heat. However, since fuel poverty impacts 650,000 (26.5%) Scottish homes, of which >183,000 are classified as extreme cases because 20% or more of their annual household budget is spent on heating, the opportunity to use geothermal heat has the chance to make a difference and could be pursued.

12 Geothermal energy, unlike other renewable resources, is not variable and can provide heat and electricity irrespective of weather conditions or season. Geothermal energy is generally considered a renewable source of energy, as the heat taken will eventually be naturally replaced. It is generally the case, however, that the heat would be removed from the source at a greater rate than is naturally regenerated.[259] Hence, the economic viability of heat production from a geothermal site depends on the rate at which the heat resource is depleted.

13 The utilisation of geothermal energy would improve energy security by allowing Scotland to produce electricity and heat homes using a domestic and reliable resource.

254 British Geological Survey Website, *Geothermal energy – what is it?*, available at: http://www.bgs.ac.uk/research/energy/geothermal/

255 UK Parliament, House of Common Libraries, 14 June 2018, *Potential for geothermal energy resources in the UK*, available at: https://researchbriefings.parliament.uk/ResearchBriefing/Summary/CDP-2018-0146

256 Harber, H & Gilles, I, Scottish Government Project AEC/001/11 (1) (2), August 2013 (a), *Study into the Potential for Deep Geothermal Energy in Scotland*, available at: https://www.gov.scot/binaries/content/documents/govscot/publications/report/2013/11/study-potential-deep-geothermal-energy-scotland-volume-1/documents/00437977-pdf/00437977-pdf/govscot%3Adocument

257 Harber, H & Gilles, I, Scottish Government Project AEC/001/11 (1) (2), August 2013 (b), *Study into the Potential for Deep Geothermal Energy in Scotland*, available at: https://www.gov.scot/binaries/content/documents/govscot/publications/report/2013/11/study-potential-deep-geothermal-energy-scotland-volume-1/documents/00437977-pdf/00437977-pdf/govscot%3Adocument

258 McCay, A.T. and Younger, P.L., Scottish Journal of Geology, 53(1), 2017, *Ranking the geothermal potential of radiothermal granites in Scotland: are any others as hot as the Cairngorms?*, pp.1–11.

259 World Energy Council Website: https://www.worldenergy.org/wp-content/uploads/2016/10/World-Energy-Resources-Full-report-2016.10.03.pdf

Social acceptability and economic wellbeing

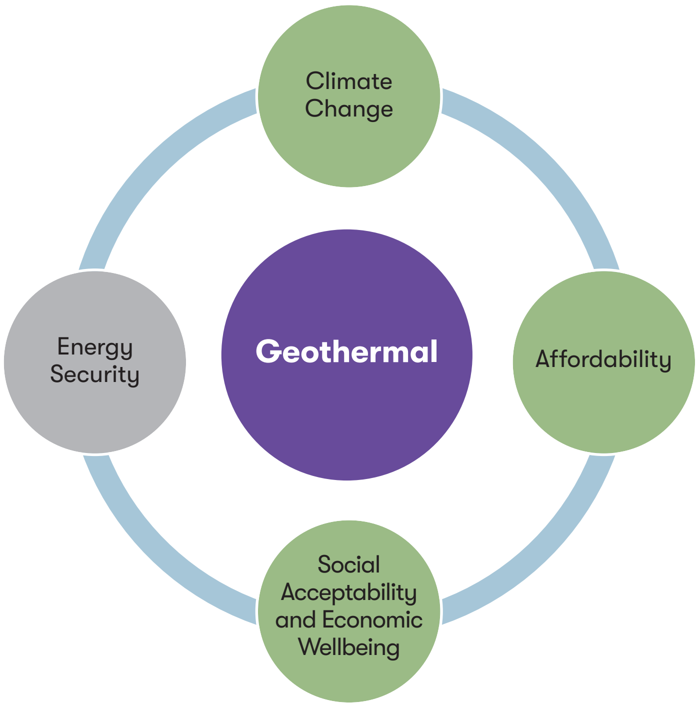
14 The 2013 study noted that there are no specialist deep geothermal energy development companies based in Scotland. Companies who deal with ground-source heat pumps, however, are present and there could be opportunities for these businesses to up-scale. As global focus has been predominately on high-temperature resources, an opportunity may exist for Scotland to develop a strong skill base around low-temperature resources and then export these skills.[260]

15 The water utilised from geothermic sources can contain small amounts of toxic elements. The process, however, of returning this water back into the earth greatly negates any risk posed by this. Some geothermal processes do not bring fluids to the surface at all.

16 Geothermal energy can be produced from rocks with poor permeability using engineered geothermal systems (EGS). As this method involves limited use of hydraulic fracturing, there is a low risk of seismic activity which may be a cause of public concern, given the controversy surrounding the technique for use in shale gas production.

Key Points

- Geothermal energy could play an important role in providing a practical, local source of ground-sourced, low-carbon energy to those in areas most affected by fuel poverty.
- When used domestically, geothermal energy has a minimal carbon footprint.
- Hotter geothermal sources are often sited away from the areas where heat is needed and challenges remain with storage and transportation.



260 Harber, H & Gilles, I, Scottish Government Project AEC/001/11 (1) (2), August 2013, *Study into the Potential for Deep Geothermal Energy in Scotland*, available at: https://www.gov.scot/publications/study-potential-deep-geothermal-energy-scotland-volume-1/

Hydrogen

1 Hydrogen could contribute towards Scotland's energy needs by being used as an alternative to natural gas and in fuel cells to power transport. One of the Scottish Government's two stated energy scenarios foresees a "hydrogen future" in which low-carbon hydrogen is produced through electrolysis and through steam methane reforming paired with carbon capture and storage.[261]

2 Hydrogen can be used to store excess energy generated from various sources, which is then available to utilise later as needed. Hydrogen can be produced by hydrolysis of water – a highly energy-intensive process – or using steam methane reformation, extracting it from natural gas. This energy is then deployed through fuel cells or other means.[262]

3 There are numerous ways to produce hydrogen which could be used to supply the gas grid. Electrolysis relies on electricity to separate water into hydrogen and oxygen. This only accounts for a small proportion of global production.

4 Steam methane reforming accounts for just under half of global hydrogen production and works by separating hydrogen from methane, usually using natural gas as the source of methane.

5 Gasification of coal and oil to produce a hydrogen-rich syngas accounts for just under half of global production.[263]

Climate change

6 While the burning of hydrogen produces virtually no carbon emissions, its production uses other forms of energy which may do so. Nevertheless, using hydrogen gas as a replacement for natural gas could significantly reduce emissions, depending on the method used for production. Hydrogen produced through steam methane reforming (paired with CCS), electrolysis, or biogasification would more than halve the carbon footprint by comparison to natural gas consumption. Using steam methane reforming without pairing it with CCS, however, could actually increase carbon emissions.[264]

Affordability

7 Significant investment in new hydrogen infrastructure, or in adapting existing natural gas infrastructure, would be required. If steam methane reforming is to be used to produce hydrogen it will require carbon capture and storage and thus the necessary investment in CCS is also required.

Energy security

8 Hydrogen can be stored as compressed gas or liquified, which would provide flexibility to meet changing demand both daily and seasonally. There are several options for storage of hydrogen, including in salt caverns, though adoption on a large scale would require significant additional storage facilities.

9 Producing and storing hydrogen domestically would improve security of supply and ensure that Scotland takes responsibility for all environmental and safety regulations.

10 A move from natural gas to hydrogen on a mass scale is technically feasible and could, with modification, use existing infrastructure. The current national transmission and high-pressure distribution pipelines are made of high-strength steel, intermediate-pressure pipes are made of steel, medium- to low-pressure pipes are made from cast iron, and pipes within buildings are mostly made from copper. While a gas mains replacement programme has already converted some intermediate- and all low-pressure pipes to polyethylene, which is compatible with hydrogen, high-pressure steel pipes are incompatible (due to hydrogen making the high-strength steel brittle, particularly under higher pressures) and would require upgrading. The intermediate-pressure steel pipes, however, would be compatible with hydrogen.[265]

261 Scottish Government, 2017, *Scottish Energy Strategy*

262 Reid, A, SPICe Briefing – Energy, 15 March 2017, available at: http://www.parliament.scot/ResearchBriefingsAndFactsheets/S5/SB_17-17_Energy.pdf

263 UK Parliament, Parliamentary Office of Science and Technology, 15 November 2017, *Decarbonising the Gas Network*, available at: https://researchbriefings.parliament.uk/ResearchBriefing/Summary/POST-PN-0565

264 UK Parliament, Parliamentary Office of Science and Technology, 2017, *Decarbonising the Gas Network*, p3

265 Karolytė, R, August 2017 (a) *Hydrogen with CCS for decarbonised heat in the Scottish context*, available at: https://www.climatexchange.org.uk/media/2123/hydrogen_for_decarbonised_heat.pdf

11 A 2016 study looking at the feasibility of converting the natural gas network in Leeds to 100% hydrogen found that the network could be segmented and converted over a period of three years.[266] SGN, who own and operate the gas distribution network in Scotland, are currently conducting a programme designed to understand and develop the necessary technical, operational and safety practice to convert gas mains to hydrogen. This will involve demonstrating conversion at several sites in Scotland.[267]

12 The use of hydrogen produced through steam methane (paired with CCS) would also require a secure supply of natural gas, which would need to either be produced domestically or imported.

13 Producing a considerable proportion of hydrogen through electrolysis would require a substantial increase in renewable energy output in Scotland, but would help to address the problem of variability due to the relative ease with which hydrogen can be stored in comparison to electricity. Steam methane reforming would require significant quantities of methane to be imported.

14 For hydrogen to play a role in balance supply for heat demand, however, storage either in salt caverns (the availability of which are restricted to certain parts of the UK, with no salt deposits in Scotland), depleted gas reservoirs or aquifers, or pressure vessels, would likely be required. Storage of hydrogen onshore may not be popular with some section of the public,[268] although the example of the project in Leeds suggests that local conversion and/or storage may be required to facilitate a phased roll-out.

15 A project to produce hydrogen through electrolysis is already underway in Orkney through the Building Innovative Green Hydrogen Systems in an Isolated Territory (BIG HIT) scheme. The project uses renewable electricity to produce hydrogen through electrolysis of water. The hydrogen is then stored at high pressure and transported. The two electrolysers have a joint capacity of 1.5 MW and it is estimated that they could produce around 50 tonnes of hydrogen per year, using renewable electricity that otherwise would have gone unused.[269]

Social acceptability and economic wellbeing

16 The appliances that are currently used in Scottish homes, such as boilers and ovens, could not run on hydrogen without adaptation. A programme would be needed to either adapt or replace existing appliances, with a decision made on who paid for this process. It should be noted that such a transition has precedent in the UK, when the country moved from the use of town gas to natural gas between 1966 and 1977, although the price, quality and lifespan of household goods have changed markedly in this time. A significant public information campaign would be required.[270] Furthermore, the logistical problem of how to convert large segments of the grid at once, before hydrogen could enter, would need to be addressed.

17 Despite hydrogen being a substantial component of town gas previously used in the UK, there is often public concern over the safety of hydrogen, due to its flammability and potential for explosion. Studies suggest that the risk of leaked hydrogen, igniting or exploding in a domestic setting are comparable with natural gas.[271]

266 Northern Gas Network Executive Summary, available at: https://www.northerngasnetworks.co.uk/wp-content/uploads/2017/04/H21-Report-Interactive-PDF-July-2016.compressed.pdf

267 SGN, H100 project website, available at: https://www.sgn.co.uk/Hydrogen-100/

268 Karolytė, R, August 2017 (b) *Hydrogen with CCS for decarbonised heat in the Scottish context,* available at: https://www.climatexchange.org.uk/media/2123/hydrogen_for_decarbonised_heat.pdf p4

269 BIG HIT Website, available at: https://www.bighit.eu/about

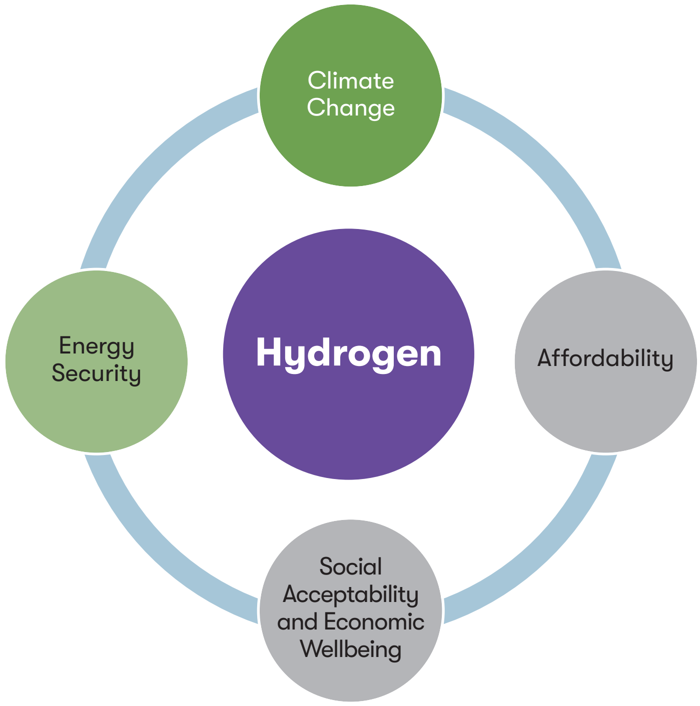
270 UK Parliament, Parliamentary Office of Science and Technology, 15 November 2017 (c), Decarbonising the Gas Network, available at: https://researchbriefings.parliament.uk/ResearchBriefing/Summary/POST-PN-0565

271 Kiwa Gastec, June 2015, Energy Storage Component Research & Feasibility, *Study Scheme HyHouse Safety Issues Surrounding Hydrogen as an Energy Storage Vector*

18 As the characteristics of hydrogen mean it could be used by consumers in a manner similar to natural gas, less behavioural change from the public would be required, although new end-use products would be necessary. It may, however, hamper efforts to deliver substantial improvements in building thermal efficiency.

Key Points

- A move from natural gas to hydrogen on a mass scale is technically feasible, but would require significant investment.
- For the use of hydrogen to play a major role in reducing carbon emissions, Scotland would also have to substantially increase its renewable energy output, or be able to rely on CCS.
- Hydrogen production and use could improve Scotland's energy security, but would require the importation of methane and considerable additional storage capacity.



Importation

Natural Gas

1 Natural gas could continue to be imported into the UK through pipelines from continental Europe, or in the form of liquefied natural gas (LNG) shipped into the country in tankers.

2 As discussed in the section addressing domestic production of natural gas, gas plays a highly significant role in Scotland's energy mix, accounting for around a third of consumption and nearly four-fifths of domestic heating.

Climate change

3 Continuing to burn substantial quantities of gas is almost universally accepted as exacerbating the problem of climate change.

4 The transport of gas via pipeline or tanker across the globe also results in fugitive emissions, leaks and a considerable use of energy, which adds to the global carbon footprint. Hence, the global carbon footprint of the gas that Scotland consumes, and the impacts at the point of production, are very likely to be higher for imported gas than producing gas domestically.

Affordability

5 Importation of gas would likely continue to be cheaper than locally produced gas. The economic implications, however, of whether an increasing reliance on foreign states for gas could lead Scotland to find itself in the position of propping up potentially morally questionable regimes with its fuel purchases must be considered.

Energy security

6 There are multiple import options available to Scotland in terms of supplier states, which should allow us to meet future demand. Various European oil and gas companies are strong players in the global LNG market and growth has taken place globally in recent years in gas pipeline infrastructure, particularly into Europe.

7 As a member of the European Union, the UK currently enjoys a level of protection and 'energy solidarity' in case of a crisis under the Treaty of Rome. The EU has further options for gas, both in terms of supply and storage. Regulation was strengthened at the European level in 2010, aiming at safeguarding security of supply by "ensuring both prevention and a coordinated response in the event of a supply disruption and by securing the proper and continuous functioning of the internal gas market".[272] The rules impose new standards on member states: for example, the UK must be able to supply at least 30 days' worth of gas to private households and other vulnerable consumers such as hospitals. These rules have yet to be called upon, but they do raise the expectation that countries will act to prepare themselves for possible disruption. The Regulation also established a Gas Coordination Group tasked with coordinating the actions and exchange of information between national authorities and industry, as well as assisting the Commission in security of gas supply issues.[273] It is far from clear that these benefits will continue to be enjoyed following the planned withdrawal of the UK from the EU.

8 Interconnectors with Belgium and the Netherlands provide Scotland with a secure and direct supply. While the interconnectors to continental Europe bring gas into England, this connects Scotland as part of the single GB energy market.

9 A heavy reliance, however, on foreign countries, irrespective of the strength of relations with suppliers or international organisations, could leave Scotland's economy at the mercy of factors outwith its control. Political instability or other seen circumstances in exporting countries could affect supply and represents significant risk. This risk is ameliorated by the broad nature of the market, which would allow Scotland to change supplier if needed.

272 EU Website, available at: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32010R0994

273 European Commission Website, Secure Gas Supplies, available at: https://ec.europa.eu/energy/en/topics/imports-and-secure-supplies/secure-gas-supplies

Social acceptability and economic wellbeing

10 Importing gas from abroad nullifies any risk to the Scottish public and workers at the source of extraction. However, it also leaves the safety regulations surrounding production completely outwith the control of the Scottish Government, resulting in the possibility of considerably less stringent rules being in place for production.

11 Relying on imported gas from abroad could be considered inconsistent with Scotland taking responsibility for its energy use. The health and safety regulations and environmental regulations in supplying countries must be taken into account, particularly if they fall below the standard they would be in Scotland, where risk of injury and death to workers may be higher or where there could be higher risk of environmental impacts to local populations.

12 Importing gas from abroad results in no disruption to the Scottish domestic environment and ecology. A lack of control, however, over environmental regulation means Scotland would have no control over such rules and would not, for example, be in a position to implement measures to reduce carbon emissions. Furthermore, largely unquantified, but possibly significant, emissions from transporting gas long distances adds to the global environmental footprint.

13 This option would also inherently mean that money would leave the domestic economy, rather than going to Scottish companies and being paid to Scottish workers.

Electricity

14 Scotland could also look to meet its energy demands through the importation of electricity via interconnectors to continental Europe and the Republic of Ireland.

Climate change

15 Importing electricity could help Scotland to reduce carbon emissions, but only if the electricity being imported is generated through low-carbon sources and replaces generation or fuel consumption that is attributable to fossil fuels.

Affordability

16 An increased reliance on imported electricity would require significant investment in new interconnectors. Seven additional interconnectors are estimated to be delivered by 2021, adding linkages to Belgium, Norway and Denmark. These could increase total capacity to around 11.7GW.[274] Investment in this infrastructure is currently encouraged by Ofgem through 'cap and floor' regulation. Under this system National Grid pays the interconnector operator the difference if its revenue falls below an agreed 'floor' price, with the operator returning any surplus should revenues rise above the 'cap'. Consumers or tax payers would be required to pick up the bill should revenues drop, but would benefit through reduced network charges should the inverse occur.[275]

Energy security

17 The ability of Scotland to meet its future demand would be severely constrained if importation of electricity constituted its primary supply. The four interconnectors currently linking the UK to Europe only provide a combined maximum capacity of 4.1GW.[276]

274 Ofgem Website, Electric Interconnectors, available at: https://www.ofgem.gov.uk/electricity/transmission-networks/electricity-interconnectors

275 UK Parliament, Parliamentary Office of Science and Technology, 9 February 2018, *Overseas Electricity Interconnection*, available at: https://www.iea.org/publications/freepublications/publication/Energy_Policies_of_IEA_Countries_France_2016_Review.pdf

276 BEIS, 2018, *Digest of UK Energy Statistics* 2018, p113

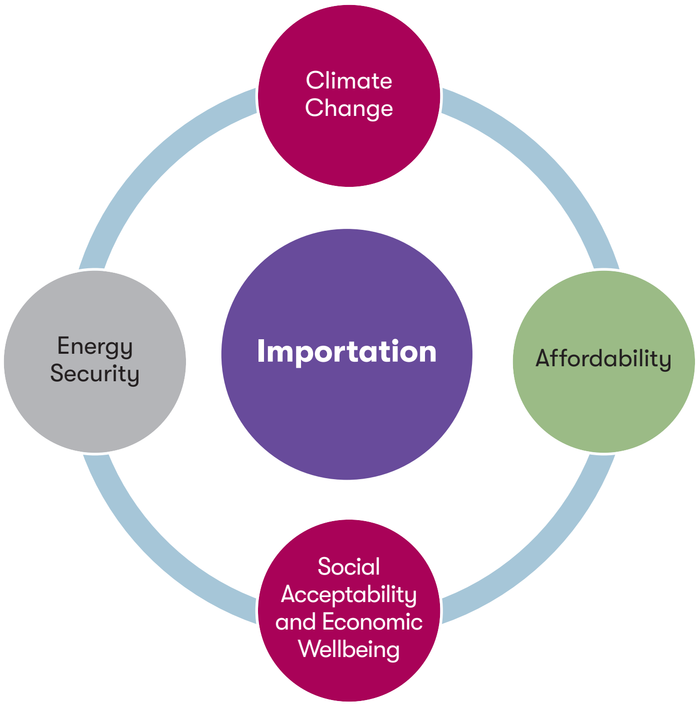
18 Increased connection to Europe could improve Scotland's security of supply both in terms of total demand and in helping to balance the grid under a scenario in which intermittent renewables are more heavily relied upon. The countries the UK are linked with are politically stable and so pose less of a risk than some suppliers that are relied upon for gas. The nature of the interconnectors, however, means that changing supplier is not an option. Furthermore, interconnectors are vulnerable to engineering failures and natural disasters, or could be targeted by terrorist groups.

Social acceptability and economic wellbeing

19 Relying more heavily on imported electricity also raises questions about Scotland's climate, environmental and social responsibilities. Scotland would not control how this electricity is generated and so have no say in reducing carbon emissions or ensuring environmental responsibility. For example, current Scottish Government policy is to reject the construction of new nuclear power stations in Scotland which rely on existing technology. Scotland will likely, however, find itself in the situation of importing electricity from the future Hinkley Point nuclear power station being built in England.

Key Points

- Importing energy from abroad does not allow Scotland fully to take responsibility for the impacts of its production and use.
- Importation is currently able to meet fluctuating demand and so plays a role in ensuring security of supply, although it does leave the UK reliant on foreign countries.
- The long-term availability of electricity for import may be impacted by implementation of similar electrification policies across Europe.



Nuclear

Large Scale

Climate change

1 Nuclear energy has zero carbon emissions at the point of generation and hence has minimal global climate impact. Compared to the carbon emissions of a combined-cycle gas turbine (CCGT) power plant, the Scottish nuclear power stations collectively saved 6.22 $MtCO_2$ in 2016.[277] Like all power systems, over the whole life-cycle nuclear is not zero-carbon or 'carbon-neutral'. There are up-front carbon costs of construction using concrete, energy and potential carbon costs in fabricating the reactors, and likely post-operational carbon costs in decommissioning and waste storage and disposal.

2 Nevertheless, nuclear energy could be consistent with pursuing a low-carbon energy strategy. For example, it has been suggested that a credible pathway to achieving a target of having 50% of energy from low-carbon sources in Scotland by 2030, could involve electricity generation from a mix of one-third nuclear, one-third renewables and one-third gas-fired plants across the UK as a whole by 2035.[278] The material requirements for compact nuclear power are substantially lower than for diffuse renewable generation.

Affordability

3 Hunterston B is scheduled to close in 2023, and Torness in 2030. Unless suitably replaced, these closures will result in a shortfall of electricity generation in Scotland. A low-carbon strategy could favour replacement via new-build nuclear stations. However, irrespective of the specific reactor type or size, if new nuclear is to be pursued, substantial up-front investment would be required to replace the current capacity. Furthermore, following planning consent, the build time for a new large-scale nuclear plant would likely be close to a decade.

4 Nuclear energy has well-recognised challenges, including decommissioning, long-term management of wastes, and understanding and apportioning full life cycle costs and liabilities. Addressing these issues will require substantial investment over a prolonged period of time. The Nuclear Decommissioning Authority (NDA) estimates that the expected cost of decommissioning and dismantling 17 of the UK's earliest nuclear sites, managing and disposing of their waste, and remediating the land previously used will amount to around £121 billion over the next 120 years. The NDA puts the current annual cost of this work at around £3 billion.[279]

5 Irrespective of whether nuclear new build plays any part in Scotland's future energy mix, it is essential that a sustainable long-term solution is found for the higher-activity radioactive waste (HAW) that has been generated in Scotland, and that which will arise from the continued operation and eventual decommissioning of existing nuclear plants.

Energy security

6 Nuclear power has made, and at present continues to make, a substantial contribution to energy generation in Scotland and has historically demonstrated the ability to meet demand. In terms of potential energy generation, Hunterston B and Torness provide 2,150 MW of operational capacity in Scotland.[280]

7 In 2015 their continuity and security of supply resulted in the generation of 17.76 TWh electricity, around 35% of total annual production in Scotland, and enough to meet 49% of Scottish electricity demand. In 2016 the two power stations produced 19.63 TWh, accounting for 42.8% of total electricity production in Scotland that year.[281]

277 Nuclear Industry Association's Response to the Royal Society of Edinburgh inquiry into Scotland's Energy Future, 29 September 2017 available at: http://www.rse.org.uk/wp-content/uploads/2017/12/Nuclear-Industry-Association.pdf

278 EDF Energy, 30 May 2017, Draft Energy Strategy – Consultation Response, available at: http://www.rse.org.uk/wp-content/uploads/2017/12/EDF-Draft-Energy-Strategy.pdf

279 UK Government Website, 12 July 2018 (updated), Corporate report – Nuclear Provision: the cost of cleaning up Britain's historic nuclear sites, available at: https://www.gov.uk/government/publications/nuclear-provision-explaining-the-cost-of-cleaning-up-britains-nuclear-legacy/nuclear-provision-explaining-the-cost-of-cleaning-up-britains-nuclear-legacy#costs-for-decommissioning-other-uk-nuclear-sites

280 Scottish Government, 2018, *Energy in Scotland* 2018, p60

281 Scottish Government, 2018, *Energy in Scotland* 2018, p47

8 Despite total electricity generating capacity in Scotland presently being around twice the maximum Scottish demand, the capacity at any particular time is highly variable. Scotland is dependent on energy imports from England (or elsewhere) when Scottish nuclear output is reduced, for example during maintenance or refuelling, or when calm conditions restrict energy generated from renewable sources.[282]

9 The UK Government (via a mechanism of the public making payments through an inflation-linked life time guaranteed price per MWh) is investing in new-build nuclear power stations as a form of low-carbon power generation that can meet high baseload demand. On announcing the decision to proceed with the power station at Hinkley Point C, Secretary of State for Business, Energy and Industrial Strategy, Greg Clark, stressed the UK Government's view that *"nuclear is an important part of ensuring [the UK's] future low carbon energy security."*[283] At time of writing, a further proposed station at Wylva Newydd has been suspended due to rising costs.[284] Whilst the planned nuclear power stations should be able to meet the large demand, Hinkley Point C has an agreed strike price of £92.5 per MWh, which compares unfavourably with renewable generation options; for example, an offshore wind price of £57.5 per MWh.

Social acceptability and economic wellbeing

10 The Scottish Government's policy of indefinite near-surface, near-site storage (and selectively, disposal) of its higher-activity radioactive waste is only partially consistent with that in the rest of the UK and most other countries with civil nuclear power programmes. Deep geological disposal following an interim period of safe and secure storage is the internationally accepted and preferred approach. The Scottish Government is due to review its radioactive waste management policy by 2020. The future of deep geological disposal will be a particular challenge, as will the future viability of continuing to send spent fuels and specific waste-forms from Scotland to England.

11 The existing nuclear power stations Hunterston B and Torness employ around 1100 staff directly, underpin the existence of a wide range of Scottish companies that are actively involved in the nuclear supply chain, and make significant contributions to their local communities.[285] The loss of a nuclear industry in Scotland, without the development of a comparable industry, could result in negative social and economic impacts in those regions, in particular.

282 Nuclear Industry Association's Response to the Royal Society of Edinburgh inquiry into Scotland's Energy Future, 29 September 2017 available at: http://www.rse.org.uk/wp-content/uploads/2017/12/Nuclear-Industry-Association.pdf

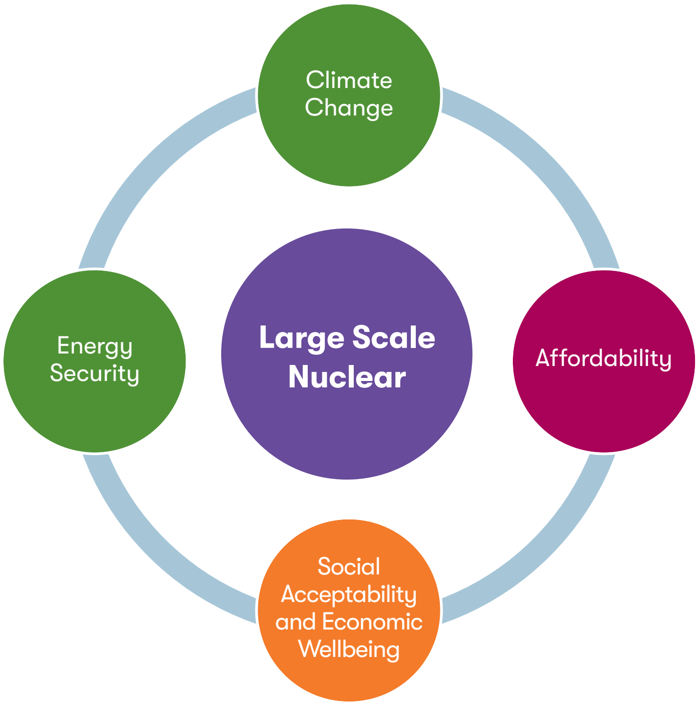
283 UK Government, 15 September 2016, Press release: *Government confirms Hinkley Point C project following new agreement in principle with EDF*, available at: https://www.gov.uk/government/news/government-confirms-hinkley-point-c-project-following-new-agreement-in-principle-with-edf

284 BBC News Website, 17 January 2019, *Nuclear plant in Anglesey suspended by Hitachi*, available at: https://www.bbc.co.uk/news/business-46900918

285 EDF Energy, 2017, Draft Energy Strategy – Consultation Response, available at: http://www.rse.org.uk/wp-content/uploads/2017/12/EDF-Draft-Energy-Strategy.pdf

Key Points

- Nuclear energy provides Scotland with a significant amount of secure, reliable generation.
- Nuclear power has zero carbon emissions at the point of generation and could play a major role in helping Scotland meet is climate targets.
- Replacing the current generation of nuclear power stations would have substantial up-front costs, in addition to the significant investment needed over the longer-term for decommissioning and waste management.
- The future of deep geological disposal would be a significant challenge as would the viability of continuing the current policy of sending spent fuels and certain waste from Scotland to England.



Small Modular Reactors

12 An alternative technology to the large-scale new-build nuclear reactors being developed in England is that of small modular reactors (SMRs). The World Nuclear Association defines SMRs as *"nuclear reactors generally 300 MWe equivalent or less, designed with modular technology..."*[286]

Climate change

13 Nuclear energy has zero carbon emissions at the point of generation and hence has minimal global climate impact.

Affordability

14 Small modular reactors, due to their relative size and nature, can be almost entirely constructed in a factory and put together module by module, resulting in improved construction quality and efficiency. The small size and improved efficiency of construction could result in easier financing when compared to large nuclear plants.[287] As a developing technology, considerable investment would be required.

Energy security

15 The viability and performance of SMRs is being actively investigated by the UK Government and the Nuclear Decommissioning Authority (NDA), and subjected to generic design assessments by the Office for Nuclear Regulation (ONR).

16 The International Atomic Energy Agency (IAEA) notes that around 50 SMR designs and concepts exist globally and are in various stages of development, with four reactors in advanced stages of construction in Russia, China and Argentina.[288] Despite this, there is considerable technological uncertainty around when, and if, certain designs will become viable.

286 World Nuclear Association, 2015, *Facilitating International Licencing of Small Modular Reactors*, p4, available at: http://www.world-nuclear.org/uploadedFiles/org/WNA/Publications/Working_Group_Reports/REPORT_Facilitating_Intl_Licensing_of_SMRs.pdf

287 World Nuclear Association, 2015, *Facilitating International Licencing of Small Modular Reactors*, p3

288 International Atomic Energy Agency website, *Small modular reactors*, available at: https://www.iaea.org/topics/small-modular-reactors

Social acceptability and economic wellbeing

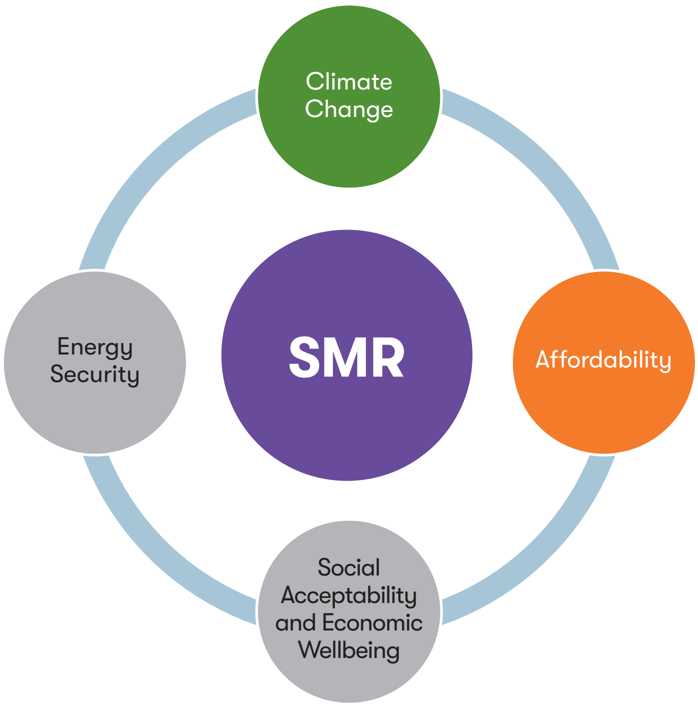
17 Molten salt- and sodium metal-based SMRs such as PRISM and MOLTEX, which can deliver 300 MW, may also be able to utilise and 'reprocess' existing UK plutonium stocks as a fuel and vastly reduce its radioactivity, thereby improving the acceptability of nuclear energy in the long term. Reusing stockpiled plutonium for civil programmes could also have the potential additional benefit of mitigating nuclear proliferation.

18 Due to some of the potentially unique features of SMRs – compact nature, lower power, smaller water requirements – they could be developed to serve isolated electrical systems in islands or remote areas, and could be compatible with district heating.[289]

19 Utilising its devolved planning powers, current Scottish Government policy is not to approve any new nuclear power stations that are based on existing technology. Although it is not clear whether this restriction extends to SMRs, the Scottish Government acknowledges in the Scottish Energy Strategy that it is *"duty bound to assess new technologies and low-carbon energy solutions"*.

Key Points

- SMRs could provide many of the benefits of large-scale nuclear energy, but in a form that may prove more acceptable to the public.
- There is a high level of uncertainty over how long this technology will take to sufficiently develop.



289 World Nuclear Association, 2015, *Facilitating International Licencing of Small Modular Reactors*, p6

Renewables

Bioenergy

1 Bioenergy is energy derived from biomass. First-generation liquid biofuels, such as biodiesel or cereal-derived ethanol, are not thought to have a bright future, due to the relatively poor lifecycle greenhouse gas emissions that arise from fertilization and other land management practices needed to grow the annual crops from which they are derived.[290]

2 Second-generation energy crops are ligno-cellulosic in nature; for example, from forest and agricultural residues or from dedicated energy crops, such as the fast-growing grass *Miscanthus*, or fast-growing trees such as poplar or willow, which are either coppiced or harvested whole and replaced.[291]

3 The biomass of second-generation energy crops can be converted to liquid transport fuels, for example by the Fischer-Tropsch process,[292] or can be burned in power stations to generate power. Since burning biomass for power produces heat, smaller scale combined heat and power (CHP) plants have been suggested as the most efficient use of biomass for energy.[293]

Climate change

4 A recent study examined the potential in Scotland for combining combustion of biomass for energy with carbon capture and storage, so-called bioenergy with carbon capture and storage (BECCS). This study suggested a climate change mitigation potential of ~6–23 $MtCO_2e$ per year, derived from a domestic biomass supply of energy crops on 520,000 ha of highly suitable land.[294]

5 Bioenergy, or BECCS, could make significant contributions to achieving Scotland's climate change targets. With the potential to replace fossil fuels in power generation, and the possibility to provide net atmospheric greenhouse gas removal *via* BECCS, bioenergy is a viable component of Scotland's energy portfolio.

Affordability

6 Studies show that growing biomass for energy is marginally or not profitable, meaning that incentives, or guaranteed markets/pricing might be required to promote domestic biomass production for bioenergy. However, relatively small increases in the price of biomass makes biomass growth viable, with competitive costs for the energy produced.[295]

Energy security

7 Estimates have been made of the potential in Scotland for producing biomass domestically for use as bioenergy for power, with a total potential of 7.35 GW – current total capacity in Scotland is around 13 GW.[296] The area of dedicated energy crops required to generate this power[297] is estimated to be 20,000 km^2 – around a quarter of the entire land mass of Scotland.[298]

290 St Clair, S, Hiller, J & Smith, P, Biomass & Bioenergy 32, 2008, *Estimating the pre-harvest greenhouse gas costs of energy crop production*, pp442-452.

291 Hastings, A; Tallis, M.J; Casella, E; Matthews, R.W; Hensall, P.A; Milner, S; Smith, P; & Taylor, G, Global Change Biology Bioenergy 6, 2014, The current and future technical potential of Great Britain to produce cellulosic and woody biomass for bioenergy production, pp 108–122

292 Wikipedia, Fischer–Tropsch process, available at: https://en.wikipedia.org/wiki/Fischer%E2%80%93Tropsch_process

293 Wang, S; Hastings, A; Wang, S.C; Sunnenberg, G; Tallis, M.J; Casella, E; Taylor, S; Wang, C; Alexander, P; Cisowska, I; Lovett, A; Taylor, G; Firth, S; Finch, J; Moran, D; Morison, J; & Smith, P; Global Change Biology Bioenergy 6, 2014, *The potential for bioenergy crops to contribute to meeting GB heat and electricity demands*, pp 136–141.

294 Alcalde, J; Smith, P; Haszeldine, R.S; & Bond, C; International Journal of Greenhouse Gas Control 76, 2018, *The potential for implementation of Negative Emission Technologies in Scotland*, pp 85–91.

295 Alexander, P; Moran, D; Rounsevell, M.D.A; Hillier, J; & Smith, P; Global Change Biology Bioenergy 6, 2014, *Cost and potential of carbon abatement from the UK perennial energy crop market*, pp 156–168. DOI: 10.1111/gcbb.12148.

296 Scottish Government, 2018, Energy in Scotland 2018 – renewables (9GW) + nuclear (2GW) + fossil fuels (1.3GW) + pumped hydro (0.74GW)

297 Andersen, R.S; Towers, W; & Smith, P, Biomass & Bioenergy 29, 2005, *Assessing the potential for biomass energy to contribute to Scotland's renewable energy needs*, pp 73-82.

298 Scotland Info Guide, Scotland Facts and Figures, available at: https://www.scotlandinfo.eu/scotland-facts-and-figures/

8 A UK-wide estimate of the potential for biomass energy from small-scale CHP plants in 2014, using only domestically produced biomass at then-current biomass prices was 1.6 GW per year.[299]

9 Other forms of energy from biomass include anaerobic digestion (AD) to produce methane, which is then combusted to produce heat and power. AD currently supplies 45 MWe of power and 11,000 m^3/hr of heat in Scotland.[300]

Social acceptability and economic wellbeing

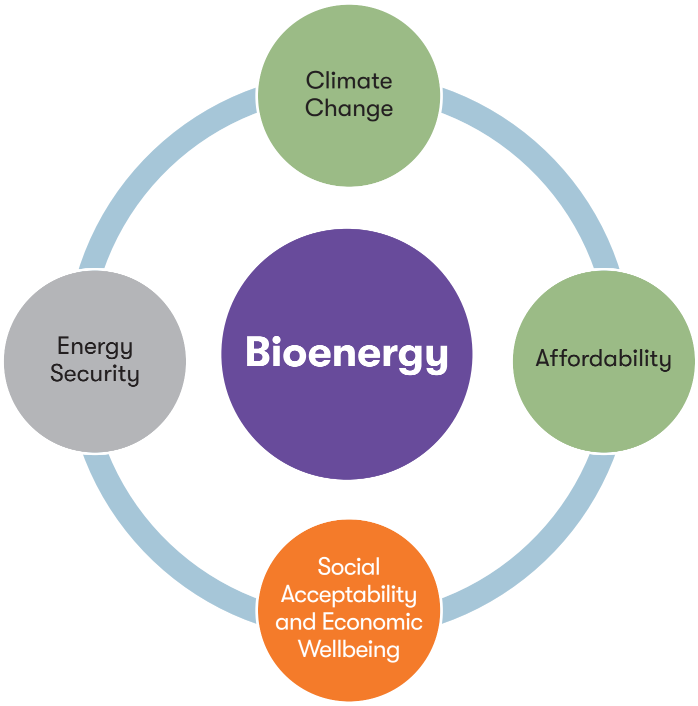
10 Much of the biomass used to feed the UK's only bioenergy power plant, Drax, in Yorkshire, is currently sourced from abroad,[301] raising similar import challenges to, for example, imported coal or LNG. The relatively low energy density of biomass means that large volumes need to be transported. There are few safety concerns with either domestically-produced or imported biomass.

11 However, relying heavily on imported biomass for use in energy production from countries that may have less rigorous environmental protection legislation, could export the environmental impact of energy generation to other countries. Relying on imported biomass from abroad could therefore be considered inconsistent with Scotland taking responsibility for its energy use.

12 Environmental impacts of large-scale cultivation of biomass for energy include potential negative effects on biodiversity,[302] food production,[303] and land water and nutrient requirements,[304] which all increase with scale.

Key Point

- Relying on bioenergy to produce a significant amount of generation would require mass importation of biomass or a vast area of Scotland's land being dedicated to energy crops.



299 Alexander, P; Moran, D; Smith P; Hastings, A; Wang, S; Sunnenberg, G; Lovett, A; Tallis, M.J; Casella, E; Taylor, G; Finch, J; & Cisowska, I; Global Change Biology Bioenergy 6, 2014, *Estimating UK perennial energy crop supply using farm scale models with spatially disaggregated data*, pp 142–155

300 Aerobic Digestion, 8 January 2018, *Aerobic Digestion in Scotland Key to new Scottish Energy Strategy*, available at: https://blog.anaerobic-digestion.com/anaerobic-digestion-in-scotland-scottish-energy-strategy/

301 Drax, Responsible Sourcing, available at: https://www.drax.com/sustainability/sourcing/

302 Smith, P; Price, J; Molotoks, A; Warren, R; & Mahli, Y; Philosophical Transactions of the Royal Society, A. 376, 20160456, 2018, *Impacts on terrestrial biodiversity of moving from a 2 C to a 1.5 C target*. DOI: 10.1098/rsta.2016.0456.

303 Heck, V; Gerten, D; Lucht, W; & Popp, A; Nature Climate Change, 2017, *Biomass-based negative emissions difficult to reconcile with planetary boundaries*. DOI: 10.1038/s41558-017-0064-y.

304 Smith, P; Davis, S.J; Creutzig, F; Fuss, S; Minx, J; Gabrielle, B; Kato, E; Jackson, R.B; Cowie, A; Kriegler, E; van Vuuren, D; Rogelj, J; Ciais, P; Milne, J; Canadell, J.G; McCollum, D; Peters, G; Andrew, R; Krey, V; Shrestha, G; Friedlingstein, P; Gasser, T; Grübler, A; Heidug, W.K; Jonas, M; Jones, C.D; Kraxner, F; Littleton, E; Lowe, J; Moreira, J.R; Nakicenovic, N; Obersteiner, M; Patwardhan, A; Rogner, M; Rubin, E; Sharifi, A; Torvanger, A; Yamagata, Y; Edmonds, J; & Yongsung, C; Nature Climate Change 6, 2016, *Biophysical and economic limits to negative CO_2 emissions* pp 42-50.

Solar Energy

1 There are four main ways of employing solar energy: 'passive' solar; solar photovoltaics (PV); solar thermal; and concentrating solar.

2 Passive solar refers to the use of sunlight to provide some or all of the heat required by buildings. This exploits the heat gain from sunlight heating the interior of the building via windows.

3 Solar PV converts sunlight directly to electricity. It does this using panels which produce direct current and, once connected together, use an inverter to produce standard 50 Hz electricity.

4 Solar thermal commonly refers to the conversion of sunlight to hot water. A collector absorbs radiation, with the standard designs being flat plate collectors, which are cheap and robust, resembling black radiators with double glazing on top; and evacuated tube collectors that comprise rows of glass tubes which have higher efficiency, particularly in winter. The heat from the panels is transferred into hot water, which is normally stored in a well-insulated water tank. This can be used to replace or pre-feed hot water from boilers. It is also possible to use the heat in low-temperature heating systems.

5 Concentrating solar power uses mirrors to focus sunlight to achieve high temperatures to generate electricity. Some of the heat can be stored to enable generation during night time as required. This technology requires a high proportion of intense direct sunlight to operate and is not suitable for Scotland.

6 Hot water from solar thermal is readily stored in tanks for daily use or as part of much larger community schemes to store heat from summer to provide heat in winter. There are examples in Denmark and the technology looks credible for Scotland.[305] PV can work effectively with storage, with some domestic PV inverters designed to work directly with storage batteries. Additionally, it is possible to divert power that would otherwise be exported to thermal storage as hot water or using phase change materials (e.g., Sunamp). Storage is already a growing part of larger-scale PV farms and provides value in controlling when power is exported to the grid, to maximise sales price or avoid curtailment in constrained networks.

Climate change

7 Solar PV and solar thermal have moderately low lifecycle greenhouse gas emissions,[306] which arise largely from the materials and manufacturing stages. The energy payback is a few years. In some types of silicon-based PV panels, very small amounts of toxic materials are used. Many EU manufacturers are starting to recycle PV modules at end of life.[307]

Affordability

8 While there are site-specific costs associated with residential and particularly large-scale solar, the systems are modular and approaches to fitting and fixing them are well established. As such, the variation in the cost per kWh is a function of resource levels and panel efficiency.

305 R. Renaldi and D. Friedrich, 2019, *Techno-economic analysis of a solar district heating system with seasonal thermal storage in the UK*, Applied Energy, 236, pp. 388 – 400.

306 Parliamentary Office of Science and Technology (POST), October 2006 (a), *Carbon Footprint of Electricity Generation*

307 Boyle G, 2011, *Renewable Energy Power for a Sustainable Future*

9 Capital costs for solar PV have come down very significantly as a result of economies of scale. IRENA[308] notes an 83% fall in PV module prices between 2010 and 2017. Large-scale solar PV has seen the largest reductions, with overall capital costs for UK solar farms declining by 76% between 2010 and 2017.[309] This has continued, with the STA estimating 2019 levelised costs as £75.50/MWh[310]. BEIS[311] estimate 2020 costs of £67/MWh, with the STA[312] estimating further reductions to around £50/MWh by 2030. Subsidy-free solar farms integrated with storage systems are now being developed. Small-scale PV has seen smaller cost reductions, around 44% between 2013 and 2017.[313] Levelised costs are estimated at around 15p/kWh in 2017 (in 2016 prices).

10 With modest take up of solar thermal, costs have not reduced to the same extent. A typical system costing around £4,500 provides modest financial savings over standard water heating systems. However, significantly raising installation rates could deliver economies of scale and lower costs.[314]

Energy security

11 Scotland has relatively modest solar energy resources. With substantial cloud cover, Scotland has relatively low irradiance and a high proportion of diffuse radiation; it can, however, experience very clear days with lots of direct sunlight. Latitude plays a major part in this, as average annual irradiance declines northwards: around 117 W/m² in Southampton to 98 W/m² in Edinburgh, to 82 W/m² in Lerwick.[315]

12 Solar radiation is seasonal, with average monthly irradiance in December around one-tenth that of June.[316] This is broadly opposite to the electricity demand pattern. The variation in available irradiance is also compounded by seasonal patterns of cloud cover. In addition to the seasonal variation, solar radiation varies substantially on a range of time scales. It follows a well-defined daily pattern, although this is heavily influenced by the level of cloud cover, and at individual sites varies on a minute-to-minute basis as clouds transit.

13 While short-term variation can be reasonably high at individual sites, geographical diversity reduces the variability of aggregate levels of solar radiation. This means that portfolios of installations tend to have a smoother and more reliable pattern. It is not, however, available at peak electricity periods on cold, dark nights in winter.

14 The Committee on Climate Change[317] estimate UK-wide potential for rooftop solar PV as 110 TWh per year from 135 gigawatt-peak (GWp) of panels, using analysis of aggregate building plan area and assuming production of 850 kWh/year per kW of capacity. Estimates for ground-mounted installations are based on land area employed and the density of panels. The density of solar farms varies, but is typically 2 ha per MW. Using 0.1% of UK agricultural land for solar farms would house 10 GW of capacity and produce around 8.5 TWh/year. More extreme estimates suggest that covering 5% of the UK with PV would yield 1,100 TWh/year, albeit requiring 1,250 GW capacity.[318]

308 International Renewable Energy Agency (IRENA), 2018, *Renewable Power Generation Costs in 2017*

309 Parliamentary Office of Science and Technology (POST), October 2006 (b), Carbon Footprint of Electricity Generation

310 Solar Trade Association, 2019, *Cost reduction potential for UK large-scale PV (LCOE)*

311 BEIS, *Electricity Generation Costs*, 2016

312 Solar Trade Association, 2019, *Cost reduction potential for UK large-scale PV* (LCOE)

313 Parliamentary Office of Science and Technology (POST), 2019 (c), *Carbon Footprint of Electricity Generation*

314 Ramos, I Guarracino, A Mellor, D Alonso-Álvarez, P Childs, N. Ekins-Daukes, C N. Markides, May 2017, *Solar-Thermal and Hybrid Photovoltaic-Thermal Systems for Renewable Heating*. Grantham Institute Briefing Paper No 22

315 D Burnett, E Barbour, G.P. Harrison, 2014, *The UK solar energy resource and the impact of climate change*. Renewable Energy, 71, pp. 333–343

316 D Burnett, E Barbour, G.P. Harrison, 2014, *The UK solar energy resource and the impact of climate change*. Renewable Energy, 71, pp. 333–343

317 Committee on Climate Change, 2011, *The Renewable Energy Review*

318 D. J. Mackay, 2009, *Sustainable Energy – Without the Hot Air*, available at: https://www.withouthotair.com/

15 Estimates of the rooftop PV potential in Scotland for the Scottish Institute for Solar Energy Research[319] (SISER) used the footprint of 600,000 domestic and commercial buildings and 750–800 kWh/kWp/year insolation levels to suggest around 7 GW of rooftop PV could deliver around 5.6 TWh, around one sixth of current electricity demand. This can be extrapolated to solar farms constructed on arable or grass land: developing 0.5% of the 1.9 million ha available for PV would equate to 4.8 GW and 3.7 TWh/year.

16 Estimates for solar thermal follow a similar approach to PV. Sir David Mackay posited that covering south-facing roofs with the equivalent of 10 m² of panels per person could supply 280 TWh/year. Other estimates suggest that providing half of UK homes with a solar water heater would require around 50 million m² of collectors, delivering around 12 TWh of heat.[320]

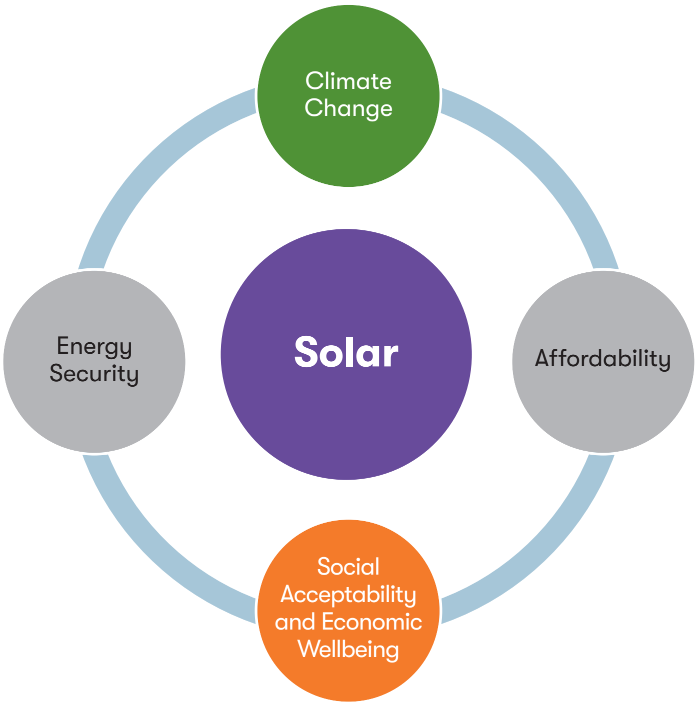
Social acceptability and economic wellbeing

17 Much of the equipment for solar PV is manufactured abroad, typically in Germany, Japan and China, although it can be reasonably efficiently transported. This is broadly similar for solar thermal, although there are domestic manufacturers, including AES Solar, headquartered in Forres.

18 For large-scale PV farms there is clearly an impact on land use, although it is possible to graze livestock between the panels. There are few safety concerns with either domestically-produced or imported PV or solar thermal technologies.

Key Points

- Increased use of solar power could play a role in helping Scotland reach its climate targets.
- In order for solar energy to play a significant role in generation, a very significant amount of space for solar panels would be required.



319 Scottish Institute for Solar Energy Research, 2014, *Solar Energy: A viable Contributor to Renewables in Scotland.*
320 Boyle G, 2011, *Renewable Energy Power for a Sustainable Future*

Wind Energy

1 Scotland has excellent wind resources due to the regular passing of low pressure systems across the North Atlantic.

2 The power available is sensitive to wind speed and a range of factors influence wind speeds, at a given site. Specific aspects of the terrain promote or reduce wind speeds, with mountainous areas and offshore areas experiencing higher speeds. The west and north of Scotland tend to have the highest wind speeds.

3 Commercial wind technology has settled on the three-blade horizontal axis turbine. Wind turbines range from a few kilowatts to around 10MW. A typical onshore wind turbine is rated at around 3MW, but larger 5MW units are commercially available, with blades approaching 100m long. Wind farms range from single turbines up to hundreds of megawatts. Offshore technology is essentially the same, but turbines are larger (6MW at present) and foundations depend on the water depth. In shallow water, turbines are fixed to the seabed using monopiles driven into the seabed or a jacket structure, similar to oil and gas infrastructure. In deep water, floating foundations are necessary, including floating vertical tubes (as used for the Hywind project off the coast of Aberdeen), submerged floating structures, and tension-leg anchor systems, again borrowed from oil and gas infrastructure.

Climate change

4 Onshore and offshore wind have relatively low lifecycle greenhouse gas emissions,[321] which arise largely from the materials and manufacturing stages. Carbon and energy payback is typically a few months, but construction of wind farms on peatlands[322] can extend carbon paybacks.[323]

Affordability

5 Costs for wind have maintained a downwards trend. Over the period from 1989, UK levelised costs for onshore wind fell by two thirds[324] While capital costs fell, a major source of the reduction has been major growth in productivity arising from larger, more efficient turbines. The first contracts for difference auction (in 2015) saw many onshore wind farms funded at around £80/MWh for delivery in 2018–19. BEIS[325] estimate larger onshore wind farms will have a levellised cost around £63/MWh in 2020 (in 2014 prices).

6 Offshore changes have been more dramatic. Reports for the UK Government in around 2012 estimate levelised cost for the large Round 3 sites centred around £150/MWh (in 2011 prices).[326] BEIS2016 assessments saw Round 3 site costing around £106/MWh in 2020.[327] The 2017 CfD auction saw offshore wind projects successful at strike prices of £57.5/MWh (in 2012 prices). The major gains relate to economies associated with fewer, larger turbines, greater experience and substantial industry collaboration.

7 The strike prices mentioned above, agreed for onshore wind farms in 2015 and offshore wind farms in 2017, both compare favourably to nuclear energy in the form of Hinkley Point C, which has an agreed strike price of £92.5 per MWh.

321 Parliamentary Office of Science and Technology (POST), October 2006 (d), *Carbon Footprint of Electricity Generation*

322 Nayak, D.R., Miller, D., Nolan, A., Smith, P. and Smith, J.U, Mires and Peat, 4(09), 2010, *Calculating carbon budgets of wind farms on Scottish peatlands* pp. 1–23.

323 A carbon calculator developed by the Scottish Government for determining the carbon impact of wind farm developments in Scotland is available at: https://informatics.sepa.org.uk/CarbonCalculator/index.jsp

324 International Renewable Energy Agency (IRENA), 2018, Renewable Power Generation Costs in 2017

325 BEIS, Electricity Generation Costs, 2016

326 C. Thomson and G Harrison, 2015, *Life Cycle Costs and Carbon Emissions of Wind Power*, ClimateXchange

327 BEIS, 2016, Electricity Generation Costs

Energy security

8 Wind power is strongly seasonal, with average monthly power in January approximately double that of July.[328] This aligns well with prevailing patterns of electricity demand. In addition to the seasonal variation, wind power varies substantially on a range of time scales. While daily patterns are pronounced at coastal locations, variations occur on a minute-to-minute basis (gusts) as well as a typical four-day pattern associated with passing weather systems. In addition, wind speeds offshore tend to be more reliable. As with solar, wind benefits from portfolio effects. The availability of wind at peak electricity demand periods varies from year to year and can be very high or on occasion very low during very cold periods.

9 Wind can be integrated with storage, although there has to date been limited uptake of site level storage, as typical four-day patterns of wind imply very large storage requirements. However, modest storage may become part of larger-scale farms, to provide value in controlling timing of export to the grid to maximise sales price or reduce curtailment in constrained networks.

10 Estimates have been made for UK-wide wind potential using assumptions about the capacity and characteristics of turbines, their spacing and wind speeds. These are then screened to omit places that might be unsuitable for wind (for example, urban, mountainous, or protected areas, or spaces which could impact on aviation or shipping) and minimum average wind speeds.

11 The Committee on Climate Change estimates UK-wide practical potential for onshore wind to be 80 TWh per year, based on 25 GW of capacity. More extreme examples have estimated onshore wind could provide 434 TWh per year using 10% of UK land.[329] The practical potential from fixed offshore wind is estimated at 400 TWh from 116 GW of capacity,[330] with a further 1,533 TWh from 350 GW of floating offshore wind, although much lies over 100 nautical miles offshore.

12 Estimates of the wind potential in Scotland suggest a practical onshore potential of 11.5 GW, including application of a local authority level 'capacity limit' derived from experience in Denmark.[331] This yields in excess of 40 TWh per year. Offshore, the practical potential is significantly higher, with 46 GW of fixed offshore wind (162 TWh) and 123 GW of floating (537 TWh).[332]

Social acceptability and economic wellbeing

13 The major wind turbine manufacturers are based in Germany, Denmark, China and the USA. Turbines can be reasonably efficiently transported on specialised vessels and vehicles. There are a number of UK manufacturing sites, typically for the tower and foundations, and the 'UK content' of turbines is growing. Certain types of turbine, however, require rare earth elements. Neodymium, which is an essential component of permanent magnets of some turbines, is costly to mine and process, with China estimated to control more than 95% of supply of the metal.[333]

14 Much of a turbine is recyclable and this is now realistically becoming the case for the glass and carbon fibre blades. The impact on land use is moderate, as the turbine bases are modest and well spaced out. There are few safety concerns with turbines, although there are documented failures and fires.

328 G Sinden, Energy Policy, 35, (1), 2007, *Characteristics of the UK wind resource: Long-term patterns and relationship to electricity demand*, pp. 112–127.

329 Mackay, D., 2009, *Sustainable Energy – Without the Hot Air*

330 The Offshore Valuation Group, 2010 (a), *The Offshore Valuation: A valuation of the UK's offshore renewable energy resource*, OVG, Machynlleth.

331 Garrad Hassan, 2001, Scotland's Renewable Resource, Scottish Executive.

332 The Offshore Valuation Group, 2010 (b), *The Offshore Valuation: A valuation of the UK's offshore renewable energy resource*, OVG, Machynlleth.

333 Zero Waste Scotland, 2014, Wind Turbine Magnets Study, p4, accessible at: http://www.wrap.org.uk/sites/files/wrap/Wind%20Turbine%20Magnet%20Study.pdf

15 A major area of contention for wind energy is the visual impact, particularly with concentrations of wind farms, as well as some issues associated with shadowing and noise pollution. This is particularly the case for communities in rural areas, where onshore wind farms are generally located, although concerns have also been raised regarding offshore wind farms which can be seen from the coast.

16 A set of Good Practice Principles for Community Benefits from Onshore Renewable Energy Developments was published by the Scottish Government in 2014,[334] with a public consultation and review of the relevance of the principles beginning in late 2018. The Principles promote a national rate for onshore wind community benefits packages equivalent to at least £5,000 per MW per year.[335] A similar document and consultation addressing Good Practice Principles for Shared Ownership of Renewable Energy Developments was also published.[336]

17 Continued expansion of, particularly onshore, wind development in Scotland will require two-way engagement with the communities in close proximity to where they are placed. It is important that rural and remote communities are not, and do not consider themselves to be, unfairly burdened with wind farms which serve to power further-away urban areas.

Key Points

- Scotland has very considerable wind energy resources, but attempting to harness these onshore requires significant areas of land and local support.
- Further onshore wind development could play a significant role in helping Scotland meet its energy demand, while simultaneously reducing carbon emissions.
- The variable nature of wind energy means that large-scale storage, or another form of generation, would likely be required in tandem.

334 The Scottish Government, 2014, Scottish Government *Good Practice Principles for Community Benefits from Onshore Renewable Energy Developments*

335 The Scottish Government, 2014, *Scottish Government Good Practice Principles for Community Benefits from Onshore Renewable Energy Developments*, p4

336 The Scottish Government, 2018, Scottish Government *Good Practice Principles for Shared Ownership of Renewable Energy Developments*, available at: https://www.gov.scot/publications/consultation-scottish-government-good-practice-principles-shared-ownership-renewable-energy-developments/

Key Points

- Developing Scotland's extensive wind resources offshore would allow Scotland to generate electricity without many of the social concerns surrounding onshore development.
- Offshore wind could play a significant role in helping Scotland meet its energy demand, while simultaneously reducing carbon emissions.
- The variable nature of wind energy means that large-scale storage, or another form of generation, would likely be required in tandem.

Wave and Tidal Energy

1 Scotland is widely regarded as having among the best wave and tidal energy resources in the world. This arises due to its position at the edge of the Atlantic, where the passing storms create powerful waves, while its position between the Atlantic and the North Sea and complex coastline and channels creates substantial tidal currents and variation in tidal range.

Climate change

2 Wave and tidal energy have relatively low lifecycle greenhouse gas emissions, which arise largely from the materials and manufacturing stages.[337] These are a little higher than wind, but this reflects the earlier development stage. Carbon and energy payback is typically a year.

Affordability

3 The £15 billion (in 2007 prices) cost of the Severn Barrage and the more recent £1.3 billion Swansea Bay lagoon are well documented. There is relatively limited scope to reduce costs with these schemes and as single, large-scale projects, these struggle in the current energy market as they represent major and risky investments.

4 As developing technologies, costs for wave and tidal are currently well above those for offshore wind. With only a few MW of capacity installed worldwide, there has been little scope for significant learning by doing, economies of scale or cost of capital reductions. BEIS[338] 2016 estimates suggest 2025 levelised costs for wave are £320/MWh and £328/MWh for tidal stream, although there is significant uncertainty around these figures. The Offshore Renewable Energy Catapult[339] suggests that significant cost reductions would be delivered using a similar approach as that used for offshore wind of accelerated development and utility scale development. For tidal stream this could see costs reduce to around £150/MWh with 150 MW installed and to around £80/MWh with 1 GW installed. Although ORE Catapult regarded cost reductions for wave as being 'too early to analyse', a 2015 IEA report[340] suggests that as wave projects moved towards first commercial scale levelised costs would fall, although the range is broad: £73 and £284/MWh.

Energy security

5 The power available in waves is very sensitive to wind speeds. Wave energy reduces in shallower water, so the highest resource is in deeper water. The west and north of Scotland tend to have the best resource, with an average of around 40 to 50 kW/m of wave front available off the Outer Hebrides.[341]

6 Wave power is strongly seasonal, with average monthly power in winter approximately five times that of summer.[342] This aligns well with prevailing patterns of electricity demand. In addition to the seasonal variation, wind power varies on a range of timescales of individual waves, as well as passing weather systems.

7 As with wind and solar, wave benefits from geographical diversity. The availability of wave at peak electricity demand periods varies from year to year, but broadly follows that of wind, albeit delayed by a number of hours.

337 Parliamentary Office of Science and Technology (POST), October 2006, Carbon Footprint of Electricity Generation, London,.

338 BEIS, Electricity Generation Costs, London, 2016.

339 Offshore Renewable Energy Catapult, April 2018, *Tidal Stream and Wave Energy Cost Reduction and Industrial Benefit*

340 IEA, May 2015, International Levelised Cost of Energy for Ocean Energy Technologies

341 Dept Business Enterprise and Regulatory Reform (BERR), March 2008, *Atlas of UK Marine Energy Resources*

342 Dept Business Enterprise and Regulatory Reform (BERR), March 2008, *Atlas of UK Marine Energy Resources*

8 Tidal range and stream are governed by the relative position of the Moon and Sun and are very predictable. The main variability is on approximately 12.5-hour and 14-day Spring neap cycles. The 12.5-hour cycle sees tidal height go from a maximum and minimum height, while tidal flows typically move between maxima in opposite directions with slack water in between. The Spring neap cycle has a strong influence on potential power generation, with production at the lowest part of the cycle (neap) around 15% of the maximum for tidal range and 25% of maximum for tidal stream.[343] There is some difference in the timing of peak range and flood around the UK, but the overall effect at suitable sites is moderate.[344] As the timing of tides varies from day to day, there is no strong association with demand.

9 Wave energy remains an early-stage technology, with some successes and well documented failures in concepts and development vehicles. Development of successful concepts is challenging, given the need to optimise production over a wide range of conditions, ensuring survival in major storms, where power levels can exceed a megawatt per metre of wavefront. Development is on-going, with a number of UK and overseas companies developing and testing devices in Scotland's scale test facilities at Flowave (University of Edinburgh) and at full scale at the European Marine Energy Centre.[345]

10 Tidal stream relies on specific bathymetric conditions in order to create flows of fast moving water, typically between islands or around headlands. In Scotland, the Pentland Firth, Orkney and Islay offer substantial opportunities. While now further down the development track than wave, the technology is still in development and a wide range of concepts have been developed and tested. There is a degree of convergence in technology towards horizontal axis, two- or three-bladed turbines with rotor diameters of between 10m and 20m. These are similar in arrangement to wind turbines and appear to have good levels of reliability. Fixed foundation concepts are similar to offshore wind, along with floating concepts such as Orbital's twin rotor system mounted on a floating tube and Nautricity's fully submerged device. Most of the devices aim for megawatt scale, but some companies, notably Edinburgh-based Nova Innovation, have deliberately targeted smaller-scale devices to minimise development risks. Development and testing is carried out at the same facilities as for wave.

11 Estuaries with specific characteristics are necessary for tidal range. A mature technology based largely on low head hydropower, it involves substantial civil engineering works for barrages across estuaries or self-contained lagoons, with operational approaches that are well understood. There are a small number of suitable sites around the UK. The Severn Estuary in particular has seen proposals for a 16-km, 8-GW barrage[346] and a 320-MW, 9-km lagoon in Swansea Bay considered in recent years. In Scotland, the Solway Firth remains the main opportunity, although some way behind the Severn in suitability.

12 Wave and tidal devices can be integrated with storage. The Pelamis wave concept had a small amount of hydraulic storage on board. Tidal range is in essence a storage scheme, although the scope to vary production is limited. The nature and predictability of the tidal cycle means it is well suited to work in tandem with storage. Again, similar benefits to wind and PV are possible.

343 A. Iyer, S. Couch, G. Harrison, A. Wallace, Renewable Energy, 51 (2013), *Variability and phasing of tidal current energy around the United Kingdom*, pp. 343 – 357.

344 A summary of the effectiveness of support for UK wave energy innovation conducted is available at: https://strathprints.strath.ac.uk/62210/

345 A summary of the effectiveness of support for UK wave energy innovation conducted is available at: https://strathprints.strath.ac.uk/62210/

346 Sustainable Development Commission, 2007, *Turning the Tide: Tidal Power in the UK.*

13 Estimates have been made for UK-wide wave and tidal potential. The Offshore Valuation[347] estimated potential to be 18 GW of wave (yielding 40 TWh/year), 33 GW of tidal stream (yielding 116 TWh/year) and 14 GW of tidal range (yielding 36 TWh/year). There is quite a wide variation in tidal stream resource estimates, relating to uncertainty over the correct method for estimation; these range from 18 to 200 TWh/year.[348]

14 The Scottish potential is estimated at 15 GW of wave (34 TWh/year), 18 GW of tidal stream (64 TWh/year) and 4 GW of tidal range (9 TWh).[349]

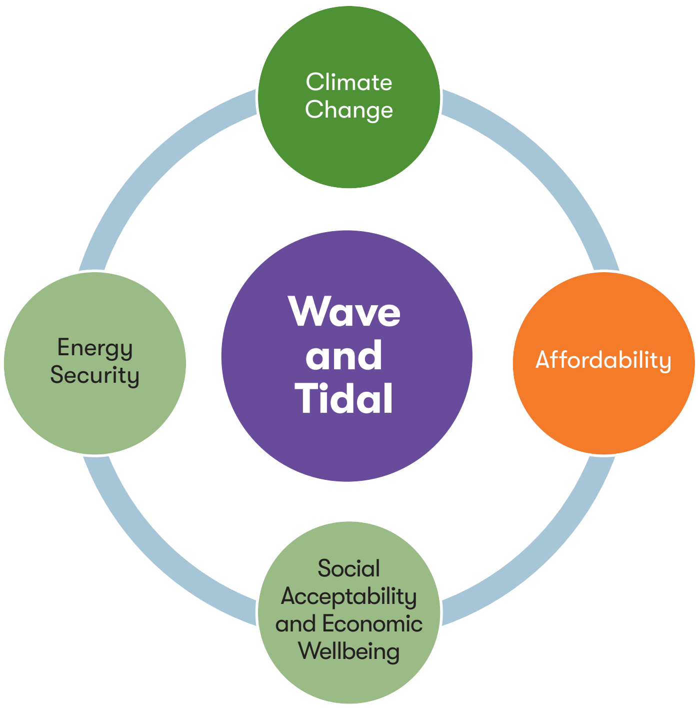
Social acceptability and economic wellbeing

15 The major developers of wave and tidal stream are and have been based in Scotland, but there are also manufacturers from the EU, Australia and Asia. Some manufacturers, such as Nova, have explicit policies of maximising 'UK content' of turbines.

16 There are few safety concerns with wave and tidal. The major area of contention has been impact on aquatic species, but the effects appear fairly modest,[350] although barrages have more significant impacts.

Key Points

- Scotland has some of the best wave and tidal resources in the world and utilising them could help Scotland meet its climate targets.
- Development of wave and tidal energy would require high levels of investment.



347 The Offshore Valuation Group, 2010, The Offshore Valuation: *A valuation of the UK's offshore renewable energy resource*, OVG, Machynlleth.

348 Committee on Climate Change, 2011, *The Renewable Energy Review*

349 The Offshore Valuation Group, 2010, The Offshore Valuation: *A valuation of the UK's offshore renewable energy resource*, OVG, Machynlleth.

350 Bonar, P.A.J; Bryden, I.G; Borthwick, A.G.L, Renewable and Sustainable Energy Reviews 47, 2015, *Social and ecological impacts of marine energy development*, pp. 486-495.

Hydropower

1 Hydropower harnesses power in falling water, specifically the volume of water and the distance through which it falls – the 'head'. Scotland has good and well exploited resources, due to its topology and the relatively high levels of rainfall, particularly in the north and west.

Climate change

2 Hydro has relatively low lifecycle greenhouse gas emissions, which arise largely from the materials and manufacturing stages.[351] Carbon and energy payback is typically a year or so. There is legitimate concern regarding methane emissions from reservoirs, although this is mainly a feature of shallow tropical reservoirs, and the effects can be minimised by removal of vegetation prior to flooding.

Affordability

3 The site-specific nature of hydro means costs vary substantially. There are generally economies of scale, and schemes with a higher 'head' tend to have lower levelised costs. As a mature technology, there is only moderate scope to reduce costs and many of the best sites have been exploited in Scotland. BEIS[352] estimates large storage hydro to have levelised costs of £80/MWh, with smaller hydro around £95/MWh. Micro hydro of less than 100 kW has costs of around £126/MWh. Pumped storage is expected to cost £148/MWh.

Energy security

4 With only modest amounts of seasonal snow coverage, river flows and hydropower potential in Scotland tends to follow rainfall patterns, with flows in summer very much lower than in winter. This aligns well with prevailing patterns of electricity demand. In smaller rivers, flows can vary substantially over a matter of hours, with longer periods of variation in the larger rivers. The changes are much slower than for wind and PV. While there is some variation between sites, as generation at certain types of hydro is able to be controlled, the availability at peak electricity demand periods is high.

5 Hydropower is a very mature technology, with the first installations in Scotland in the early 20th Century. It can take several forms: 1) run-of-river, using a dam or weir to divert flow through turbines; 2) storage hydro, with more substantial volumes of water retained behind the dam which is released as required for power generation, flood control or other reasons; and 3) pumped storage, using two water bodies with one at elevation. Run-of-river hydro is often seen as small, but there are examples of quite large, high-capacity schemes in Scotland with no effective storage. Although schemes have a standard set of features, they are highly site specific. Schemes can vary from a few kW up to hundreds of MW.

6 Estimates have been made for Scottish and UK-wide hydropower potential, typically either using river flow data and simple rules-of thumb to size schemes or highly complex automated search algorithms underpinned by hydrological modelling.[353] The Committee on Climate Change[354] estimates the practical UK hydropower as 8 TWh/year. Remaining hydro potential in Scotland ranges from 270 MW up to 1 GW, delivering 3.4 TWh/year with the resource level very sensitive to economic assumptions.

351 International Renewable Energy Agency (IRENA), 2018 (d), *Renewable Power Generation Costs in 2017*

352 BEIS, 2016, *Electricity Generation Costs*

353 J. Sample, N. Duncan, M Ferguson and S. Cooksley, Renewable and Sustainable Energy Reviews, 52 2015, *Scotland's hydropower: Current capacity, future potential and the possible impacts of climate change*, pp. 111-122.

354 Committee on Climate Change, 2011 (b), *The Renewable Energy Review*, London.

Social acceptability and economic wellbeing

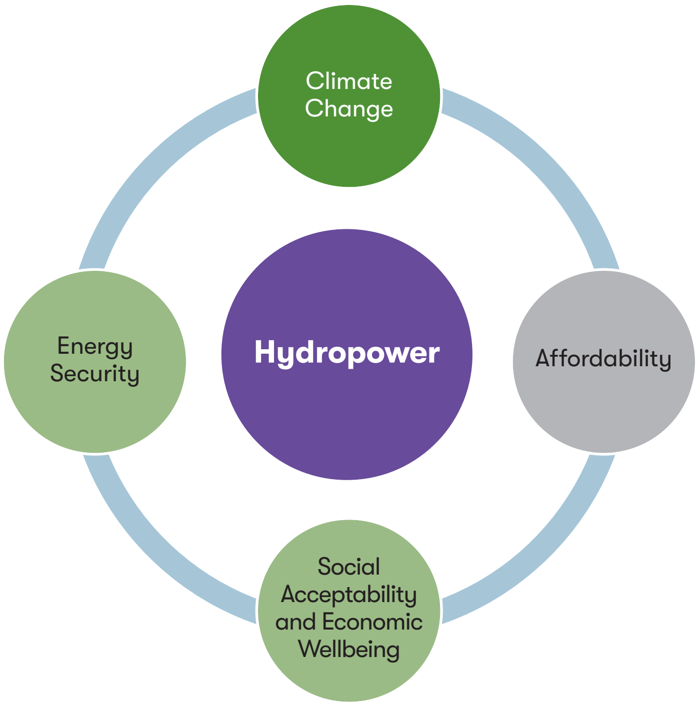
7 Much of the value in hydro schemes relates to civil engineering and UK firms and consultants are well represented internationally. The major turbine and generator manufacturers are based in the EU, North America and Asia, but UK companies do exist.

8 The impact on land use is significant where reservoirs are constructed, but effects on fish populations and flora can be managed effectively with the use of fish ladders and careful rules over compensation flows. There are few safety concerns, although dams must be well maintained and inspected regularly.

9 Hydro has made a made a critical contribution to achieving Scotland's climate change targets. With careful new development and refurbishment of existing schemes, it can continue to be an important part of Scotland's energy portfolio.

Key Point

- Hydropower has played an important role in helping Scotland achieve its climate change targets in the past and, with development, could continue to do so in the coming decades.



Smart Energy Systems

1 The increased deployment of renewable energy generation, including at local levels, has led to a new range of challenges to be addressed. In particular, the electricity grid now has to deal with bi-directional power flow and manage voltage and thermal constraints in real time to avoid costly network reinforcement.

2 At the same time, the variability of renewable energy means that a greater focus on generation and demand management has been necessary. These challenges, and a range of further complex technical electricity grid issues, have led to major programmes of innovation and development in smart grids.

3 A smart grid combines advanced uses of data, control, automation, artificial intelligence and autonomy to ensure that consumers are served electricity from renewable sources while avoiding costly network reinforcement.

4 Significant projects have been funded in the UK through Ofgem, using a range of mechanisms such as the Innovation Funding Initiative (IFI), Low Carbon Network Fund (LCNF), Network Innovation Allowance (NIA) and the Network Innovation Competition (NIC).[355] In November 2018, the UK Energy Research Centre (UKERC) issued its Review of UK Energy System Demonstrators, which details the extent of Scotland's role in these.[356]

Climate change

5 Smart energy systems have the ability to play a positive role in reducing carbon emissions by facilitating the use of local renewable energy generation through addressing challenges associated with variability and demand management.

Affordability

6 The UK has just invested £102.5 million into smart local energy systems through its Industrial Strategy. The Prospering from the Energy Revolution programme within the Industrial Strategy Challenge Fund will deliver designs, demonstrators and academic insight in this area.[357]

7 The investment required for local energy schemes will vary greatly, depending on the location, type and scale of the project. Evidence suggests that the cost of community energy projects varies more than that of commercial projects, but that these costs are decreasing. There may also be opportunities for communities to reduce costs by partnering with commercial developers.[358] Included in the cost of projects is the need for skilled staff, including the correct project management support.

8 The Scottish Government has made £35 million available to support local energy projects through the Community and Renewable Energy Scheme (CARES) since its inception in 2013, with £5 million available in 2018. The scheme, which encompasses grants and loans of up to £150,000, is one of the Scottish Government's primary vehicles to reach its target of 1 GW of local and community energy by 2020 and 2 GW by 2030.[359]

355 Further details can be found via the Energy Networks Association Innovation Portal: (http://www.energynetworks.org/electricity/futures/network-innovation/network-innovation.html)

356 Flett, G; Kelly, N; McGhee, R; UK Energy Research Centre, November 2018, *Review of UK Energy System Demonstrators*, available at: http://www.ukerc.ac.uk/publications/review-of-uk-energy-system-demonstrators.html

357 UK Government, 7 December 2018, *Energy systems of the future: local communities to benefit sooner*, available at: https://www.gov.uk/government/news/energy-systems-of-the-future-local-communities-to-benefit-sooner

358 ClimateXChange, The Comparative Costs of Community and Commercial Renewable Energy Projects in Scotland Executive Summary, available at: https://www.climatexchange.org.uk/media/1893/the_comparative_costs_of_community_and_commercial_renewable_energy_projects_in_scotland.pdf

359 Scottish Government Website, Renewable and low carbon energy, available at: https://www.gov.scot/policies/renewable-and-low-carbon-energy/local-and-small-scale-renewables/

Energy security

9 In Scotland, 666 MW of community- or locally-owned renewable generation capacity already exists, with a further 50 MW under construction, 283 MW consented but not yet built, 101 MW in planning, and 62 MW in scoping. The current capacity is a 12% increase on the previous year and is generated from nearly 18,000 different installations.[360] Greater local renewable generation can assist in Scotland meeting its climate change obligations, both through replacing energy that was previously generated through the use of fossil fuels and as a result of this generation taking place much closer to the point of use, resulting in shorter transport distances.

10 Of this capacity, nearly half is accounted for by wind generation, just over a quarter from biomass, and the rest from a mixture of heat pumps, solar (PV and thermal), hydro, and energy from waste. Around 60% of this is electrical capacity, just under 40% is thermal, with only 1% combined heat and power.[361]

11 The Levenmouth Community Energy Project is an example of such a system in Scotland. The project, which received £4,361,900 of funding through the Local Challenge Energy Fund, uses wind and solar power to produce hydrogen. This hydrogen is stored on-site and can then be reconverted into electricity when wind or solar generation is low, be used to fuel what is hoped will be one of Europe's largest fleet of hydrogen dual-fuel vehicles, and be utilised by the local council's fleet of hydrogen vehicles.[362]

12 The impact of smart local energy systems on security of supply is mixed. While these systems produce energy domestically, lessening our reliance on importing energy, they also often face serious restrictions in connecting to the wider grid.

13 The fact that so many different installations already provide community energy in Scotland illustrates the viability of community energy schemes. Over 40 different locally-owned energy systems projects have been awarded support through the CARES-resourced Innovation and Infrastructure Fund.[363] The viability of individual projects, however, depends heavily on specific local features, including geography. Projects which may be strongly supported and successful in one community or environment may not transfer or scale to other areas of the country.

Social acceptability and economic wellbeing

14 With a recognised research base in energy, technology, data science and wider informatics, Scotland can capitalise on the move from smart grids (electricity focused) to smart energy systems (multi-vector energy focused) and offer new products and services in this area.

15 Scotland could attempt to address several of the challenges it faces related to energy through the adoption and proliferation of smart local energy systems. The Scottish Government, through its Energy Strategy, highlights a smarter local energy model as one of the core principles guiding the Strategy.

16 Smart local energy systems can incorporate different areas, including decentralised energy generation, district heating, smart technologies and the use of data analytics. This could be operated by a commercial or industrial organisation that is looking to gain efficiency, reduce costs or increase resilience in its own energy across a site or region. In addition, under such a system, local communities can take direct responsibility for generating and storing the energy they use and, through community ownership, receive the benefits of reduced costs, profits made from this energy or improved energy resilience.

360 Scottish Government, 2018, *Energy in Scotland 2018*, p2

361 Scottish Government, 2018, *Energy in Scotland 2018*, pp16-17

362 Bright Green Hydrogen, Levenmouth Community Energy Project An industry-leading green hydrogen development, available at: https://www.localenergy.scot/media/77557/LCEP-flyer-FINAL.pdf

363 Local Energy Scotland, IFF Project Summaries, available at: https://www.localenergy.scot/resources/infrastructure-and-innovation-fund-project-summaries/

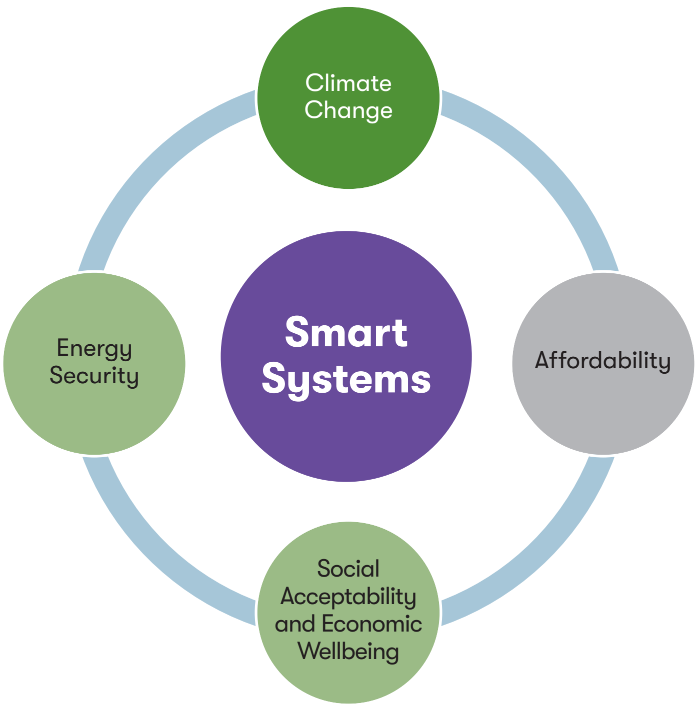
17 A report commissioned by Co-operatives UK and the Co-operative Group in 2013 identified various barriers to connection, including varying standards in distribution network operators (DNOs), process issues, unnecessarily formal connection processes, and the costs of grid reinforcement. The report outlined a package of measures to facilitate connection, including identifying best practice, access to a clearer breakdown of costs, and better communication with DNOs. More fundamentally, the report argued for priority grid access for community projects, the ability for generators to pay back costs over a longer period of time, and the socialisation of the wider costs of reinforcement works.[364]

18 Local systems allow coordination of local supply, storage and use, and put community involvement at the core of the planning process. This ensures that those impacted by energy generation have ownership of the project and share the responsibility and potential benefits, including profits. This ownership also allows communities to incorporate local supply chains and seek to employ people from within the community. This can also help to build community unity and resilience.

19 A move towards increased use of smart local energy systems would require potentially significant behavioural changes in those using the systems. The public may need to be educated into considering energy use as more of a community than individual endeavour and this would require investment. Agreement and co-operation on projects may also be more easily gained in rural and remote areas where strong community links may already be in place, as opposed to in some urban areas where geographic communities are often less easily defined.

Key Points

- Scotland has the recognised research base in energy, technology, data science and wider informatics to capitalise on a move to smart energy systems.
- Greater local renewable generation capacity could play an important role in helping Scotland meet its climate change obligations.
- Smart local systems could facilitate greater community involvement in energy, planning and building community resilience.



364 Cornwall Energy, 3 October 2013, *Overcoming grid connection issues for community energy projects for Co-operatives UK and The Co-operative Group*, available at: https://www.localenergy.scot/media/33075/Cornwall-Energy-report_Overcoming-grid-connection-issues-for-community-energy.pdf p5

Energy Storage

1 Developing significant energy storage capabilities could facilitate an enormous change in how Scotland produces and uses energy. Storage can take various forms, including battery storage of electricity, pumped hydroelectric storage, and storing natural gas or, in the future, hydrogen, in salt caverns or depleted fields.

Climate change

2 A move towards significantly reducing carbon emissions almost certainly involves reducing, if not eliminating, the traditional use of fossil fuels to produce electricity. Battery storage on a large scale and pumped hydroelectric storage could both allow for increased use of energy generated from low-carbon, renewable sources, which would help Scotland meet its climate targets. Increasing storage space for natural gas, however, could be seen as facilitating the burning of fossil fuels, with the related carbon footprint.

Affordability

3 While the cost of battery storage has fallen – the cost of electric vehicle battery packs has decreased by 70% since 2010[365] – even with continued reduction in costs, it is likely to remain an expensive solution on a large scale. Substantial development would require enormous capital investment.

4 Pumped hydroelectricity would also require substantial investment, with the proposed Coire Glas project estimated to cost £800 million. A feasibility study undertaken by Scottish Power estimated that increasing the capacity of Cruachan by 400–600MW would cost up to £400 million.[366]

5 A report undertaken by the Carbon Trust and Imperial College London found that significant deployment of energy storage in the UK could provide savings of up to £2.4 billion to the electricity system. If around half of this saving was passed onto consumers, the average household energy bill would be reduced by £50 per year.[367] The report found that even greater savings would be possible if action was taken as early as possible – with the potential to make annual savings of as much as £7 billion.[368]

Energy security

6 As of 2017, the UK had nine gas storage facilities with combined storage space of 1.14 billion m^3. None of these facilities are located in Scotland, with one, Rough, going through the process of closure at the time of writing.[369] There is limited capacity for onshore storage because of the small size of depleted fields and lack of halite-bearing formations. However, substantial potential exists for the use of oil and gas fields in offshore waters.

7 Following the closure of the gas storage site at Rough – previously the largest available – the UK's spare capacity will fall to its lowest levels in a generation. Available storage covers around 6% of UK annual demand, a significantly smaller proportion than that in other EU countries. Gas storage in Germany, France and Italy covers around 20% of demand.[370]

365 UK Government, October 2017, The Clean Growth Strategy: Leading the way to a low carbon future, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700496/clean-growth-strategy-correction-april-2018.pdf

366 Scottish Power Website, Press Room, 29 February 2016 (a), *Scottish Power concludes feasibility study for Cruachan expansion*, available at: https://www.scottishpower.com/news/pages/scottishpower_concludes_feasibility_study_for_cruachan_expansion.aspx

367 Carbon Trust, Imperial College London (a), *Can storage help reduce the cost of a future UK electricity system?*, p6, available at: https://www.carbontrust.com/media/672486/energy-storage-report.pdf p6

368 Carbon Trust, Imperial College London (a), *Can storage help reduce the cost of a future UK electricity system?*, p6, available at: https://www.carbontrust.com/media/672486/energy-storage-report.pdf p6

369 BEIS, 2018, Digest of UK Energy Statistics 2018

370 Warwick Faculty of Social Sciences Website, *The Future of UK Gas Security*, available at: https://warwick.ac.uk/fac/soc/impact/gassecurity/ p3

8 Scotland currently houses two pumped hydroelectricity sites, Cruachan and Foyers, which provide 440 MW and 300 MW of capacity respectively.[371] A pumped storage scheme – Coire Glas – near Loch Lochy proposed by SSE is currently under consideration, with the potential to provide 1,500 MW. The sole large-scale battery storage facility in Scotland is located in Orkney and provides 2 MW of capacity.[372]

9 Each of these options would provide a level of flexibility to the system to assist in hours of peak demand, store currently wasted energy when production exceeds demand or the transmission or distribution network is constrained, and address issues of frequency response.

10 While battery storage may be able to meet demand peaks over the short term, it is uncertain if the technology will ever develop to become cost effective for longer periods, for example storing energy produced in the summer to be used in the winter. Storage of heat in the form of hot water or as gas can provide seasonal storage.

11 All potential forms of increasing storage capacity would provide security of supply benefits to Scotland by providing accessible reserves of energy during periods of high demand, when national supply issues arise, or at times of increased fuel prices.

12 While storage of electricity on an industrial scale using batteries is not yet viable, a report by the International Renewable Energy Agency estimates that total global electricity storage capacity will triple by 2030, provided the share of renewable energy in the world system doubles as expected. The report also found that there was potential for new and emerging battery storage technologies to reduce in cost significantly, with total installed costs of lead-acid, high-temperature, flow and lithium-ion batteries all falling by at least 50% between 2016 and 2030.[373]

13 A substantial increase in Scotland's pumped hydroelectric storage is feasible, but would need to occur over the medium to long term. The feasibility study undertaken on the expansion of Cruachan found that the build programme would take 8–10 years.[374]

Social acceptability and economic wellbeing

14 Of the storage options available to Scotland, natural gas or future hydrogen storage possibly presents the fewest environmental and social problems. Gas could be stored offshore in depleted fields leading to minimal impact on local communities or the environment.

15 Battery storage requires the mining of materials which would need to be imported into the UK. This leaves Scotland without any say over the environmental or safety regulations related to the sourcing of these materials.

16 Environmental and social concerns have been expressed over the production and processing of these materials. For example, depending on the method of lithium extraction, the process can be highly energy intensive and requires the use of toxic chemicals.[375] Artisanal and small-scale mining used to produce cobalt in the Democratic Republic of Congo has been the focus of accusations of human rights abuses, while larger-scale mining has been linked to corruption and dangerous conditions for workers.[376]

17 Pumped hydroelectric storage requires significant land resource and inherently has an impact on the local environment. Large-scale interventions in creating dams and building necessary infrastructure are highly disruptive and transformative to the area concerned. There can also be adverse impact on local wildlife.

371 Scottish Government, 2018, Energy in Scotland 2018, p71

372 SSE Website, *Coire Glas is the first new large scale pumped storage scheme to be developed in UK for over 30 years*, available at: http://sse.com/whatwedo/ourprojectsandassets/renewables/CoireGlas/

373 International Renewable Energy Agency, October 2017, *Electricity Storage and Renewables: Costs and Markets to 2030*, available at: http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Oct/IRENA_Electricity_Storage_Costs_2017_Summary.pdf?la=en&hash=2FDC44939920F8D2BA29CB762C607BC9E882D4E9 pp8-12

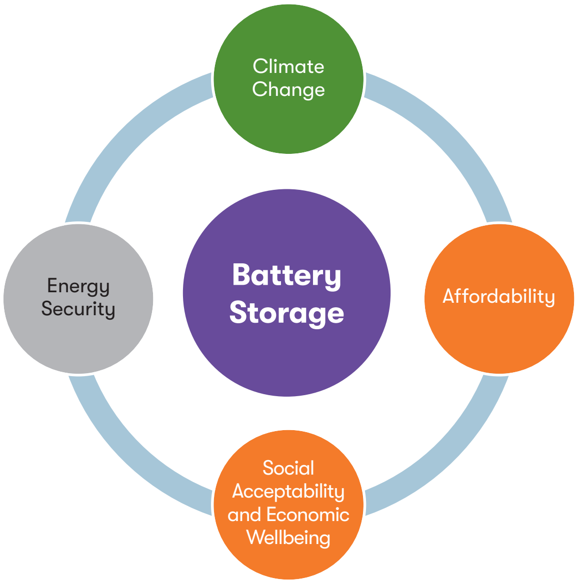
374 Scottish Power Website, Press Room, 29 February 2016 (b), Scottish Power concludes feasibility study for Cruachan expansion, available at: https://www.scottishpower.com/news/pages/scottishpower_concludes_feasibility_study_for_cruachan_expansion.aspx

375 https://www.transportenvironment.org/sites/te/files/publications/2017_10_EV_LCA_briefing_final.pdf

376 Katz-Lavigne, S, The Washington Post, 21 February 2019, *Demand for Congo's cobalt is on the rise. So is the scrutiny of mining practices*, available at: https://www.washingtonpost.com/politics/2019/02/21/demand-congos-cobalt-is-rise-so-is-scrutiny-mining- practices/?utm_term=.2de2619f26f2

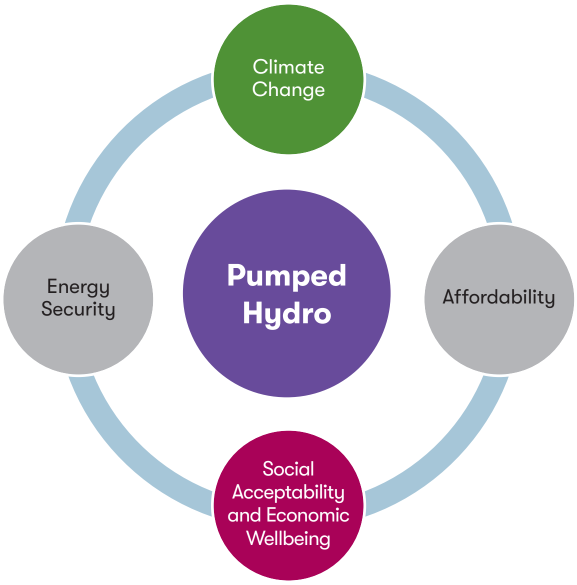
Key Points

- Development of large-scale battery storage could be transformative in facilitating the increased use of renewable energy.
- Developing to the scale required, however, is likely some way off and may ultimately prove prohibitively expensive.



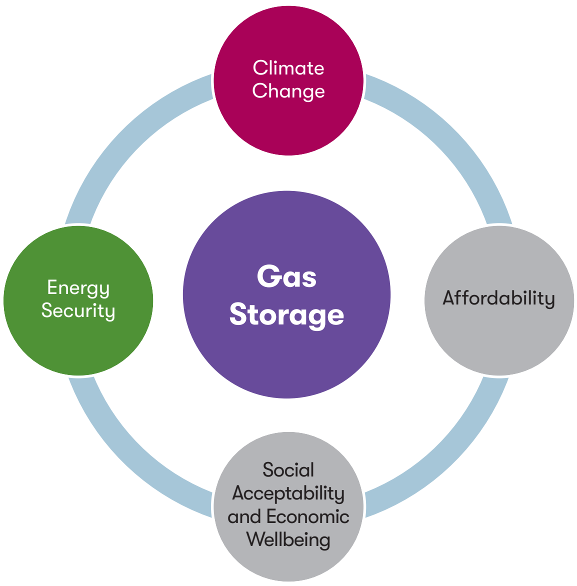
Key Points

- Increased pumped hydroelectric storage could provide an important level of flexibility to the system, particularly in hours of peak demand.
- Increasing capacity would, however, require substantial investment and have very significant impacts on the local environment.

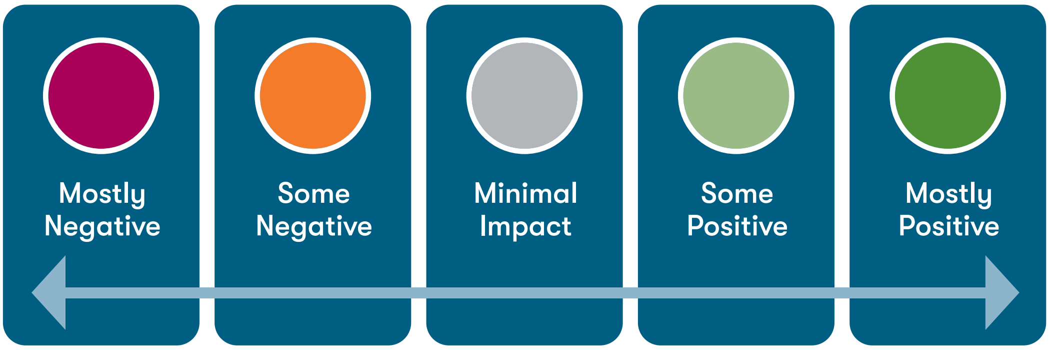


Key Point

- Increasing gas storage capacity in Scotland would improve energy security and may prove necessary to facilitate the use of other options, such as hydrogen development.



Overall Summary Matrix



	Climate Change	Affordability	Energy Security	Social Acceptability & Economic Wellbeing
CCS	Mostly Positive	Mostly Negative	Some Negative	Some Positive
District heating	Minimal Impact	Minimal Impact	Some Positive	Some Positive
Electrification	Some Positive	Some Negative	Minimal Impact	Minimal Impact
Efficiency/reduction	Mostly Positive	Minimal Impact	Some Positive	Some Positive
Onshore gas	Mostly Negative	Some Negative	Some Negative	Some Negative
Offshore gas	Mostly Negative	Some Negative	Mostly Positive	Some Positive
Geothermal	Some Positive	Some Positive	Minimal Impact	Some Positive
Hydrogen	Mostly Positive	Minimal Impact	Some Positive	Minimal Impact
Importation	Mostly Negative	Some Positive	Minimal Impact	Mostly Negative
Large-scale nuclear	Mostly Positive	Mostly Negative	Mostly Positive	Some Negative
SMR	Mostly Positive	Some Negative	Minimal Impact	Minimal Impact
Bioenergy	Some Positive	Some Positive	Some Negative	Some Negative
Solar	Mostly Positive	Minimal Impact	Minimal Impact	Some Negative
Onshore wind	Mostly Positive	Some Positive	Some Negative	Some Negative
Offshore wind	Mostly Positive	Minimal Impact	Minimal Impact	Some Positive
Wave and tidal	Mostly Positive	Some Negative	Some Positive	Some Positive
Hydropower	Mostly Positive	Minimal Impact	Some Positive	Some Positive
Smart energy	Mostly Positive	Minimal Impact	Some Positive	Some Positive
Batteries	Mostly Positive	Some Negative	Minimal Impact	Some Negative
Pumped hydro	Mostly Positive	Minimal Impact	Mostly Negative	Mostly Negative
Gas storage	Mostly Negative	Minimal Impact	Mostly Positive	Minimal Impact

Chapter Six

Guiding Principles and Recommendations

Introduction

1 Society is highly reliant on intensive consumption of energy. It dictates the places we choose to live, what we eat and wear, our travel patterns, the jobs we do, and how we enjoy ourselves. Too often the ability to use energy as we see fit is taken for granted.

2 Obtaining and supplying energy in the forms we choose frequently involves inefficiency and waste, and damages the environment; for example, through the release of pollutants and intensive mining of materials needed. It may export ill effects to other parts of the planet (where the energy is produced) and is the leading contributor to a changing climate, which puts the welfare of all of us at risk.

3 Many in our society cannot afford to enjoy a supply of energy adequate to meet their basic needs, with damaging consequences for their lives, their physical and mental health and that of their families.

4 So, what are we to do? The standard answers, greatly simplified, would be:

- Use less energy
- Use energy in "better" forms
- Waste less energy
- Find ways of supplying energy to those unable to afford enough of it now

5 There is no shortage of policy prescriptions, aspirations and targets, produced by governments, NGOs, academics and interest groups, among others. Inherent in some of these are enthusiastically promoted "magic bullet" solutions, some of them depending on relatively mature technologies, others more speculative, and some predicated on a variety of behavioural changes.

6 In this report, we have not attempted to advocate particular technological or behavioural solutions. Such an approach could only be sure of being proved wrong and would have given our work a very short shelf life.

7 Instead we have aimed to do two things:

- Provide some realism about the position we face in Scotland – as part of a complex international market, highlighting key interdependencies, and subject in the UK (like other economies) to a highly developed, if not always effective, regime of regulation and control that seeks to influence the market. (Chapters 1–3)
- Provide a guide to the challenges faced and advantages offered by the various technological solutions on offer in order to facilitate informed debate over the role they might be able to play and the realism of this. (Chapters 4–5)

8 In this final chapter we try to set out some key principles to guide future consideration and development of energy policy, demand and use, and highlight the main recommendations and conclusions we feel can be drawn from our work.

Guiding Principles

No pain, no gain

10 First, to put it very simply, "no pain, no gain". We conclude that there is no technological or regulatory solution that will meet all the objectives set out above, without hard and generally costly choices being made. From time to time we have heard of "no regrets" strategies, but even these are not completely painless or easy. Addressing the diverse nature of Scotland's energy needs will necessitate an energy mix and trade-offs.

An opportunity to lead

11 Despite this, we strongly believe that the challenges Scotland, and the world, faces regarding energy should not only be seen as a threat, but also viewed as an enormous opportunity; and one which Scotland must grasp. Some of the options available for meeting future energy needs may prove more financially costly than 'business as usual', but this investment is also a real contribution towards the country's prosperity and wellbeing, and could position Scotland as a global innovator.

12 Scotland has led in the oil and gas sector, something that has seen the country export technology, know-how, skills and people. It is possible for the very same prowess to be (re)used to impact and accelerate decarbonisation, since the very same methods can be deployed for subsurface storage, be it methane, hydrogen or for carbon sequestration.

13 There have been past opportunities for Scotland, for example in wind power and nuclear energy, which were not seized to the extent they could have been. Many ideas and technologies, however, are still live and there is latent potential for Scotland to lead if we are ready to invest in this energy future.

14 We must be willing to have an informed, evidence-based conversation around the challenges we face to wean ourselves off fossil fuels and decarbonise, and on the merits and demerits of the options available to us. With informed debate, we can make the grown-up decisions necessary and Scotland could become a world leader.

15 Responding to the emergence of a new regime of generation and supply could offer various opportunities for Scotland, including the potential to take a lead in key areas of research and development through its world-leading universities and Innovation Centres, potentially supported by sector or city deals.

Making decisions

16 For the same reasons that this report has not advocated specific technological or behavioural solutions, we have also not attempted to endorse particular forecasts of demand.

17 The UK's energy supply for heating, transport and (less so) for electricity is still heavily reliant upon oil and gas. However, the country has gone from having surplus supplies at the turn of the century to a position where over half its needs are now imported. This means the UK needs a secure supply or to look to make up the shortfall through other means.

18 The reality of where we find ourselves, however, is that the planned closures of both of Scotland's remaining nuclear power stations by 2030 will see Scotland lose the source of generation for almost 43% of its electricity, going into a period where it is widely expected that demand for electricity will increase. These closures potentially coinciding with the end-of-life of the first wave of offshore wind only adds to this problem.

19 This is occurring alongside a Scottish Government commitment to generate half of overall energy consumption from renewable sources by 2030. This target is laudable, but very ambitious. In 2015 over 87% of Scotland's total energy consumption could be attributed to fossil fuels or nuclear power.

20 Difficult decisions must be made on how to address this future shortfall, which was around 37% of consumption in 2015.[377] Either significant additional generating capacity will need to be built, an unprecedented reduction in demand facilitated, or the amount of energy imported from outside Scotland will need to rise markedly. Avoiding a proactive decision will simply lead to the final option of increased importation occurring.

Responsibility for, and understanding of, the transition

21 Scotland's climate change legislation has set the targets for transition to a low-carbon energy system and economy. The Committee wholeheartedly endorses this, but considers that all of us, as citizens in a democracy, share the responsibility to take part in the changes needed to successfully complete this transition.

377 The difference between the total energy consumed from electricity generated by nuclear power and fossil fuels, plus fossil consumption, minus the renewable target of 50%

22 While there is uncertainty over exactly what the public are being asked to transition to, in truth, there are challenges and unintended consequences associated with any of the energy solutions and it is likely that there is no single answer. Scotland has, however, put significant plans in place – including the Energy Strategy, Climate Change Plan, Energy Efficient Scotland, and new Fuel Poverty Bill – and finds itself in the enviable position of having considerable technical, natural, social and financial resources which make these possible.

23 While the proposed new landscape we strive for must be attainable, we must also accept that there is, again, no single definitive answer to what can be achieved. This being said, the Committee believes that targets and goals should be set alongside a responsible plan explaining how these can be met. This categorically does not rule out visions for a more radical transition; it merely stresses that plans with more ambitious targets or sweeping changes – which may be considered outwith what is attainable in the current landscape – must be built on a robust strategy and plan, setting out how they can be achieved.

24 Behavioural change cannot simply be imposed. But it can be factored in with suitable judgements on realism. For example, attitudes to diesel cars appear to be changing, with significant disruption to established patterns of purchase. Additionally, considered regulation, for example on energy performance of buildings, can play an accompanying role, as it did with the ban on smoking in enclosed public spaces in 2006. How far and how fast changes will go, however, is uncertain. Moreover, change that requires the public simply to substitute one form of technology for another will always be easier to introduce than more substantive behavioural change which requires significant alterations to how people live their lives.

25 It is tempting to rule certain changes out, on the basis that they are too disruptive, too costly or would take too long. We must, however, be mindful of the scale and timeline of changes that we have seen accomplished in the past. Numerous examples of successful transitions exist: the move to natural gas; cabling of our cities; and even to regular renewal of petrol station storage – all in some senses analogous to the options canvassed.

26 There are solutions suggested that depend on heroic or unproven assumptions surrounding feasibility, timescale and cost, such as carbon capture and storage, various forms of energy storage such as in depleted oil and gas fields, and batteries. Further, and realistic, evidence of the costs and benefits of these is needed.

A more local approach

27 There is a promising approach in more local systems of generation and distribution, with the prospect of matching supply and demand more economically, less dependent on major reinforcements of the transmission grid. These require more local co-operation, and to that extent behavioural change, for example in district heating and new forms of demand management, as well as smaller-scale generation. Changes to energy market regulation will also be required to facilitate investment.

28 However, exploiting Scotland's renewable resources at the scales necessary for decarbonisation will require a substantial and reliable transmission system. This will support local energy systems, facilitate economies of scale, particularly in the islands for nascent offshore wind and marine energy industries, and promote the export of energy and expertise.

Leaving no one behind

29 While finding policy solutions to the competing challenges we face will unquestionably require significant compromise, the costs of developing a secure, low-carbon, sustainable energy system cannot and must not fall disproportionately on the most vulnerable.

30 All the options discussed in Chapter 5 come with significant cost. There is no guarantee that emerging technologies will reduce the cost of energy; indeed, the best solutions may be significantly more expensive in the short term than the energy upon which we currently rely.

Balancing evidence-based policy with public opinion

31 The RSE has long championed the need for evidence-based policy making, and the area of energy is no exception. We stress the importance that governments rely on robust scientific evidence when developing and implementing policy, and do not lean on unverified or speculative materials simply for political expediency.

32 We acknowledge that other, potentially important economic, political and cultural factors play a role in the formation of policy. It is, however, incumbent on our governments to make informed decisions using the evidence base available to them and to provide strong leadership in bringing the public along with them.

Education, training and outreach

33 For Scotland's energy future to be realised and quality of life to be enhanced, there is a need for significant additional research, development and training in the field to educate the next generation of practitioners and academics.

34 There is a need for the education system to respond at all levels, including University undergraduate degree content and postgraduate (Masters and PhD) research and complementary training programmes. Government support for undergraduate teaching and doctoral training in the relevant fields is likely to be required. Indeed, if correctly harnessed, an opportunity exists for Scotland to play an important role in meeting global training needs for this transition.

35 A greater understanding of how energy is sourced and used, and the implications of this on communities, the environment and global climate, is required across the general public. The RSE hopes that reports such as this one, which outline the key challenges we face and the issues inherent in the options available to us, can play a role in achieving this.

36 Similarly, significant public engagement and outreach activity is needed to properly communicate with the public about the challenges we face, the concerns they hold, and involve them in finding the solutions to these challenges.

37 Of equal importance is that all of these issues are presented to children from a young age as part of their education. Many of the effects that could result from our use of energy, both now and in the past, will impact on the next generation. It is vital that they are provided with the knowledge, training and skills to understand and tackle obstacles to our energy future.

Recommendations

Recommendation 1

An independent expert advisory commission on energy policy and governance for Scotland should be established under statute.

This commission would provide the Scottish Government, legislators and regulators with integrated and impartial advice on all aspects of energy policy and governance, and could also serve to highlight opportunities. This commission would assist in informing evidence-based decision taking and support the operation of robust regulatory structures and processes.

Chapter 2 of this report highlighted the considerable complexities of the inter-connected reserved/devolved policy and governance structures and processes involving the energy system, the Just Transition, climate change mitigation, economic development, environmental protection, planning, transport and community development. These and other energy related issues (e.g., public health) require ongoing and comprehensive whole systems analysis at the Scottish level, which an advisory commission would provide.

The remit of the commission should be set out in statute to ensure that it has the requisite authority, independence and resources required. The quality of membership will also be paramount, with a broad range of independent experts required.

Recommendation 2

Decisions on how and in what to invest must be made, and the most effective timeframes for investment activity and the potential nature of returns on different types of investment must be properly considered, by both the Scottish and UK governments, in a timely manner.

The options outlined in Chapter 5 come with varying degrees of uncertainty in terms of viability and potential economic opportunity. This uncertainty, however, cannot be allowed to stop much-needed decisions being taken on what will be necessary investment in transitioning to a low-carbon energy system. Indeed, it may be the case that all of the options put forward merely serve as stop-gaps to something entirely different, but this does not negate the need for them to be adequately financed and developed. The role of governments extends beyond any public sector contribution, with crucial foundations lying in the policy environment on which a wide range of decision makers need to act.

If handled correctly, the range of investment activity enabled to reduce carbon emissions and produce the energy we require could also provide significant returns through sustaining existing jobs, creating new roles and adding value to different sectors of the economy, both directly and through extensive supply chains that both exist and may evolve.

Recommendation 3

Scotland requires a clearly articulated position on security of supply and must decide whether domestic energy-generating capacity should be increased.

Chapter 3 draws attention to the significant proportion of electricity generated in Scotland from nuclear power. As the current generation of nuclear power stations go off-line, and demand for electricity rises as forecast – as a result of the planned electrification of heat and transport – we will see an inevitable increase in the proportion of energy imported from abroad, unless there is significant investment in domestic generating capacity.

As highlighted in the section discussing importation in Chapter 5, there are serious concerns over whether this course of action provides suitable energy security, provides acceptable economic benefits or adequately allows Scotland to take responsibility for its energy use.

Investment in a balanced portfolio of energy generation options may be the necessary approach.

Recommendation 4

Scotland should look to improve its energy security by increasing the capacity, and diversifying its range, of storage options.

Many of the options discussed in Chapter 5 rely upon, or would be considerably more advantageous with additional, storage which is generally lacking in Scotland, particularly in regard to natural gas.

Storage is only one part of the solution, however, with greater interconnection and improved demand management also key.

Recommendation 5

Achieving our climate protection targets can be made easier by reducing overall demand for energy and achieving this should be a priority.

While as the report stresses throughout, there are no easy answers, taking action to reduce our consumption of energy is potentially one of the quickest and most sensible ways in which we can tackle several elements of the energy quadrilemma (as highlighted in Chapter 5).

The Scottish Government and local authorities will need to invest in the necessary programmes to drive behavioural change, to develop a highly skilled workforce and quality assured supply chain, as well as funding grants, low- or zero-cost loan schemes and other incentives to make this feasible. Local authorities will need new powers and secure resources to support area-based planning and implementation.

Demand reduction must incorporate business and industry, not simply the public. New regulatory standards will be needed to ensure that current building stock is retrofitted for low energy use. The Energy Efficient Scotland programme will be critical to success and needs strong political endorsement and leadership.

Recommendation 6

Enforcing higher standards of energy efficiency in new-build housing and infrastructure should be a regulatory priority.

This should be a priority where it does not affect structural performance. This could include the installation of low-temperature district heating schemes in areas of new-build homes or even a decision to mandate that all new housing is energy neutral. The requirement for sustainable drainage systems (SuDS) in all new housing developments illustrates a similar precedent.

Recommendation 7

Building regulations around energy efficiency and their enforcement should be regularly reviewed to ensure they are both more responsive to R&D and consistent with policy targets.

As stressed in the section on Energy Efficiency and Demand Reduction in Chapter 5, Scotland's varied, and ageing, housing stock is a considerable obstacle to improving the energy efficiency of buildings. Ensuring that building regulations are consistent with policy targets and properly enforced would be an important, and easy-to-take, step in ensuring this problem is not exacerbated by newly constructed buildings.

The process could be built in with a set period-of-time review, for example every five years.

Recommendation 8

The Scottish Government should review the need for R&D investment and skills development:

- in energy-related areas in which they also consider there to be strong opportunities for economic growth (potentially through exporting technologies and skills);
- to pilot community energy schemes that include storage and managing small-scale rural grid supply/frequency and balancing issues. Further work is required on the economics of these schemes in order to make distributed small-scale generation viable;
- into low-carbon technologies addressing the long term;
- into energy education throughout the school, college, university and general skills curricula to ensure that the next generation of practitioners have the right skills for our decarbonised energy future.

Recommendation 9

Serious consideration should be given to how best to socialise the costs of transition to address issues of social justice.

All of the options put forward in Chapter 5 require investment in some way, whether to develop technologies, help transition workers to new skills or to facilitate changes in public behaviour.

It would not be acceptable for the transition to a low-carbon energy system to unfairly impact the most vulnerable in society and plans must be put in place to ensure this does not occur. If, for example, a decision is made to fund the transition through putting a levy on energy bills, rather than through general taxation, then it is imperative that the impacts on low-income households are sufficiently mitigated.

Recommendation 10

All levels of government must be prepared to review and change existing policies where these policies are at odds with, or variant from, the overriding principle of carbon reduction.

Chapter 2 notes that both the Scottish and UK governments have identified mitigating the impacts of climate change and reducing carbon emissions as priority matters. Chapters 2,3 and 5, however, also highlight various policies and actions which can be viewed as being inconsistent with this vision.

If reducing carbon emissions is to remain the primary driver of the future energy direction, governments must be willing to audit existing positions and policies against this and be receptive to amending these to reflect this reality. This may mean taking politically difficult decisions and will require strong leadership.

Conclusion

1 Scotland faces substantial obstacles to successfully developing an energy future that provides low-carbon, secure, affordable energy in a manner that is sustainable and fair. So does every other nation on Earth. What we cannot do is let the enormity of the challenges we face blind us to the opportunities that are present, obscure the significant progress that has already been made, or stop us from taking much-needed action.

2 Scotland has achieved a great deal over the last several decades, from virtually eliminating the burning of coal to producing 100% of its electricity from renewable sources on days when conditions are favourable. It has similarly set some of the world's most ambitious carbon emission reduction targets, which should be lauded.

3 Energy use is integral to all aspects of life in Scotland, and the vast majority of this is derived from fossil fuels. Energy continues to be unaffordable for a sizeable minority of the population, communities are concerned over what a transition will mean for their jobs and families, and recent events have highlighted concerns over how secure our supply of energy truly is.

4 There are many options available to Scotland to meet our energy needs. There is, however, no single solution to all of our problems and all of them will require acceptance of trade-offs and a willingness to compromise.

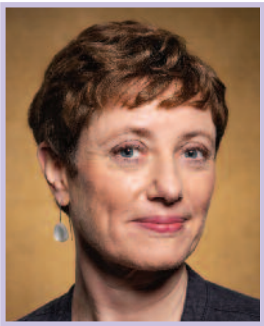
5 Only through informed and continuing discussion across civil, state and business sectors can we understand the advantages and drawbacks of the options available, and build acceptance of the trade-offs necessary. In this way we can achieve the version of Scotland's energy future that best serves us all.

APPENDIX A **THE COMMITTEE**

Sir Muir Russell (Chair)

Sir Muir Russell KCB FRSE was Permanent Secretary to the Scottish Office (1998–1999) and Permanent Secretary to the Scottish Executive (1999–2003). Between 2003 and 2009 he was Principal and Vice-Chancellor of the University of Glasgow, and from 2008 to 2016 he was Chairing Member of the Judicial Appointments Board for Scotland.

Sir Muir, who was elected a Fellow of the RSE in 2000, currently serves as Chairman of Trustees of the Royal Botanic Garden Edinburgh and Vice-chair of the Board of Governors of the Glasgow School of Art, and is a non-executive director of the National House Building Council, among other roles.



Professor Rebecca Lunn (Deputy Chair)

Professor Rebecca Lunn MBE FRSE is Professor of Civil and Environment Engineering at the University of Strathclyde. She is a Fellow of the Institution of Civil Engineers and was elected a Fellow of the RSE in 2014. She has served as a member of several Government Advisory Bodies, including the Scottish Government Working Group on Geothermal Energy and the UK Government Committee on Radioactive Waste Management.

Professor Lunn's research focuses on the development of low-carbon technologies for ground engineering, with specific applications in nuclear decommissioning, nuclear waste disposal, geological carbon storage and hydrocarbon production.

Professor Simon Harley

Professor Simon Harley FRSE is Professor of Lower Crustal Processes at the University of Edinburgh. He served as a member of the Committee on Radioactive Waste Management between 2007 and 2016 and was elected a Fellow of the RSE in 1998.

Professor Harley's research interests include processes in the formation and evolution of continental crust; geological development of Antarctica; melting and metamorphism, particularly high and ultra-high temperature deep-crustal rocks; and, chemical processes bearing on the behaviour of minerals used in isotopic age dating.

Professor Gareth Harrison

Professor Gareth Harrison is Bert Whittington Chair of Electrical Power Engineering and Deputy Head of the Institute of Energy Systems at the University of Edinburgh. He was a founding member of the RSE Young Academy of Scotland, and now holds the position of emeritus member.

Professor Harrison's research interests include renewable energy sources, grid integration of renewable energy, life cycle carbon emission of energy sources, operation and planning of energy networks, energy systems integration, and climate impacts and adaptation in energy systems.

Professor Gavin Little

Professor Gavin Little is Professor of Environmental and Public Law at the University of Stirling. He is also Adjunct Professor at the School of Law, Queensland University of Technology in Australia.

Professor Little's research addresses environmental and energy law and public law regulation; and developing new, interdisciplinary approaches to legal scholarship. A key theme in his work is integrating legal and regulatory analysis with politics, public administration, history and culture. He is co-editor of "Delivering Energy Law and Policy in the EU and the US" (EUP, 2016).

Professor Stephen McArthur

Professor Stephen McArthur is Professor of Intelligent Energy Systems at the University of Strathclyde. He is Academic Director of the Advanced Nuclear Research Centre and the Low Carbon Power and Energy Research Programme at Strathclyde. He also Directs the EPSRC Centre for Doctoral Training in Future Power Networks and Smart Grids.

Professor McArthur's research interests include intelligent system applications in power engineering, condition monitoring, diagnostics and prognostics, active network management and wider smart grid applications.

Professor Peter Smith

Professor Peter Smith FRSE FSB is Professor of Soils and Global Change at the University of Aberdeen. He also serves as Science Director of ClimateXChange, and Director of Food Systems at the Scottish Food Security Alliance. He was elected a Fellow of the RSE in 2009.

Professor Smith's research interests include global change impacts on ecosystems, soils, agricultural and land-based options to mitigate climate change, greenhouse gas emissions, environmental and agricultural sustainability, global carbon cycle, ecosystem modelling, food security, ecosystem services and bioenergy.

Professor Karen Turner

Professor Karen Turner is Director of the Centre for Energy Policy at the University of Strathclyde. She previously held academic posts in the Economics departments of Heriot-Watt, Stirling and Strathclyde universities.

Professor Turner's research interests include modelling the economy-wide impacts of energy and climate policy. The main focus of her current work is investigating economy-wide rebound effects and macroeconomic impacts of energy efficiency enhancing and/or carbon reduction technologies such as carbon capture and storage (CCS).

Professor John Underhill

Professor John Underhill FRSE is Chair of Exploration Geoscience and Chief Scientist at Heriot-Watt University. He served as President of the European Association of Geoscientists and Engineers (EAGE) in 2011–12 and UK Energy Minister's Technology Leadership Board (TLB) between 2014 and 2017. He is a member of the Scottish Science Advisory Council (SSAC), the UK Exploration Task Force and Natural Environmental Research Council (NERC)'s UK Geoenergy Observatories Science Advisory Group (GSAG). He was elected a Fellow of the RSE in 2004.

Professor Underhill's research interests primarily focus upon the use of geological and geophysical methods to understand earth evolution using structural geology, sedimentology and stratigraphy. Outcomes from his work permit an accurate picture of subsurface geology to be constructed which have a direct application for oil and gas exploration and the assessment of carbon storage sites in the UK and further afield.

Professor Janette Webb

Janette Webb is Professor of Sociology of Organisations at the University of Edinburgh. She leads a portfolio of research on European comparative heat and energy efficiency policy and practice, acted as 2016 Chair of the UK Committee on Climate Change Advisory Group on Heat and Energy Efficiency, and is a member of the Scottish Government Panel to Review The Definition Of Fuel Poverty. She is also a UK-nominated expert to the International Energy Agency Programme on District Heating.

Professor Webb's research interests include sociology of climate change and energy markets, energy and cities, and practices of energy use in buildings.

APPENDIX B

EVIDENCE GATHERING, ENGAGEMENT & SUPPORTERS

During the process of producing the report, the Inquiry Committee received evidence from, and engaged with, numerous stakeholders in a number of ways, including soliciting written responses to our public consultation, holding one-to-one conversations, hosting roundtable discussions, and holding public engagement events around the country.

The written submissions received, summaries of engagement events, and notes of roundtable discussions are available to read on the Inquiry website: **www.therse.org.uk/energyinquiry**

We would like to extend our thanks to the following organisations and individuals for engaging with the Inquiry during this process:

2050 Climate Group
Alex Quayle
BP
Brian Richardson
British Geological Survey
Centrica
Citizen Advice Scotland
ClimateXChange
Colin Gibson
Community Energy Scotland
Competition and Markets Authority
COSLA
Derek Birkett
Dr Astley Hastings
Dr Euan Mearns
Dr Theo Koutmeridis
DumGal Against Pylons
Dunelm Energy
EDF
Edinburgh Centre for Carbon Innovation
Energy Action Scotland
Energy Agency
Existing Homes Alliance
Friends of the Earth Scotland
Geological Society
GMB
INEOS
Institute of Engineers and Shipbuilders in Scotland
James Hutton Institute
Johanna Carrie
John Burnett
Joseph Proskauer
Local Energy Scotland
Margaret Burnett
Marksman Consulting
Mike Travers
NESTA
Nuclear Industry Association
Ofgem
Orkney Islands Council
Our Power
Paul Spare
PetroMall
Prof Brian Smart
Prof Dragan Jovcic
Prof Roger Crofts
Prof Stephen Salter
Prof Stuart Haszeldine
Prof Raphael Heffron
Reach Coal Seam Gas
Robert Schneider
RSPB Scotland
Scotland's Futures Forum
Scottish Accessible Transport Alliance
Scottish Communities Climate Action Network
Scottish Council for Development and Industry
Scottish Enterprise
Scottish Federation of Housing Associations
Scottish Government
Scottish Power
Scottish Renewables
Scottish Science Advisory Council
Shetland Islands Council
Sir Donald Miller
SSE
Stephen Shellard
STUC
Transform Scotland
UK Energy Research Centre
UK Government
Western Isles Council
William Barrie Heptonstall
Zero Waste Scotland

Those engaging with the Inquiry were given the opportunity to remain anonymous and so the list above omits such stakeholders and also does not include those attending the public engagement events.

Public Consultation

The Committee solicited responses to the following questions which were published as part of an open consultation:

Energy Landscape

1 What are the most significant challenges to, and influences on, the energy landscape that any future energy strategy needs to take into account?

Supply and Demand

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

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

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?

The Energy Mix

5 What overall role should be played by various elements of the energy landscape, for example:

- Different sources of renewable energy;
- Offshore oil and gas;
- Unconventional oil and gas;
- Nuclear power;
- Energy storage;
- Others?

Climate Change and Renewable Energy

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?

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?

Environmental Impact

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?

Ethics, Social Issues and Impact on Communities

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

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?

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:

a) Rural and remote communities;

b) Urban communities?

Regulation and Governance

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:

a) With one another;

b) Internationally;

c) With existing energy generators, network operators and retailers?

Informed Debate

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

Skills

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

Meeting the Challenge

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

Public Engagement Events

The Committee held the following public engagement events during the Inquiry process:

Location	**Venue**	**Date**
Dumfries	Easterbrook Hall	November 2017
Lerwick	Shetland Museum and Archives	April 2018
Edinburgh	Royal Society of Edinburgh	April 2018
Glasgow	IET Glasgow: Teacher Building	May 2018
Aberdeen	The James Hutton Institute	July 2018

The RSE would like to express particular thanks to Shetland Islands Council and the James Hutton Institute for their assistance in organising the events in Lerwick and Aberdeen, respectively.

Roundtable Discussions

The following roundtable discussions were also hosted by the RSE and assisted in informing the Inquiry report:

Social and Community Aspects of Energy, July 2018

Moving Towards a Low-carbon Economy, October 2018

Supporters

The RSE would like to extend its sincere thanks to the following organisations for supporting the Inquiry.

APPENDIX C **ABBREVIATIONS**

AD: Anaerobic Digestion
ACER: European Union Agency for the Cooperation of Energy Regulators
BECCS: Bioenergy with Carbon Capture and Storage
BEIS: Department of Business, Energy & Industrial Strategy
BGS: British Geological Survey
BIG HIT: Building Innovative Green Hydrogen Systems and Isolated Territory
CARES: Community and Renewable Energy Scheme
CBM: Coalbed Methane
CCC: The Committee on Climate Change
CCGT: Combined-Cycle Gas Turbine
CCUS: Carbon Capture, Usage and Storage
CCS: Carbon Capture and Storage
CfD: Contracts for Difference
CID: Commonwealth of Independent States
CHP: Combined Heat and Power
CLCL: Control for Low-carbon Levies
CM: Capacity Market
CMA: Competition and Markets Authority
CPS: Carbon Price Support
DECC: Department of Energy and Climate Change
DH: District Heating
DNOs: Distribution Network Operators
EES: Energy Efficient Scotland
EGS: Engineered Geothermal Systems
EOR: Enhanced Oil and Recovery
ETI: Energy Technology Institute
EU ETS: European Union Emission Trading Scheme
Euratom: European Atomic Energy Community
FIT: Feed-in Tariffs
GEMA: Gas and Electricity Markets Authority
GW: Gigawatt
GHh: Gigawatt Hour
Ha: Hectare
HAW: Higher-activity Radioactive Waste
HSA: Hot Sedimentary Aquifers
HDR: Hot Dry Rock
Ktoe: Kilotonnes of Oil Equivalent
IFI: Innovation Funding Initiative
LCF: Levy Control Framework
LHEES: Local Heat and Energy Efficiency Strategies
LCNF: Low Carbon Network Fund
LNG: Liquified Natural Gas
MW: Megawatt
MWh: Megawatt Hour
NAO: National Audit Office
NDA: Nuclear Decommissioning Authority
NETA: New Electricity Trading Arrangements
NERC: Natural Environment Research Council
NIA: Network Innovation Allowance
Ofgem: Office of Gas and Electricity Markets
OGA: Oil and Gas Authority
ONR: Office for Nuclear Regulation
PRT: Petroleum Revenue Tax
REE: Rare Earth Elements
RHI: Renewable Heat Incentive
RSE: The Royal Society of Edinburgh
SISER: Scottish Institute for Solar Energy Research
SMR: Small Modular Reactors
TW: Terawatt
TWh: Terawatt Hour
UCG: Underground Coal Gasification
ULEVs: Ultra-low-emission Vehicles
UKCS: United Kingdom Continental Shelf
UKERC: United Kingdom Energy Research Centre
UKGEOS: United Kingdom Geoenergy Observatories

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